

# Essays on Institutions and Development

by

Ideen Riahi

M.Sc., Sharif University, 2006

B.Sc., Shahid Beheshti University, 2003

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## APPROVAL

**Name:** Ideen Riahi  
**Degree:** Doctor of Philosophy  
**Title of Thesis:** Essays on Institutions and Development

**Examining Committee:** Chris Binder  
Associate Professor, Department of Economics  
Chair

---

Alexander Karaivanov,  
Senior Supervisor  
Associate Professor, Department of Economics

---

Simon Woodcock,  
Supervisor  
Associate Professor, Department of Economics

---

Chris Muris,  
Supervisor  
Assistant Professor, Department of Economics

---

Greg Dow,  
Supervisor  
Professor, Department of Economics

---

Dr. Fernando Arogorn,  
Internal Examiner  
Assistant Professor, Department of Economics

---

Dr. Christian Robert Ahlin,  
External Examiner, Associate Professor  
Department of Economics, Michigan State University

**Date Defended:** June 20th, 2014

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# Abstract

This thesis studies three different aspects of the development of societies. The first chapter studies the effect of monopolistic competition in the presence of moral hazard on consumer welfare and the efficiency of resource allocation based on market institutions. The second chapter analyses the effect of capital market imperfections on the evolution of inequality and conflict between different socio-economic classes. The goal of this chapter is to provide a framework of the study of the effect of economic development on the dynamics of state repression. The third chapter looks at the process of development from a historical perspective and studies the effect of European colonization on contemporary economic development of former colonies. To this end, I examine the effect of colonization on genetic and non-genetic (e.g. institutional) aspects of former colonies. The broad message of this thesis is that non-market factors - historical and contemporary factors relating to social norms, beliefs, and institutions - play a crucial role in determining societies' potential for development and their prosperity.

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# Chapter 1

# Colonization and Genetics of Comparative Development

## 1.1 Abstract

This paper explores the hypothesis that genealogical closeness to populations at the frontier of technological innovations facilitates the diffusion of development (e.g., Spolaore and Wacziarg, 2009). Proponents of this hypothesis argue that it is supported by a strong and highly robust statistical association between countries' genetic distance to the United States and income per capita. I show that there is no evidence of a *causal* relationship between these two variables. This is because there are important historical factors, such as European settler mortality at the time of colonization, that simultaneously affect countries' genetic distance to the technological frontier and their economic performance. Controlling for these confounding factors removes the statistical association between genetic distance and economic performance. IV estimates that control for possible endogeneity of genetic distance to the technological frontier and/or institutions also confirm that there is no causal relationship between genetic distance and economic performance. Furthermore, fixed effect estimates show that countries that became genetically closer to the world technological frontier over the past 500 years did not become richer because of it.

## 1.2 Introduction

The broad message emerging from more than a decade of empirical research on the fundamental causes of economic development is that the history of populations matters a great deal for their current standards of living.<sup>1</sup> There is, however, considerable disagreement among scholars about which aspects of history are relevant for contemporary comparative development and why. While some maintain that history matters because societal structures and institutions are highly persistent

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<sup>1</sup>See for example, Acemoglu, Johnson, and Robinson (2001, 2002), Acemoglu and Robinson (2012), Ashraf and Galor (2013), Coming, Easterly, and Gong (2010), Bockstette, Chanda, and Putterman (2002), Diamond (1997), Putterman and Weil (2012), Spolaore and Wacziarg (2013).

(e.g. Acemoglu et al., 2001; North and Thomas, 1973; Engerman and Sokoloff, 2011), others argue that, due to the persistence of populations' genetic characteristics, the roots of contemporary development might go much deeper into history - to the dawn of *Homo sapiens* in Africa (e.g. Ashraf and Galor, 2013; Spolaore and Wacziarg, 2009, 2013).

Among the latter group, Spolaore and Wacziarg (2009) - hereafter SW - provide what appears to be strong empirical support for the effect of human biology on contemporary economic development. They document a negative cross-country correlation between genetic distance to the United States and income per capita (Figure 1.1) and show that the statistical association between the two variables remains robust under different econometric specifications and when they control for various measures of geographical distance, climate differences, transportation costs, and measures of historical, linguistic, and religious distance.<sup>2</sup> SW suggest that, since it is easier for societies that are genealogically more closely related "to learn from each other and to adopt each other's innovations" (2009, p.470), genetic distance to the United States acts as a barrier to the diffusion of development from the world technological frontier.<sup>3</sup>

This paper re-examines the relationship between genetic distance to the technological frontier and economic performance. I show that genetic distance to the United States is highly correlated with other historical determinants of comparative development that have been suggested in the literature, such as initial biogeographical conditions (Diamond, 1997; Olsson and Hibbs, 2005), and the hostility of the disease environment to European colonists (Acemoglu et al., 2001). After controlling for these confounding factors, genetic distance to the United States has no statistically significant effect on income per capita.

SW's barrier interpretation of genetic distance has two components. First, they suggest that genetic distance, measuring the elapsed time since two populations shared common ancestors, is an excellent summary of "slowly changing genealogically transmitted characteristics, including habits and customs" (p.523). I do not dispute this part of their interpretation.<sup>4</sup> The second component is their identifying assumption: that genetic distance captures *random* differences between populations.<sup>5</sup> The empirical evidence presented in this paper suggests that this assumption is not valid in the case of countries' genetic distance to the United States (or Western Europe). To see this, note that the two fundamental determinants of genetic distance to the United States are the migratory path of *Homo sapiens* out of Africa (which determines populations' genetic distance to Western Europeans before the start of colonization), and the great migration of Europeans to the New World after 1500 A.D. (which affects contemporary genetic distance to the United States as a direct result

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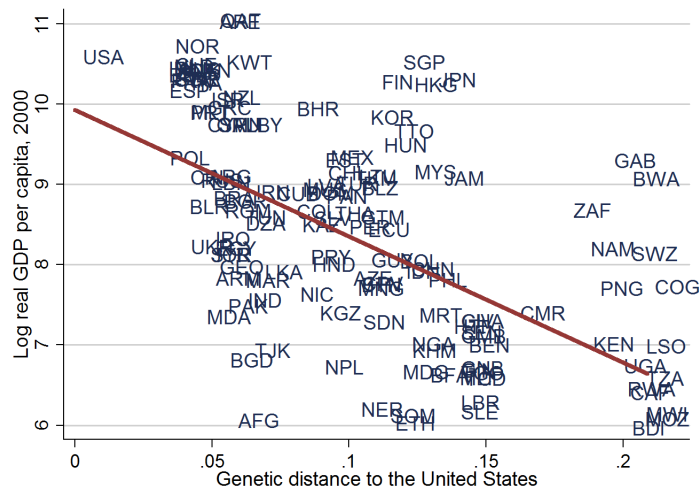
<sup>2</sup>The spectrum of traits which are the base of calculation of genetic distance refers only to "random drifts" in the distribution of genes, and not to the divergence in genetic characteristics that occurs due to natural selection. As such, genetic distance measures the elapsed time since two currently separated populations shared a common ancestor. Larger values of genetic distance refers to a longer period of separation between populations, or, equivalently, less genealogical relatedness between them. See section 4 for the technical definition of genetic distance to the United States.

<sup>3</sup>Note that SW's theory does not explain the emergence of the technological frontier, i.e., they are not trying to explain for example, why Great Britain or the United States became the technological frontier. They take the emergence of the frontier as given, and argue that countries that are genetically far from the frontier of technological and institutional innovation have a comparative disadvantage in development because of their genetic divergence.

<sup>4</sup>There is relative consensus among scholars regarding this interpretation; see, for example, Ashraf and Galor (2013), Desmet et al. (2007), Guiso et al. (2004, 2009), and SW (2012, 2013), and Section 2 for a review of this literature.

<sup>5</sup>SW's key hypothesis is that this "long-term (and *mainly random*) divergence has created barriers to the diffusion of technological and institutional innovations across societies in more recent times" (p.471, the emphasize on "mainly random" is mine).

Figure 1.1: Income per Capita and Genetic Distance to the United States



Notes: This figure is a reproduction of Spolaore and Wacziarg's Figure III (2009, p.489) and visually summarizes their barrier hypothesis, i.e., countries with higher genetic distance to the United States have a lower income per capita. The regression represented by the fitted line yields a coefficient of  $-15.723$  (standard error= $1.807$ ),  $N=136$ ,  $R^2=0.35$ . The measure of genetic distance used in this figure is the current match of weighted  $F_{ST}$  genetic distance to the United States, which is the same measure used in Spolaore and Wacziarg (2009). This measure refers to expected genetic distance between two randomly selected individuals, one from the United States and one from another country, and is measured on the scale of 0 to 0.2088, where a larger value means less genealogical relatedness. See Section 4 for more detailed discussion of  $F_{ST}$  genetic distance.

of European settlement). However, as I argue below, neither the migratory path of *Homo sapiens* nor the great migration of Europeans is independent of the geographic distribution of the pre- and the post-colonial determinants of economic development.

With regard to the pre-colonial era (before 1500 A.D.), I show that the prehistoric ecological prerequisites for good economic performance were absent in those societies that were genetically farther from Western Europeans. For example, Africans had a high genetic distance to Western Europeans before the start of European colonization, because only a fraction of *Homo sapiens* who evolved in East Africa around 200,000 years ago migrated out of Africa.<sup>6</sup> At the same time, Africa's initial biogeographical conditions were not suitable for transition to sedentary life and the development of agriculture (Diamond, 1997).<sup>7</sup> Since both genetic distance and economic performance are highly persistent and since the majority of the current population of the United States is of Western European origin, the negative prehistoric correlation between genetic distance and economic performance is partly reflected in the contemporary correlation (observe a cluster of sub-Saharan countries in the lower right quadrant of Figure 1.1).

<sup>6</sup>The earliest fossils of *Homo sapiens* have been found at Omo Kibish in Ethiopia and originated from 200,000 years ago. The "out of Africa" hypothesis of the origins of modern humans is widely accepted among scholars. See Ashraf and Galor (2013) for more detailed discussion of this hypothesis and Section 3 for an argument regarding the effect of the migratory path of *Homo sapiens* on genetic distance to Western Europeans.

<sup>7</sup>Ahsraf and Galor (2011a) and Olsson and Hibbs (2005) provide empirical evidence confirming Diamond's theory, and suggesting that the timing of transition to agriculture has a persisting effect on historical and contemporary economic performance of nations.

With regard to the colonial era (after 1500 A.D.), I document that former colonies that experienced more extensive settlement by Europeans became genetically closer to Western Europe and the United States. Acemoglu, Johnson, and Robinson (2001, 2002) - henceforth AJR - argue that European settlement is among the most important determinants of the *institutional* path of former colonies. That is, former colonies which experienced relatively larger shares of European settlement were also relatively immune to the adverse effects of colonization. AJR argue that this is because European settlement brought “inclusive” (European) institutions in those countries. This implies that the colonization strategies of Europeans have a simultaneous and opposing effect on the genetic distance of former colonies to their colonizers and their contemporary economic performance. For example, sub-Saharan Africa has a relatively higher genetic distance to Western Europe and the United States compared to other regions, partly because of the lack of European settlement in sub-Saharan Africa during the colonial era. According to AJR, lack of settlement in sub-Saharan Africa resulted in “extractive” colonial institutions, with a persisting negative effect on the quality of institutions and the contemporary economic performance of this region.

Thus, while SW's barrier hypothesis implies, for example, that the underdevelopment of sub-Saharan Africa is partly explained by the genetic divergence of its population from Western Europeans and/or the United States population, the empirical evidence of this paper shows that this hypothesis ignores: (a) the importance of the initial ecological disadvantages of this region (e.g., Diamond, 1997; Ashraf and Galor, 2011a; Olsson and Hibbs, 2005), and (b) the significance of the regions' colonial history (e.g., AJR, 2001, 2002; North and Thomas, 1973; Engerman and Sokoloff, 1997). Econometrically, this argument implies that all of SW's estimates of the effect of genetic distance on economic performance suffer from omitted variable bias.

Consistent with the aforementioned argument, I show that once we control for the simultaneous effect of time-invariant pre- and post-colonial factors on genetic distance and economic performance, genetic distance to the world technological frontier does not explain the diverging development paths of nations. To be more specific, in a sample that includes both former colonies and non-colonies, controlling for continent fixed effects and proxies for the influence of Western Europe during colonization (measures of contemporary institution, percent European descent, or absolute latitude) removes the statistical association between genetic distance to the United States and income per capita.<sup>8</sup> This result remains robust when I control for the possible endogeneity of institutions using an IV strategy.<sup>9</sup>

Next, I focus on a sample that includes only former European colonies and find a strong positive correlation between contemporary genetic distance to the United States and log of European settler mortality at the time of colonization.<sup>10</sup> I show that under different econometric specifications,

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<sup>8</sup>The results remain robust to controlling for geographic factors (log ancestry adjusted timing of Neolithic Revolution, log arable land area, absolute latitude, and a landlock dummy), legal origin, and OPEC fixed effects, and the fraction of the population affiliated with major religions.

<sup>9</sup>The endogeneity of institutions arises from the fact that historical factors might be responsible for the contemporary quality of institutions and economic performance. Further, there is a possibility of reverse causality i.e., more affluent countries might be able to afford better institutions. There is a consensus among scholars that institutions are endogenous with respect to natural and human circumstances, see for example, AJR, 2001, 2004.; Acemoglu, Gallego, and Robinson, 2014; Engerman and Sokoloff, 2011, and Hall and Jones, 1999; for a discussion of the endogeneity of institutions.

<sup>10</sup>60 percent of my entire sample are former colonies and most of the cross-country variation in genetic distance to the United States stems from this sample. Former colonies underwent significant transformation in both genetic and non-genetic (e.g., institutions and human capital) aspects of their societies as a direct result of European colonialism and are a prominent

controlling for log settler mortality completely removes the statistical association between genetic distance to the United States and income per capita. This result provides direct and strong support for this paper's main argument regarding the simultaneous effect of colonization on colonies' genetic distance to the technological frontier and their economic performance. Moreover, IV estimates suggest that once the effect of other factors that Europeans brought to their colonies (e.g., institutions or human capital) is accounted for, the genetic divergence of former colonies from Europeans does not explain their divergent development paths.

To address the effect of colonization on countries' genetic distance to the technological frontier, SW use genetic distance to the United Kingdom in 1500 as an instrument for contemporary genetic distance to the United States. This IV strategy, however, might exacerbate the bias of their OLS estimates. This is for two reasons. First, countries' genetic distance to British populations, or more generally to Western Europeans before the start of colonization in 1500, is highly correlated with their initial biogeographical conditions and therefore, with the timing of Neolithic revolution. Second European colonists experienced higher mortality rates when they encountered populations that had been separated from them for a longer time (e.g., in sub-Saharan Africa). Therefore, SW's instrument (genetic distance to British population in 1500) is correlated with countries' current income per capita through pre- and post-colonial channels that are not accounted for in their second stage. When I include geographic fixed effects and proxies of colonization strategies (such as log settler mortality or percent European descent) in IV regressions, I find no evidence that genetic distance to the technological frontier acts as an obstacle to the diffusion of development.

To further examine the validity of SW's barrier interpretation of genetic distance, I explore the relationship between the within-country variations in genetic distance and economic performance over the past 500 years. The idea is to ask whether it is more likely for a country to become richer as it becomes genetically closer to the technological frontier.<sup>11</sup> The results suggest that former colonies that became genetically closer to Europeans over the past 500 years did not become richer because of the changes in their genetic characteristics.

The paper proceeds as follows. Section 2 reviews the related literature. In Section 3, I present my argument and descriptive evidence regarding the endogeneity of genetic distance to the technological frontier. Section 4 describes the data. The empirical analysis is presented in Section 5. Section 6 concludes.

### 1.3 Related Literature

This study contributes to the empirical literature on the fundamental determinants of economic development.<sup>12</sup> The most closely related research is the empirical literature that uses genetic distance

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example of natural experiment of history (AJR, 2001, 2002, 2004; Engerman and Sokoloff, 2011), and therefore, a horse race between biological and institutional explanations of the causes of underdevelopment is possible in this sample.

<sup>11</sup>Note that SW suggest that the result of their study can help policy-makers to "reduce barriers to the flows of ideas and innovations across populations" (Callaway, 2012, p.154). Therefore, their interpretation of their results has an inherent causal theme.

<sup>12</sup>In the contemporary literature, the works of Diamond (1997), Gallup et al. (1998), and Sachs (2001) refers to the effect of geography. The studies by Ahsraf and Galor (2013), Guiso et al. (2006, 2009), SW (2009, 2012, 2013) emphasize cultural and/or biological characteristics of populations. AJR (2001, 2002, 2004, 2012), Engerman and Sokoloff (1997), Hall

to examine the effect of cultural and biological characteristics of populations on economic outcomes, and the literature that studies the effect of historical experience of countries during colonization on institutions.

Among the first group, Guiso et al. (2004, 2009) suggest that somatic and genetic differences between European countries have an indirect effect on their contemporary level of development. In their view, higher genetic distance between Europeans (among other factors) leads to lower level of trust between them, which then leads to lower investment and bilateral exchange. Demset et al. (2007) provide empirical evidence that genetic distance is a proxy for cultural heterogeneity, and show that cultural heterogeneity has a direct effect on the stability of European nations. Ashraf and Galor (2013) also provide support for cultural and biological explanations of the causes of underdevelopment by showing that genetic diversity, a measure which like genetic distance is based on expected heterozygosity, has a hump-shaped effect on historical and contemporary income per capita, i.e., very high and very low levels of genetic diversity are not conducive for development. They suggest that sub-Saharan Africa's high genetic diversity decreases the level of trust and cooperation and leads to socioeconomic disorder. On the other hand, Latin America's low levels of genetic diversity decreases the production possibility frontier of these societies and is an obstacle to "successful implementation of superior technological paradigms" (2013, p.2).

In this paper, I accept the consensus among scholars that genetic distance (or diversity) could be a proxy for biological and cultural heterogeneity. I argue, however, that these measures - while might be considered "random" in a purely genetic sense - are endogenous with respect to historical determinants of contemporary comparative development and do not have a direct or indirect *causal* effect on economic performance.

Two main objections to SW's barrier interpretation of genetic distance to the United States have been advanced in the literature. Angeles (2012) suggests that SW's results are not robust to controlling for the fraction of population descended from Europeans.<sup>13</sup> Campbell and Pyun (2011) show that the effect of genetic distance to the United States on income per capita is sensitive to controlling for distance from the equator, and suggest that SW are capturing the effect of geographic and climate similarity. While related to these studies, this paper is more comprehensive in clearly distinguishing between the effect of time-invariant pre- and post-colonial factors on genetic distance and economic performance. To the best of my knowledge, this paper is also the first to argue that genetic distance to the technological frontier is an endogenous determinant of former colonies' economic performance.

Within the literature on the effect of European colonialism on economic development, this paper is most closely related to AJR (2001, 2002), who maintain that colonizers' mortality rate and the density of indigenous population at the time of colonization were among the most important determinants of colonization strategies.<sup>14</sup> In places where Europeans faced high mortality rates

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and Jones (1999), La Porta et al. (1999), Knack and Keefer (1995), North (1971), North and Thomas (1973), and Rodrik (1999) highlight the effect of institutions. Michalopoulos and Papaioannou (2013) explain the role of pre-colonial institutions. Reviewing all of these studies is out of the scope of this paper. Readers who are interested in these topics are referred to Acemoglu and Robinson (2012), who provide an excellent non-technical review of the literature, and a recent paper by SW (2013) on the historical and deep-rooted factors of contemporary comparative development.

<sup>13</sup>However, SW (2013) control for Putterman and Weil's (2012) share of descendent of Europeans and show that their result remains robust.

<sup>14</sup>The effect of colonial experience on institutions and the development path of countries has been emphasized by scholars

and/or high population density, settlement was costly so they imposed “extractive” institutions to exploit the natural and human resources of those regions. On the other hand, locations where Europeans faced low mortality rates and/or low population density encouraged settlement by European colonists. Settlers generally established “inclusive” institutions, which mitigated the adverse effect of colonization.<sup>15</sup>

## 1.4 Colonization, Genetic Distance, and Economic Performance

This section explains how the pre- and post-colonial time-invariant factors simultaneously affect countries’ genetic distance and their economic performance. To this end, I explain the effect of two major human migrations, the early migrations of Homo sapiens out of Africa and the great migration of Europeans during colonization, on the historical and contemporary genetic distance of populations. The goal is to highlight the implications of these two major migrations for statistical inference, especially causal inference, based on genetic distance to the United States.

### 1.4.1 The Pre-Colonial Era

The fundamental determinant of the current genetic distance between populations is the timing of separation of early modern humans, Homo sapiens, from each other in the prehistoric era. Map 1 depicts the migratory path of Homo sapiens and its relation to the genetic distance between Western Europeans and other populations in 1500 A.D. Modern humans evolved in East Africa and over a period of 200,000 years migrated to the north of this continent.<sup>16</sup> Around 100,000 years ago a fraction of them reached the Near East, and through there, colonized the rest of the planet by propagating first to South and East Asia and then, to the Americas. On the map, the numbers beside arrows refer to the time elapsed since early modern humans have arrived in a specific geographical area, and “ $F_{ST}(1500)$ ” is the regional average of the genetic distance of countries to Western Europe in 1500 A.D. While early human migration had been generally eastward, at some point a fraction of the human population, who were residing in the Middle East, started migrating to the west and reached Western Europe around 40,000 years ago.

Two important points emerge out of Map 1: First, in 1500, roughly before the start of European colonization, sub-Saharan Africans had the highest genetic distance to Western Europeans. This is because only a subset of Homo sapiens who evolved in Sub-Saharan Africa migrated to the north of Africa, and only a fraction of this group migrated to the Middle East. As a result, human

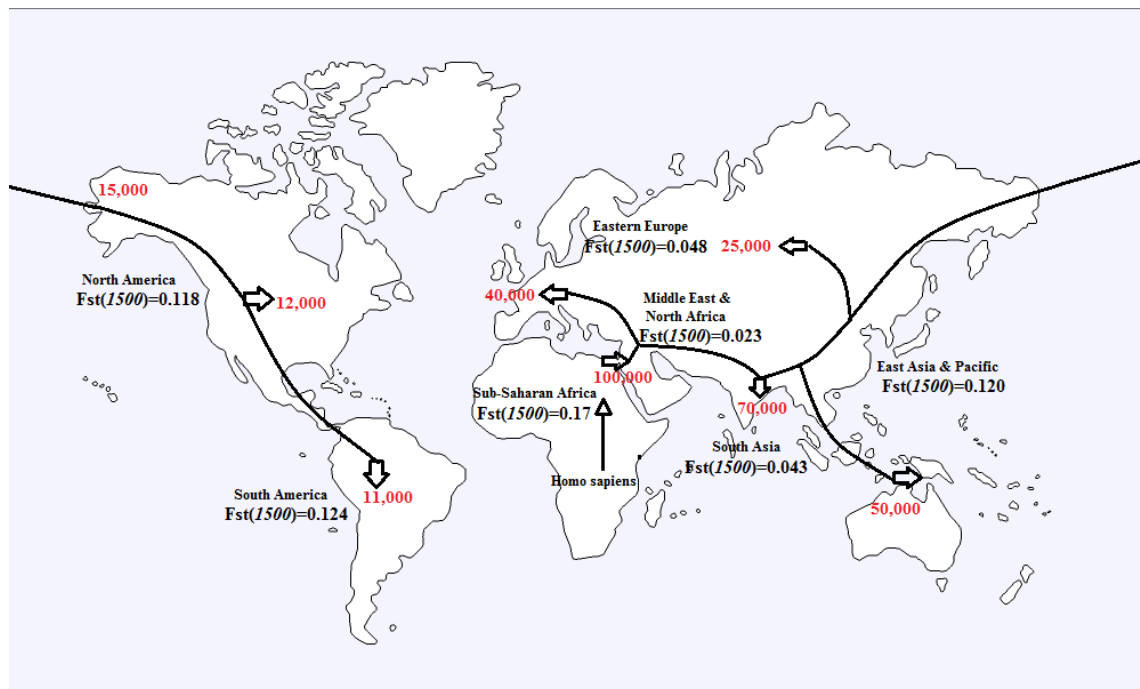
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such as Hayek (1960), La Porta et al. (1998, 1999), and North et al. (1998), among many others. These authors point to the effect of colonization on shaping the early institutions of former colonies. Acemoglu et al. (2008), Acemoglu and Robinson (2012), Engerman and Sokoloff (1997), Knack and Keefer (1995), North (1971), North and Thomas (1973), and Rodrik (1999), among others, further suggest that historical experience of countries during colonization has a persistent effect on their contemporary level of development.

<sup>15</sup>The importance of European settlement during colonization for contemporary comparative development also confirmed by Glaeser et al. (2004) and Easterly and Levine (2012). Glaeser et al. (2004) suggest that European human capital has a stronger effect compared to institutions, and Easterly and Levine (2012) find evidence for the effect of both institutions and human capital.

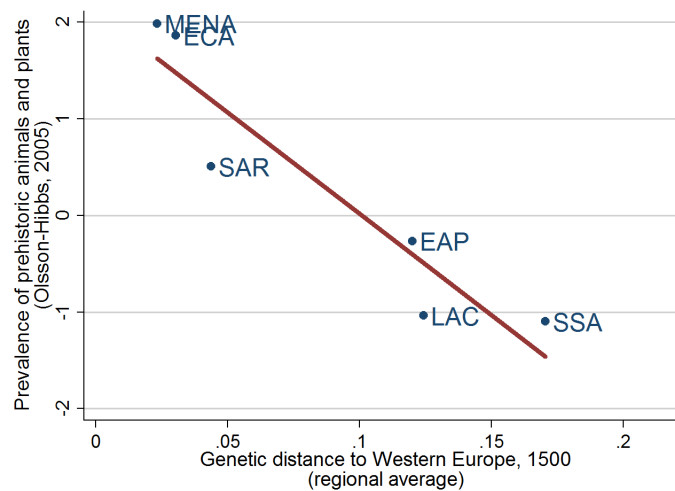
<sup>16</sup>An alternative hypothesis regarding the origins of Homo sapiens is that they evolved as a result of the transfer of genetic materials between hominids that evolved independently across the planet. However, genetic and paleontological evidence do not confirm this alternative hypothesis (Ashraf and Galor, 2013).



**Map 1.** Migration of Homo sapiens and Genetic Distance to Western Europe in 1500 A.D.

*Notes:* This map illustrates the “out of Africa” hypothesis regarding the origins of modern humans, and its effect on the genetic distance of populations to Western European in 1500 A.D. “ $F_{ST}(1500)$ ” refers to the regional average of genetic distance to British population in 1500. However, since genetic distance of Belgium, France, Iceland, Ireland, Luxembourg and Spain to British population in 1500 is 0 and genetic distance of Austria, Denmark, Germany, Netherlands, Norway, Sweden and Switzerland is very close to zero (0.0021), the genetic distance of countries to British population in 1500 could be interpreted as their genetic distance to Western Europe in 1500. Information on the migratory paths of Homo sapiens out of Africa is gathered from resources available on the World Wide Web, For example from Smithsonian Foundation (<http://www.smithsonianmag.com/history-archaeology/human-migration.html>), National Geographic (<https://genographic.nationalgeographic.com/human-journey>). Data on genetic distance is taken from Sploaore and Wacziarg (2009). Data definition and sources are presented in Appendix C.

Figure 1.2: The Initial Biogeographical Conditions and Genetic Distance to Western Europe in 1500.



Notes: Genetic distance to Western Europe in 1500 refers to  $F_{ST}$  genetic distance between plurality groups. Prevalence of prehistoric animals and plants refers to the first principal component of the regional average of the number of prehistoric animals and plants available for domestication. Both variables are taken from Olson and Hibbs (2005). ECA=Europe and Central Asia, MENA=Middle East and North Africa, EAP=East Asia and Pacific, SAR=South Asian Region, LAC=Latin America, SSA=sub-Saharan Africa, according to the World Bank classification of regions. Data definitions and sources are presented in Appendix C.

populations outside sub-Saharan African were genealogically closer to each other than to sub-Saharan Africans.<sup>17</sup> Second, Map 1 shows that outside Africa, there is a proportional relationship between migratory distance of populations and their genetic distance to Western Europeans i.e., as we move eastward along the migratory path of *Homo sapiens*, genetic distance to Western Europeans increases.<sup>18</sup>

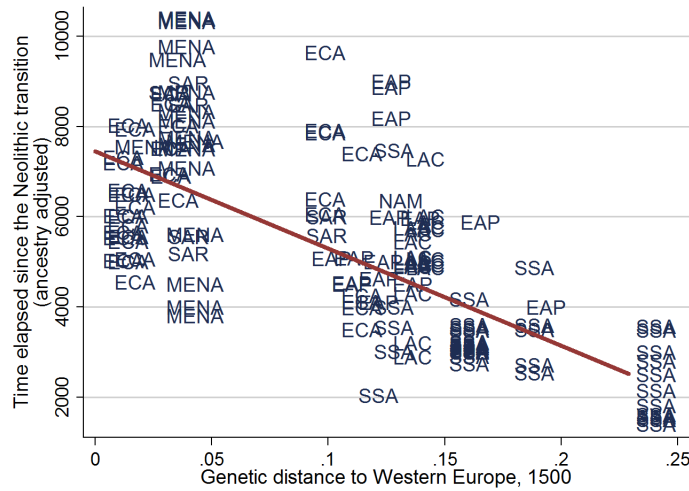
This pattern of early human migration is relevant for statistical inference based on genetic distance. Figure 1.2 plots the first principal component of the regional average of the number of prehistoric animals and plants available for domestication against the regional average of genetic distance to Western Europe in 1500.<sup>19</sup> There is a strong negative correlation between the two variables (their correlation is -0.93). Similarly, Figure 1.3 shows that there is a negative correlation between the number of years since the Neolithic transition and genetic distance to Western Europe in 1500. Diamond (1997) argues that the ecological advantages of Eurasia provided suitable conditions for early transition to sedentary life and the development of agricultural technologies, and

<sup>17</sup>The average of genetic distance of sub-Saharan Africans to Western Europeans in 1500 is 0.1704 (on the scale of 0 to 0.2288), while the average of the genetic distance of the rest of the world (excluding Western Europe itself) is 0.0835. Note that 0.0869 (=0.1704-0.0835) units difference in contemporary genetic distance of countries to the United Kingdom approximately corresponds to the difference between Netherlands and Guatemala (the current match of weighted  $F_{ST}$  genetic distance of Netherlands and Guatemala to the United Kingdom is 0.005 and 0.091 respectively).

<sup>18</sup>This phenomenon is known as the serial founder effect in population genetics. It refers to the loss of genetic variations when populations migrate over a long distance, resulting in a positive proportional relationship between genetic distance and migratory distance outside Africa.

<sup>19</sup>Number of prehistoric domesticated animals refers to the geographical distribution of the worlds 14 domesticable herbivorous or omnivorous, terrestrial mammals weighing more than 45 kg. Number of prehistoric domesticated plants refer to the geographical distribution of the worlds 56 heaviest wild grasses.

Figure 1.3: The Timing of The Neolithic Revolution and Genetic Distance to Western Europe in 1500.

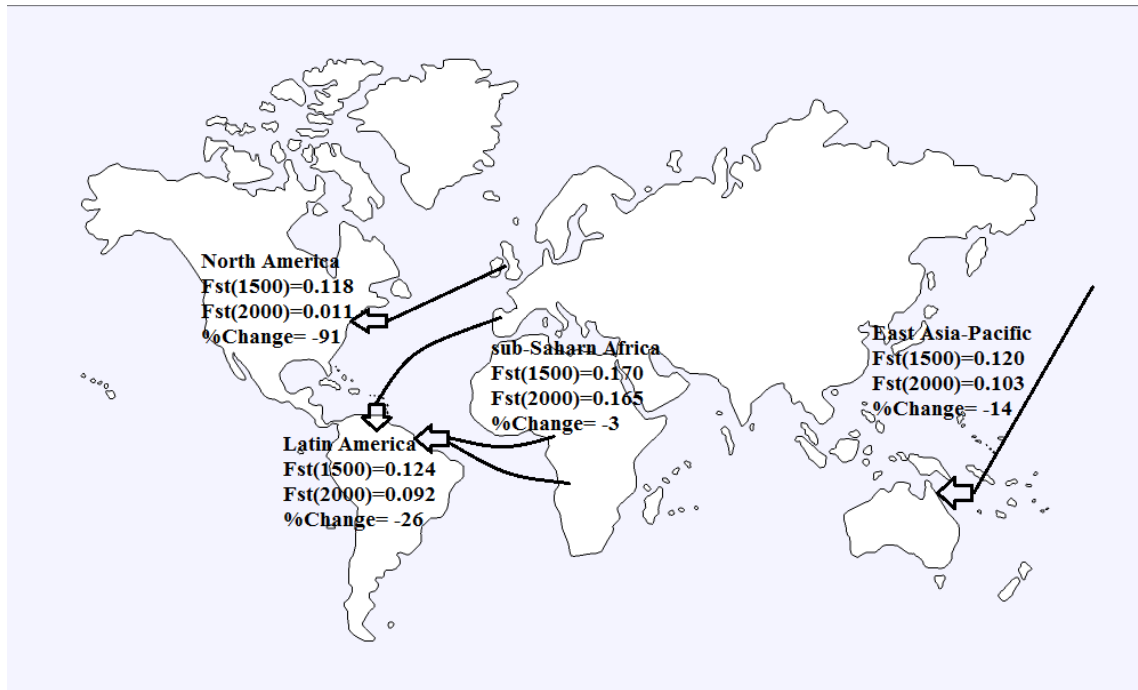


Notes: Genetic distance to Western Europe in 1500 refers to  $F_{ST}$  genetic distance between plurality groups. The vertical axis is the weighted average of Neolithic transition timing, where the weight associated with a given country represents the fraction of the year 2000 population that can trace its ancestral origins to the given country in 1500. ECA=Europe and Central Asia, MENA=Middle East and North Africa, EAP=East Asia and Pacific, SAR=South Asian Region, LAC=Latin America, NAM=North America, SSA=sub-Saharan Africa, according to the World Bank classification of regions. Data definitions and sources are presented in Appendix C.

the East-West orientation of Eurasia facilitated the diffusion of agricultural resources and technology across this continent. Diamond partly attributes the subsequent economic success of Europe to its initial biogeographical advantages. Olsson and Hibbs (2005) and Ashraf and Galor (2011a) provide confirmatory econometric evidence regarding the effect of initial biogeographical conditions on historical and contemporary levels of development.<sup>20</sup>

These ecological advantages were not present in other continents. Figures 3-1 and 3-2 show that regions with populations that were genetically more distant from European also had fewer domesticable animals and plants, and as a result, underwent the Neolithic transformation later. As a consequence, populations' genetic distance to Western Europeans before the start of European colonization was not independent of the distribution of the prehistoric determinants of economic performance. Since both genetic distance and economic performance are highly persistent, this negative pre-colonial correlation persists to the contemporary era.

<sup>20</sup>Further indirect evidence in favour of Diamond's argument is provided by Coming, Easterly, and Gong (2006, 2010), who show that the level of technological advancement of countries even 3000 years ago has explanatory power for current level of development; and by Bockstette, Chanda, and Putterman (2002), who suggest that an index capturing experience with state level institutions from year 1 to 1950 is significantly correlated with contemporary measures of political stability and institutional quality, and the level and the rate of growth of income.

**Map2.** Migration of Europeans and Contemporary Genetic Distance to the United Kingdom.

Notes: This map refers to the effect of European colonization on the regional average of the genetic distance of former colonies to the British population. " $F_{ST}(1500)$ " refers to the regional average of genetic distance to British population in 1500, and " $F_{ST}(2000)$ " refers to the regional average of the current match of weighted  $F_{ST}$  genetic distance to United Kingdom. % Change in genetic distance is calculated as  $(F_{ST}(2000) - F_{ST}(1500)) * 100 / F_{ST}(1500)$ . Data on genetic distance is taken from Sploaore and Wacziarg (2009). Data definition and sources are presented in Appendix C.

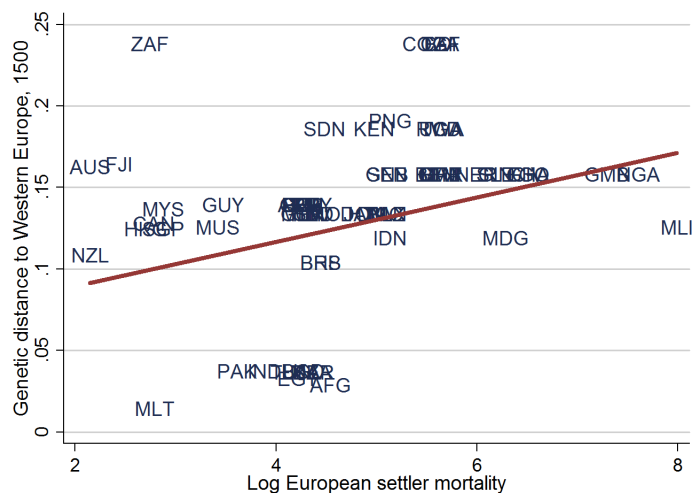
## 1.4.2 The Colonial Era

Map 2 depicts the effect of European migration to the New World on the contemporary genetic distance of former colonies to the United Kingdom.<sup>21</sup> European settlement significantly reduced the genetic distance of former colonies outside sub-Saharan Africa to Western Europeans (in absolute value, 91 and 26 percent in North and South America respectively and 14 percent in the Pacific region). In contrast, Europeans generally didn't settle in sub-Saharan Africa due to an unfavourable disease environment, leaving genetic distance to Europeans relatively unchanged. It is well known in the literature that European settlement brought inclusive institutions (AJR, 2001) and/or European human capital (Glaeser et al.; 2004). Therefore, colonization induced a negative cross-country correlation between genetic distance to the United States and current income per capita that might be unrelated to SW's barrier effect of genetic distance.

Further clarifying the underlying mechanism, Figure 1.4 plots the genetic distance of former colonies to Western Europe in 1500 against the log of European settler mortality. The positive correlation between the two variables suggests that, *on average*, Europeans experienced higher

<sup>21</sup> On this map, " $F_{ST}(2000)$ " refers to the regional average of the contemporary genetic distance to the United Kingdom, and "% Change" refers to the percentage change in the regional average of genetic distance over the past 500 years. In practice, one can use genetic distance to the United States and genetic distance to the United Kingdom interchangeably, since the cross-country correlation between the two measures is 0.99.

Figure 1.4: European Settler Mortality and Genetic Distance to Western Europe in 1500.



Notes: The sample includes former colonies. The regression represented by the fitted line yields a coefficient of 0.014 (standard error=0.062),  $N=70$ ,  $R^2=0.10$ . Genetic distance to Western Europe in 1500 refers to  $F_{ST}$  genetic distance between plurality groups. The covariance between the two variables is 0.38. Data definition and sources are presented in Appendix C.

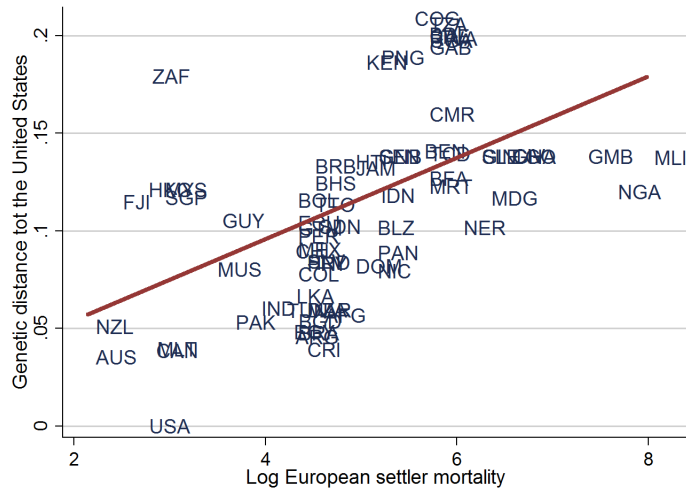
mortality rate when they encountered populations that were genetically more distant from them.<sup>22</sup> Figure 1.5 plots the contemporary genetic distance of former colonies to the United States against the log of European settler mortality. Compared to Figure 1.4, the fitted line is steeper, highlighting the impact of European settlement on genetic distance of former colonies to the frontier of technological innovation.

Figure 1.6 plots the log of real GDP per capita against the log of European settler mortality in the sample of former colonies, and shows a strong negative correlation between the two variables. AJR famously argued that this correlation is a direct result of European settlement, because colonizers generally didn't settle in geographic regions with an unfavourable disease environment, and they followed an extractive strategy to exploit natural and human resources of those regions. The correlations depicted in Figures 3-4 and 3-5 suggest that genetic distance to the United States is *endogenous* in the sample of former colonies, i.e., Europeans' colonization strategy had a simultaneous and opposing effect on genetic distance and economic performance of former colonies (Figure A1 of Appendix B formalizes this argument using a diagram).

To summarize, the prehistoric ecological prerequisites for good economic performance were absent in those societies that were genetically farther away from Western Europeans. This results in a negative cross-country correlation between genetic distance to Western Europe and measures of economic performance before the start of colonization in 1500. Since both genetic distance and economic performance are highly persistent, this historical correlation is partly reflected in

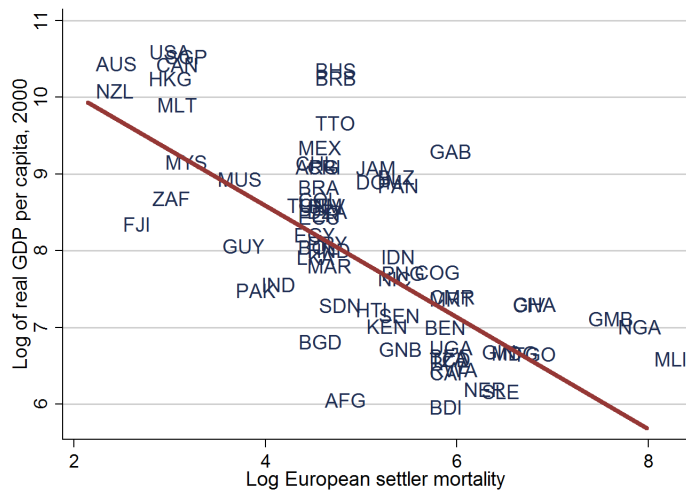
<sup>22</sup>Regression performed but not presented here suggest that genetic distance to Western Europe in 1500 is not a statistically significant determinant of European settler mortality at the time of colonization, once I control for continent fixed effect and/or percentage of tropical land and latitude. Therefore, I am not implying that the correlation between the two variables is causal.

Figure 1.5: European Settler Mortality and Contemporary Genetic Distance to the United States.



Notes: The sample includes former colonies. The regression represented by the fitted line yields a coefficient of 0.020 (standard error=0.012),  $N=71$ ,  $R^2=0.28$ . The measure of genetic distance is the current match of weighted  $F_{ST}$  genetic distance to the United States. The covariance between the two variables is 0.57. Data definition and sources are presented in Appendix C.

Figure 1.6: Income per Capita and European Settler Mortality.



Notes: This figures illustrates AJR's (2001) main argument regarding the colonial origins of comparative development. The regression represented by the fitted line yields a coefficient of -0.726 (standard error=0.080),  $N=71$ ,  $R^2=0.50$ . The sample includes former colonies Data definition and sources are presented in Appendix C.

Figure 1.1. Moreover, the colonization strategy of Europeans in their former colonies reinforced this negative correlation. A empirical strategy that does not properly control for the confounding effect of pre- and post-colonial factors suffers from bias due to correlated missing variables and yields inconsistent estimates, which may lead to misleading interpretations.

## 1.5 Data and Descriptive Statistics

### 1.5.1 Genetic Distance

Data on genetic distance are from SW and are available online from <http://sites.tufts.edu/enricospolaore>. The original source of the genetic distance data is Cavalli-Sforza, Menozzi, and Piazza (1994). Here I briefly review the main concepts and the definition of genetic distance; readers are referred to SW (2009, 2012, 2013) for a more detailed and technical discussion.

The main measure of genetic distance used in this paper (and SW) is  $F_{ST}$  genetic distance to the United States. This measure is based on indices of expected heterozygosity, or the probability of the dissimilarity of alleles between two randomly selected individuals from the relevant populations.<sup>23</sup> By construction,  $F_{ST}$  distance is a measure of the degree of genealogical relatedness, i.e., the time elapsed since two currently separated populations were one. Higher values of  $F_{ST}$  distance refer to longer periods of separation between populations and smaller degrees of relatedness between them. Since data on genetic distance are available at the population level, and not at the country level, SW use the ethnic composition data of Alesina et al. (2003) to match the population level genetic distance to the country level. Further, to account for the fact that the United States is a genetically diverse society, they weight the country level  $F_{ST}$  genetic distance by shares of ethnic groups residing in each country. More specifically, the weighted  $F_{ST}$  genetic distance of a country  $k$  from the United States ( $US$ ) is calculated according to the formula below:

$$F_{ST}^W = \sum_{i=1}^I \sum_{j=1}^J (s_i^k \times s_j^{US} \times d_{ij})$$

where  $s_i^k$  and  $s_j^{US}$  refer to the share of population  $i = 1, \dots, I$  and  $j = 1, \dots, J$  in countries  $k$  and the United States, respectively, and  $d_{ij}$  is the  $F_{ST}$  genetic distance between groups  $i$  and  $j$ . SW refer to this index as “the current match of weighted  $F_{ST}$  genetic distance to the United States”. To save space, I refer to this measure simply as “genetic distance to the United States”. This index captures the expected genetic distance between two randomly selected individuals, one from country  $k$  and one from the United States, and takes values on the interval 0 to 0.2088, where a greater value means less genealogical relatedness between populations.

Following SW, in Section 5.3 I use genetic distance to the United Kingdom in 1500 as an instrument for genetic distance to the United States. I refer to this index as “genetic distance to Western Europe in 1500”. This is because the genetic distance of Belgium, France, Iceland, Ireland, Luxembourg and Spain to the British population in 1500 is 0, and genetic distance of Austria, Denmark, Germany, Netherlands, Norway, Sweden and Switzerland to the British population is very close to zero (0.0021).

<sup>23</sup>An allele is one of the various forms a gene can take.

Table 1.1: Summary Statistics

	<b>Mean</b>	<b>Std. Dev.</b>	<b>Min</b>	<b>Max</b>	<b>N</b>
Sample: The World					
Log of real GDP per capita, 2000	8.442	1.365	5.965	11.041	136
Genetic distance to the United States	0.094	0.051	0	0.209	136
Genetic distance to Western Europe, 1500	0.097	0.068	0	0.229	134
Latitude (absolute value)	26.467	17.104	0.422	67.47	136
Percent European descent	30.836	40.53	0	100	136
Average of government effectiveness	-0.003	0.987	-1.921	2.364	136
Log Neolithic transition timing	8.507	0.436	7.244	9.25	136
Log arable land area	9.786	2.065	2.301	14.381	136
Sample: Former Colonies					
Log of real GDP per capita, 2000	8.004	1.236	5.965	10.588	68
Genetic distance to the United States	0.11	0.05	0	0.209	68
Genetic distance to the United Kingdom	0.105	0.063	0.008	0.226	67
Genetic distance to Germany	0.098	0.053	0.009	0.174	68
Genetic distance to Western Europe, 1500	0.127	0.053	0.005	0.229	67
Log European settler mortality	4.746	1.24	2.146	7.986	68
Latitude (absolute value)	16.208	12.29	0.422	61.063	68
Percent European descent	19.191	29.011	0	99.5	68
Percent European settler, 1900	14.158	24.766	0	99	66
Log Neolithic transition timing	8.386	0.359	7.617	9.101	68
Log arable land area	9.936	2.085	2.301	14.381	68
Social infrastructure, (1986-1995)	0.393	0.211	0.118	0.973	66
Average years of schooling (1960-2000)	3.625	2.529	0.409	10.862	57
Log population density, 1500	0.582	1.503	-3.817	4.135	66

Notes: Data definitions and sources are presented in Appendix C.



## 1.5.2 Other Variables and Summary Statistics

My empirical analysis is based on two samples. The first is a world sample that includes 136 countries for which data on income per capita, genetic distance to the United States, and other control variables are available. The second is a sample of 68 former European colonies for which data on income per capita, genetic distance to the United States, and log of European settler mortality are available.<sup>24</sup> Table 2.1 presents summary statistics of the main variables used in empirical analysis. The dependent variable in all regressions is the log of real GDP per capita in 2000 in purchasing power parity and constant 2005 US dollars from the Penn World Tables. Data on institutions are from AJR (2001), Acemoglu et al. (2008), Hall and Jones (1999), and the Worldwide Governance Indicator (WGI). Data definitions and sources are presented in Appendix C.

## 1.6 Empirical Analysis

Let  $Y$  and  $D$  denote current income per capita and genetic distance to the United States, respectively, and let  $M$  denote a historical determinant of economic performance which is correlated with both  $D$  and  $Y$ , for example log of European settler mortality at the time of colonization. Suppose that the true relationship between  $Y$ ,  $D$ , and  $M$  is

$$Y = \alpha D + \beta M + u \quad (1.1)$$

where  $u$  is a disturbance term.<sup>25</sup> The hypothesis I am interested in is that, apart from its correlation with the pre- and the post-colonial determinants of economic performance, genetic distance to the technological frontier does not have any direct effect on income per capita; that is,  $\alpha=0$ .

As is well-known, if  $M$  is correlated with both  $D$  and  $Y$ , its inclusion in the regression is necessary for consistent estimation of  $\alpha$ . Remember that in the case of settler mortality, Figures 3-4 and 3-5 show that  $\text{Cov}(D, M) > 0$  and  $\text{Cov}(Y, M) < 0$ . Let  $D = \theta M + v$  denote the statistical association between genetic distance to the United States and log European settler mortality. Also assume that  $D$  and  $M$  are independent of  $u$  and that  $v$  is independent of  $M$ . Suppose that one ignores  $M$  and estimates the effect of genetic distance on economic performance in a regression like  $Y = \alpha D + \epsilon$ . Standard arguments imply that the probability limit of the OLS estimator in this regression is

$$\text{plim } \hat{\alpha} = \alpha + \beta\theta. \quad (1.2)$$

Figure 1.5 suggests that  $\theta$  is positive and Figure 1.6 suggests that  $\beta$  is negative. Therefore, according to equation (1.2), the OLS estimate of  $\alpha$  has a downward bias if one omits  $M$ . Also note that adopting an empirical strategy similar to SW and using country-pairs and regressing income differences on the differences in countries genetic distance to the United States (which is referred to as relative genetic distance in SW) does not solve the problem of omitted variable bias. In this case, the regression equation is  $\Delta Y = \alpha \Delta D + \Delta \epsilon$ , where  $\Delta Y$  is the difference in income per capita

<sup>24</sup>For former colonies, the sample size varies based on the choice of technological frontier. For example, if Germany is taken as the technological frontier, the sample size increases to 76 countries.

<sup>25</sup>For the sake of exposition, the dependence of income pre capita,  $Y$ , on other covariates is suppressed. The extension to that case is trivial.

of countries  $i$  and  $j$  and  $\Delta D$  is the difference in their genetic distance to the United States, an argument similar to the one used in deriving equation (1.2) suggests that  $\text{Cov}(\Delta D, \Delta \epsilon) = \beta \theta \neq 0$ .<sup>26</sup>

Therefore, it is easy to see that this bias is present in all of SW's estimates of the effect of genetic distance on economic performance. This is for two reasons: First, SW do not control for the simultaneous effect of colonization on genetic distance to the United States and income per capita.<sup>27</sup> Second, they do not properly control for heterogeneity between continents.<sup>28</sup> To eliminate the bias, I estimate (5.1) keeping in mind the facts described in Section 3, and test for  $\hat{\alpha}=0$ . The empirical results are described in the remainder of this section.

### 1.6.1 Genetic Distance and Economic Performance in the World Sample

This section examines the robustness of the statistical association between genetic distance to the United States and income per capita in the world sample. Because as shown in Section 3, there are important geographic factors that are correlated with both genetic distance to Western Europe in 1500 and pre-colonial economic performance, I include geographic fixed effects in the empirical specification. The most important dimension of heterogeneity between continents is the difference between sub-Saharan Africa and the rest of the world. This is for three reasons: First, because human populations outside sub-Saharan Africa are genealogically much more closely related to each other than to sub-Saharan Africans (see Map 1). Second, compared to other regions, sub-Saharan Africa had a lower biogeographical endowments (see Figure 1.2). And third, Europeans settled in relatively higher proportions in colonies outside sub-Saharan Africa (see Figure 1.5). Therefore, in the baseline specification, I only include a fixed effect for sub-Saharan Africa. In other specifications that examine the robustness of the baseline results, I add fixed effects for other regions, the ancestry-adjusted timing of the Neolithic transition, arable land area, and a landlock dummy.<sup>29</sup>

<sup>26</sup>Note that SW's bilateral approach does not add any new information to the existing sample and does not have any empirical validity per se. SW suggest that "If our [barrier] interpretation is correct, the relevant measure of genetic distance associated with economic distance between two societies should not be the absolute genetic distance between them, but their relative distance from the world technological frontier" (p.471). Therefore, as this statement suggests, the relevance of SW's bilateral approach hinges on the validity of their barrier interpretation of genetic distance to the technological frontier.

<sup>27</sup>SW control for variables such as absolute differences in latitude and longitude relative to the United States, absolute differences in tropical land area, differences in countries' elevation, measure of geographical distance to the United States, transportation cost, climate differences, measures of linguistic and religious distance. None of these variables are proper proxies for colonization strategies or the other factors that European brought to their former colonies, such as institutions and human capital.

<sup>28</sup>SW include two sets of continent dummies, one set of six dummies (one for each continent) that equal one if the two countries in a pair were on the same continent, and a set of six dummies each equal to one if one country belonged to a given continent and the other did not. Neither set of dummies properly controls for the differences between continents. The following example illustrates the reason: take three countries, The United States (North America), China (Asia), and Congo (sub-Saharan Africa), as an example. SW's first and second sets of continent dummies corresponding to sub-Saharan Africa will be (0, 0, 0), and (0, 1, 1) for US-China, US-Congo, and China-Congo as pairs of observations, respectively. Therefore, the first set of continent dummies imposes an assumption of homogeneity across all three countries, and the second set implies homogeneity between China and the United States relative to Congo. See Campbell and Pyun (2011) for a more detailed discussion of this issue.

<sup>29</sup>Timing of the Neolithic transition captures Diamond's (1997) hypothesis. Since after 1500 the world witnessed mass migration of Europeans to the New World, following the literature (e.g. Putterman and Weil, 2010; Ashraf and Galor, 2013), the ancestry adjusted timing of Neolithic Revolution is used. Arable land area captures the feasibility of agriculture, and the landlock dummy captures the potential effect of geographical isolation on the diffusion of development.

To capture the simultaneous effect of colonization on genetic distance and economic performance, I control for either the average of government effectiveness (1996-1998) as a proxy for current institutions,<sup>30</sup> percent of current population with an ancestor who lived in Europe in 1500, or the absolute value of latitude. The absolute value of latitude partially captures the extent to which countries were influenced by Western Europeans and is used by Hall and Jones (1999) as an instrument for social infrastructure. The use of percent of European descent and government effectiveness capture AJR's (2001, 2002) argument regarding the importance of European settlement in affecting the institutional path of former colonies. To examine the robustness of the results, in some specifications I also include legal origin fixed effects to capture La Porta et al.'s (1999) argument regarding the importance of the legal origin of countries for the quality of government, and the fraction of the population affiliated with major religions to account for the importance of religion as an institutional barrier (or facilitator) for development (e.g. Weber, 1930; Huntington, 1991; Fish, 2002).

Estimates of equation (1.1) are presented in Table 1.2. Column (1) is the simple regression of income per capita on genetic distance to the United States. The coefficient on genetic distance has the expected negative sign and is significant at the 1-percent level. To have a sense of the magnitude of the effect, note that the coefficient of -15.723 implies that, if we take a country like Burkina Faso (a sub-Saharan country in the low income group according to the World Bank's classification), and replace a fraction of Burkinabé with Europeans, to reduce genetic distance from 0.12 to 0.04 (which is the level of Egypt), Burkina Faso's income per capita should increase, permanently, from \$753 to \$1684. If SW's interpretation of genetic distance is correct, this increase in income per capita of Burkina Faso would be a result of the reduction in biological and cultural barriers to the diffusion of innovations from the world technological frontier.

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<sup>30</sup>This index captures perceptions of the quality of public services, the quality of the civil service and the degree of its independence from political pressures, the quality of policy formulation and implementation, and the credibility of the government's commitment to such policies. See Appendix C for data definitions and sources.

Table 1.2: OLS Regression of Income per Capita

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent Variable: Log Real GDP per Capita, 2000 / Sample: The World						
Panel A						
Genetic distance to the United States	-15.723 <sup>***</sup> (1.808)	-2.599 (1.716)	-1.943 (1.907)	-0.161 (2.092)	-0.308 (2.145)	-0.214 (2.009)
Government effectiveness (1996-1998)		0.872 <sup>***</sup> (0.062)	0.831 <sup>***</sup> (0.063)	0.814 <sup>***</sup> (0.072)	0.819 <sup>***</sup> (0.093)	0.824 <sup>***</sup> (0.101)
R <sup>2</sup>	0.350	0.751	0.780	0.787	0.792	0.800
Panel B						
Genetic distance to the United States	-15.723 <sup>***</sup> (1.808)	-2.337 (2.750)	-0.552 (2.894)	1.473 (3.134)	3.521 (2.892)	2.584 (2.572)
Percent European descent		0.012 <sup>***</sup> (0.003)	0.014 <sup>***</sup> (0.002)	0.027 <sup>***</sup> (0.006)	0.030 <sup>***</sup> (0.005)	0.030 <sup>***</sup> (0.005)
R <sup>2</sup>	0.350	0.513	0.617	0.638	0.715	0.730
Observations	136	136	136	136	136	136
sub-Saharan fixed effect	-	Yes	Yes	Yes	Yes	Yes
Geographical controls	-	-	Yes	Yes	Yes	Yes
Other continents fixed effects	-	-	-	Yes	Yes	Yes
Legal origin fixed effects	-	-	-	-	Yes	Yes
Major religion shares	-	-	-	-	-	Yes

Table 3.2 (Continued)

	(1)	(2)	(3)	(4)	(5)	(6)
Panel C						
Genetic distance to the United States	-15.723 <sup>...</sup> (1.808)	-3.804 (2.683)	-1.551 (3.026)	0.259 (3.335)	2.342 (3.108)	-0.442 (2.991)
Latitude (absolute value)		0.021 <sup>...</sup> (0.006)	0.033 <sup>...</sup> (0.005)	0.031 <sup>...</sup> (0.008)	0.036 <sup>...</sup> (0.007)	0.033 <sup>...</sup> (0.007)
R <sup>2</sup>	0.350	0.472	0.601	0.627	0.701	0.715
Observations	136	136	136	136	136	136
sub-Saharan fixed effect	-	Yes	Yes	Yes	Yes	Yes
Geographical controls	-	-	Yes	Yes	Yes	Yes
Other continents fixed effects	-	-	-	Yes	Yes	Yes
Legal origin fixed effects	-	-	-	-	Yes	Yes
Major religion shares	-	-	-	-	-	Yes

Notes: Genetic distance to the United States is the current match of weighted  $F_{3,7}$  genetic distance to this country. Column (1) report the result of cross-sectional OLS regression where genetic distance is entered alone. The estimated coefficient of genetic distance is comparable to the reported result in Spolaore and Wacziarg (2009, Table 1, column 1, p.488); they report a coefficient of -12.906 (standard error=1.383),  $R^2=0.39$ , for 137 countries using income per capita in PPP in 1995 from the World Bank. Percent European descent is from Putterman and Weil's (2010) *World Migration Matrix* and refers to the share of current population of countries with ancestors who lived in Europe in 1500. Government effectiveness is from Worldwide Governance Indicator (WGI) and is measured on a scale of -2.5 to 2.5, where a higher score means more effective government, averaged over 1996-1998. Geographical controls are the log of ancestry adjusted timing of Neolithic transition, log arable land area, and a dummy variable taking value of 1 if a country is landlocked. Robust standard errors are reported in parentheses. Data definition and sources are presented in Appendix C. <sup>...</sup> Significant at 1 percent, <sup>\*\*</sup> Significant at 5 percent, <sup>\*</sup> Significant at 10 percent.

Column (2) adds a dummy for sub-Saharan Africa and the average of government effectiveness (1996-1998) in Panel A, percent of European descent in Panel B, and the absolute value of latitude in Panel C. Estimates in all three panels confirm that the inclusion of a dummy for sub-Saharan Africa and proxies of Western influence during colonization dramatically reduce the magnitude of the coefficient on genetic distance to the point of statistical insignificance. The remaining columns in Table 1.2 examine the robustness of the baseline results by controlling for other historical determinants of contemporary comparative development. These robustness checks produce fairly similar results. To avoid unnecessary repetition, I therefore discuss estimates in Panel B, where the share of European descent is used to capture the effect of colonization.

Column (3) includes a set of geographical controls that the literature suggest might have an effect on the contemporary level of development (timing of the Neolithic transition, arable land area, and a landlock dummy). Adding these controls does not alter the statistical insignificance of genetic distance to the United States. Column (4) includes fixed effects for other continents and shows that the coefficient on genetic distance has the “wrong” (positive) sign and remains statistically insignificant. Adding more controls for institutional and cultural factors (columns 5 and 6) does not alter the results: percent of European descent remains highly significant, and the coefficient on genetic distance to the United States remains positive and statistically insignificant.

A valid concern regarding the estimates in Panel A is the possible endogeneity of institutions. More developed countries might be able to afford better institutions, and/or good institutions and high levels of income could be driven by historical factors that are not captured in the econometric model. To address this concern, I instrument for government effectiveness using the absolute value of latitude or percent of European descent in Table 1.3.<sup>31</sup> Hall and Jones (1999) use latitude to instrument for social infrastructure, and it is generally accepted among scholars that distance from the equator does not have a direct effect on contemporary economic outcomes.<sup>32</sup> AJR’s argument regarding the effect of European settlement on shaping the institutional path of former colonies motivates using percent of European descent as an instrument for government effectiveness.<sup>33</sup>

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<sup>31</sup>It is worth mentioning that the results presented in Tables 5-1 and 5-2 do not depend on the specific measure of institutions used in the regressions, i.e., one could obtain similar result using for example, constraint on executive, risk of expropriation, social infrastructure, indices of the quality of governance from WGI dataset.

<sup>32</sup>There is a relative consensus among scholars that the effect of geographic and climatic factors, captured with variables such as latitude and longitude, on comparative development is not direct and work through the historical effect of initial geographic conditions on factors such as institutions, social capital, and culture. See Spolaore and Wacziarg (2013) for a comprehensive discussion of the effect of geography on comparative development.

<sup>33</sup>AJR (2001) use percent of European settlers in 1900 as an instrument for risk of expropriation in their overidentification tests, and find that the effect of European settlement on income per capita is through institutions. I use Putterman and Weil’s (2011) share of European descent instead. The two variables are tightly correlated (the covariance between them is 0.89). This allows me to keep the sample size at 136 countries (percent of European settler in 1900 is available for 118 countries).

Table 1.3: IV Regression of Income per Capita

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent Variable: Log Real GDP per Capita, 2000 (Penn World Tables) / Sample: The World						
Panel A-I: Two-Stage Least Squares / Instrument: Latitude (absolute value)						
Genetic distance to the United States	-2.795 (1.931)	0.049 (2.087)	1.856 (2.438)	4.205 (2.734)	2.167 (2.067)	3.213 (2.399)
Government effectiveness	0.836... (0.137)	1.070... (0.113)	1.259... (0.242)	1.546... (0.348)	1.391... (0.246)	1.365... (0.255)
AR confidence interval	[0.55, 1.14]	[0.87, 1.33]	[0.90, 2.21]	[1.09, 2.91]	[1.01, 2.16]	[0.97, 2.10]
Panel A-II: First Stage for Government Effectiveness, 1996-1998						
Genetic distance to the United States	-1.208 (2.025)	-1.495 (2.700)	-1.268 (2.825)	-1.717 (2.836)	0.897 (2.522)	-1.943 (2.244)
Latitude (absolute value)	0.025... (0.006)	0.030... (0.005)	0.025... (0.008)	0.023... (0.008)	0.029... (0.007)	0.029... (0.007)
R <sup>2</sup> (first stage)	0.307	0.410	0.464	0.473	0.673	0.718
F-stat (first stage)	17.58	35.65	9.43	7.59	15.91	18.03
Panel B-I: Two-Stage Least Squares / Instrument: Percent European descent						
Genetic distance to the United States	-2.127 (1.984)	0.305 (2.326)	1.633 (2.541)	3.386 (2.388)	1.723 (1.877)	3.002 (2.211)
Government effectiveness	0.959... (0.159)	1.100... (0.148)	1.210... (0.210)	1.377... (0.225)	1.247... (0.160)	1.332... (0.199)
AR confidence interval	[0.65, 1.29]	[0.84, 1.44]	[0.87, 1.80]	[1.03, 2.06]	[0.97, 1.62]	[0.99, 1.83]

Table 3.3 (Continued)

	(1)	(2)	(3)	(4)	(5)	(6)
Panel B-II: First Stage for Government Effectiveness, 1996-1998						
Genetic distance to the United States	-0.219 (1.935)	-0.778 (2.505)	-0.132 (2.846)	-0.567 (2.824)	2.228 (2.437)	-0.077 (2.314)
Percent European descent	0.012** (0.002)	0.013** (0.002)	0.022** (0.005)	0.022** (0.005)	0.026** (0.004)	0.023** (0.004)
R <sup>2</sup> (first stage)	0.366	0.427	0.483	0.493	0.704	0.726
F-stat (first stage)	31.58	39.41	17.02	15.95	36.62	28.18
Observations	136	136	136	136	136	136
Panel C: Overidentification Test						
<i>p</i> -value (from $\chi^2$ test)	[0.40]	[0.82]	[0.85]	[0.59]	[0.54]	[0.89]
sub-Saharan fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Geographical controls	-	Yes	Yes	Yes	Yes	Yes
Other continents fixed effects	-	-	Yes	Yes	Yes	Yes
OPEC fixed effect	-	-	-	Yes	Yes	Yes
Legal origin fixed effects	-	-	-	-	Yes	Yes
Major religion shares	-	-	-	-	-	Yes

Notes: Panels A and B report the result of the instrumental variable regression using absolute latitude and percent European descent as instruments for government effectiveness, respectively. Panel C reports the *p*-value from the appropriate  $\chi^2$  overidentification test where government effectiveness is instrumented with both absolute latitude and percent European descent. Geographical controls are log of ancestry adjusted timing of Neolithic transition, log arable land area, and a dummy variable taking value of 1 if a country is landlocked. Robust standard errors are reported in parentheses. Data definition and sources are presented in Appendix C. \*\* Significant at 1 percent, \* Significant at 5 percent, · Significant at 10 percent.



Table 1.3 reports estimates using the latitude and the percent of European descent instruments in Panels A and B, respectively. The estimated coefficients on genetic distance and government effectiveness in both Panels A-I and B-I are comparable to the OLS estimates reported in Table 1.2. In both panels, the estimated coefficient on genetic distance to the United States is quantitatively small and statistically insignificant, and government effectiveness is significant at the 1-percent level. The estimates are robust to the inclusion of additional control variables, as we move from column (1) to (6).

To show that the second stage results in Panels A and B is not driven by “weak-instrument” problem, I report the first stage F-statistic and Anderson-Rubin (AR) 95 percent confidence set for each specification. Overall, both instruments appear to be strong, and even when the first stage F-statistics is below the conventional level of 10 (columns 3 and 4 of Panel A), AR confidence intervals are bounded and exclude zero, which lead to the rejection of the hypothesis that government effectiveness has no effect on GDP per capita.

The first stage regression results are of independent interest, because they shed light on SW’s hypothesis that genetic distance to the United States is a barrier to the diffusion of technological and *institutional* innovations. The results in Panels A-II and B-II contradict their hypothesis: After controlling for the pre-colonial and colonial confounding factors, genetic distance to the United States is not a statistically significant determinant of government effectiveness.<sup>34</sup>

Finally, Panel C reports the  $p$ -value of  $\chi^2$  overidentification test, where both absolute latitude and percent European descent are simultaneously used as instruments for government effectiveness. In all of the regressions the  $p$ -values are sufficiently large, and therefore, I don’t reject the hypothesis that the estimated coefficients of government effectiveness using absolute latitude or percent European descent are equal at the 5-percent significant level.<sup>35</sup>

Overall, the results of Tables 1.2 and 1.3 provide evidence that pre- and post-colonial factors simultaneously affect genetic distance and economic performance and cast serious doubt on SW’s barrier interpretation.

## 1.6.2 Genetic Distance and Economic Performance in Former Colonies

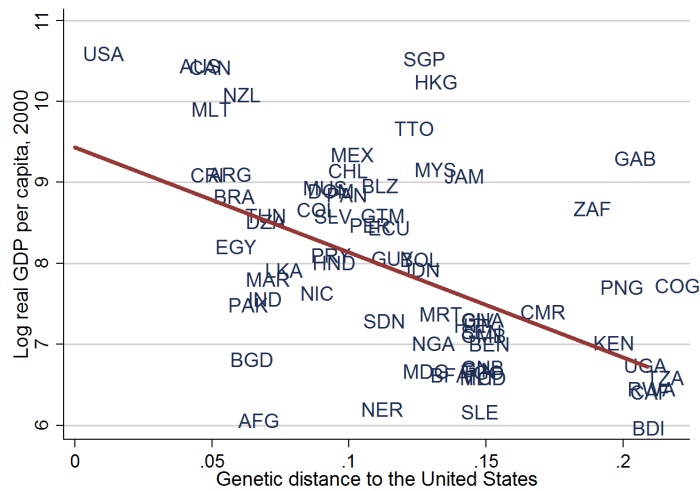
Figure 1.7 plots log of real GDP per capita in 2000 against genetic distance to the United States in the sample of 68 former colonies. The coefficient on genetic distance in the regression represented by the fitted line is -12.967 (standard error=2.615). Therefore, the relationship between genetic distance and economic performance in this sample is comparable to the world sample. As mentioned before, this is unlikely to be an unbiased estimate of the effect of genetic distance to the technological frontier on economic performance because of omitted variables.

Table 1.4 presents estimates that address this bias by controlling for European settler mortality as a proxy for colonization strategy. In Panel A genetic distance to the United States is used as the

<sup>34</sup>Note that these results suggest that controlling for institutions in the regression of income per capita on genetic distance to the United States is not an example of what Angrist and Pischke (2008, p. 64-68) have referred to as “bad control”, i.e., the effect of genetic distance on income per capita is not through institution. If that was the case, genetic distance to the United States should have been a statistically significant determinant of institution.

<sup>35</sup>These results should be interpreted with caution, since absolute latitude and percent European descent are highly correlated.

Figure 1.7: Income per Capita and Genetic Distance to the United States in Former Colonies



Notes: The regression represented by the fitted line yields a coefficient of -12.967 (standard error=2.615),  $N=68$ ,  $R^2=0.27$ .

proxy for genetic distance to the world technological frontier. Panels B and C use genetic distance to the United Kingdom and Germany, instead, as a robustness check.<sup>36</sup> The estimated coefficients in column (1) suggest that the genetic distance of former colonies to the world technological frontier is negatively correlated with income per capita and is significant at the 1-percent level. Once we control for the European settler mortality (column 2), the magnitude of the coefficients on genetic distance falls substantially, and the coefficients are no longer statistically significant. The coefficients on log settler mortality, on the other hand, are negative and significant at the 1-percent level.

<sup>36</sup>According to Putterman and Weil's (2010) *World Migration Matrix*, almost 55 percent of the United States population have British or German ancestors. Further, both countries are in the front-end of technological and institutional innovations compared to former colonies.

Table 1.4: OLS Regression of Income per Capita, Controlling for Colonization Strategies

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent Variable: Log of Real GDP per Capita, 2000 / Sample: Former Colonies						
Panel A - Technological Frontier: The United States						
Genetic distance to the United States	-12.967 <sup>...</sup> (2.615)	-3.825 (2.594)	-3.645 (3.255)	0.742 (3.843)	0.192 (4.171)	-1.772 (3.939)
Log European settler mortality		-0.661 <sup>...</sup> (0.090)	-0.563 <sup>...</sup> (0.118)	-0.455 <sup>...</sup> (0.136)	-0.444 <sup>...</sup> (0.128)	-0.360 <sup>...</sup> (0.130)
Observations	68	68	68	68	68	68
R <sup>2</sup>	0.271	0.575	0.654	0.722	0.726	0.749
Panel B - Technological Frontier: The United Kingdom						
Genetic distance to the United Kingdom	-9.506 <sup>...</sup> (2.071)	-2.422 (2.122)	-2.200 (2.623)	1.871 (3.108)	1.497 (3.508)	0.139 (3.192)
Log European settler mortality		-0.654 <sup>...</sup> (0.093)	-0.532 <sup>...</sup> (0.118)	-0.403 <sup>...</sup> (0.128)	-0.400 <sup>...</sup> (0.124)	-0.336 <sup>...</sup> (0.126)
Observations	67	67	67	67	67	67
R <sup>2</sup>	0.246	0.551	0.646	0.719	0.721	0.738
Geographical controls	-	-	Yes	Yes	Yes	Yes
Continent fixed effects	-	-	-	Yes	Yes	Yes
Legal origin fixed effects	-	-	-	-	Yes	Yes
Major religion shares	-	-	-	-	-	Yes

Table 3.4 (Continued)

	(1)	(2)	(3)	(4)	(5)	(6)
Panel C - Technological Frontier: Germany						
Genetic distance to Germany	-12.138 <sup>***</sup> (2.377)	-3.232 (2.512)	-2.881 (2.688)	2.246 (3.366)	1.830 (3.480)	0.060 (3.400)
Log European settler mortality		-0.680 <sup>***</sup> (0.102)	-0.565 <sup>***</sup> (0.111)	-0.462 <sup>***</sup> (0.122)	-0.444 <sup>***</sup> (0.118)	-0.418 <sup>***</sup> (0.128)
Observations	74	74	74	74	74	74
R <sup>2</sup>	0.274	0.554	0.636	0.712	0.717	0.723
Geographical controls	-	-	Yes	Yes	Yes	Yes
Continent fixed effects	-	-	-	Yes	Yes	Yes
Legal origin fixed effects	-	-	-	-	Yes	Yes
Major religion shares	-	-	-	-	-	Yes

Notes: In all three panels, the measure of genetic distance is the current match of weighted  $F_{ST}$  genetic distance. Geographical controls are absolute value of latitude, percentage of tropical land, and a dummy variable taking value of 1 if a country is landlocked. Continent fixed effect are dummies for Africa, Asia, and Other continents with America being the omitted group. Data definitions and sources are presented in Appendix C.<sup>\*\*\*</sup> Significant at 1 percent, \*\* Significant at 5 percent, \* Significant at 10 percent.

The remaining columns in Table 1.4 show that the estimates in column (2) are robust to controlling for other historical correlates of income per capita. In column (3) log of ancestry-adjusted timing of the Neolithic transition, log percentage of arable land, and a landlock dummy are added to the model. Columns (4) and (5) include continent and legal origins fixed effects, and column (6) adds major religion shares. In all three panels, the inclusion of additional control variables does not affect the baseline results of column (2), i.e., genetic distance remains statistically insignificant, sometimes with an estimated positive effect, and log of European settler mortality has the expected sign and is highly statistically significant. Overall, the results presented in Table 1.4 provide strong empirical support in favour of the simultaneous effect of colonization on genetic distance and economic performance.

A possible concern with the result presented in Table 1.4 could be that measurement errors in settler mortality data are affecting the results. For example, Albouy (2012) argues that AJR's bishop mortality rates in Latin America are not a reliable source of Spanish and Portuguese's mortality rates at the time of colonization, and that AJR do not properly distinguish between peacetime and campaign episodes. To remove the possible effect of such measurement error in the settler mortality data on the results, in Table (1.11) of Appendix A I check the robustness of the results of Table 1.4 using Albouy's preferred sample (26 or 27 out of 68 countries for which according to Albouy the data on settler mortality is reliable). As we can see from Table 1.11, this doesn't change the results presented in Table 1.4.

### **Robustness Check**

As mentioned in the introduction, former colonies experienced significant changes in both genetic and non-genetic aspects of their societies as a result of the feasibility and the extent of European settlement, and, therefore, a horse race between biological and institutional explanations of the causes of underdevelopment is possible in this sample.

In Table 1.5 I control for the social infrastructure index of Hall and Jones (1999), instrumented with log European settler mortality (AJR), and ask whether it is the genetic distance of former colonies to the technological frontier, or the colonial heritage that is embedded in their institutions that affects their income per capita? Panel A reports the result of the second stage of the IV regressions, and Panels B and C report the corresponding first stage and OLS, respectively.

Table 1.5: IV Regression of Income per Capita / Instrumented Variable: Social Infrastructure

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent Variable: Log of Real GDP per Capita, 2000 (Penn World Tables) / Sample: Former Colonies						
Panel A: Two-Stage Least Squares / Instrument: Log European Settler Mortality						
Genetic distance to the United States		-3.002 (2.780)	-2.428 (3.284)	3.852 (2.932)	3.865 (3.119)	3.779 (2.993)
Social infrastructure		6.289*** (0.917)	5.823*** (1.263)	4.325*** (1.043)	4.327*** (1.067)	4.282*** (1.309)
AR confidence interval		[4.97, 9.93]	[4.07, 10.77]	[2.71, 8.41]	[2.68, 8.51]	[2.26, 9.41]
Panel B: First Stage for Social Infrastructure, 1986-1995						
Genetic distance to the United States		-0.264 (0.477)	-0.068 (0.692)	-0.652 (0.789)	-0.722 (0.840)	-1.145 (1.079)
Log European settler mortality		-0.103*** (0.024)	-0.088*** (0.029)	-0.093*** (0.034)	-0.092*** (0.034)	-0.076** (0.036)
R <sup>2</sup> (first stage)		0.429	0.444	0.478	0.480	0.514
F-stat (first stage)		14.90	9.36	7.40	7.41	4.55
Geographical controls	-	-	Yes	Yes	Yes	Yes
Continent fixed effects	-	-	-	Yes	Yes	Yes
Legal origin fixed effects	-	-	-	-	Yes	Yes
Major religion shares	-	-	-	-	-	Yes

Table 3.5 (Continued)

	(1)	(2)	(3)	(4)	(5)	(6)
Panel C: Ordinary Least Squares						
Genetic distance to the United States	-13.799 <sup>***</sup> (2.489)	-7.540 <sup>***</sup> (2.112)	-1.621 (2.982)	4.097 (3.261)	3.907 (3.532)	2.621 (2.877)
Social infrastructure		3.645 <sup>***</sup> (0.396)	2.816 <sup>***</sup> (0.462)	2.691 <sup>***</sup> (0.383)	2.678 <sup>***</sup> (0.391)	2.463 <sup>***</sup> (0.417)
Observations	66	66	66	66	66	66
Geographical controls	-	-	Yes	Yes	Yes	Yes
Continent fixed effects	-	-	-	Yes	Yes	Yes
Legal origin fixed effects	-	-	-	-	Yes	Yes
Major religion shares	-	-	-	-	-	Yes

Notes: Panel A report the result of the second stage of the instrumental variable regression, where social infrastructure (1986-1996) is instrumented with log of European settler mortality. Panel B reports to the results of the corresponding first stage, and Panel C report the result of Ordinary Least Squares regressions. Geographical controls are log of the ancestry adjusted timing of Neolithic Transition, log percentage of arable land, a landlock dummy, and the absolute value of latitude. Robust standard errors are reported in parentheses. Data definitions and sources are presented in Appendix C. \*\*\* Significant at 1 percent, \*\* Significant at 5 percent, \* Significant at 10 percent.

Column (1)-Panel C shows that when genetic distance is the only independent variable, its coefficient is significant at 1 percent. Column (2)-Panel A adds social infrastructure (instrumented with log settler mortality) and shows that genetic distance to the United States is no longer statistically significant. The comparison of OLS and IV results (column 2-Panels C and A) suggests that OLS regression substantially underestimates the effect of institutions. Column (3) demonstrates that this result is robust once I control for log ancestry adjusted timing of Neolithic transition, log arable land area, landlock dummy, and absolute latitude. Controlling for continent, legal origin, and major religion shares (columns 4-6) does not alter the results, i.e., social infrastructure remains significant at the 1-percent level, and the coefficient on genetic distance to the United States is positive and insignificant. Panel B demonstrates that the biological divergence of former colonies from the United States has no significant effect on their institutions.

Note that the first stage F-statistics suggest that log settler mortality gradually becomes a weak instrument as I add the geographical and historical determinants of income per capita to the regressions. However, in all specifications Anderson-Rubin (AR) 95 percent confidence interval excludes zero, which leads to the rejection of the null hypothesis that social infrastructure has no effect on the level of development. Regardless, to remove any source of concern regarding the problems associated with weak instrument, I check the robustness of these results using average years of schooling instead of social infrastructure in Table 1.6, and using alternative instrument for social infrastructure in Table 1.7.

Glaeser et al. (2004) suggest that Europeans brought their growth-inducing human capital to colonies in which they settled, and that human capital captures relatively “deeper” factors compared to institutions.<sup>37</sup> To address their argument, Table 1.6 controls for the average years of schooling (1960-2000) in IV regressions. Column (1)-Panel C shows that in a simple OLS regression of income per capita on genetic distance to the United States, the coefficient on genetic distance is quantitatively large and is highly statistically significant. The IV and OLS estimates in columns (2)-(6) suggest that, with and without the set of control variables, the inclusion of the average years of schooling completely removes the statistical association between genetic distance and economic performance (except column 2-Panel C, in which genetic distance to the United States is significant at 10 percent in the OLS regression). The first stage results in Panel B suggest that the genetic distance between former colonies and the world technological frontier is not a significant determinant of these countries’ human capital. Note that except in column (6), the first stage F-statistics is above the conventional level of 10, and in all specifications AR confidence interval excludes zero.

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<sup>37</sup>A recent paper by Acemoglu, Gallego, and Robinson (2014), however, shows that the effect of institution on contemporary economic performance of nations might work through human capital and therefore, institutions are indeed the fundamental cause of long-run development.



Table 1.6: IV Regression of Income per Capita / Instrumented Variable: Schooling

Dependent Variable: Log of Real GDP per Capita, 2000 (Penn World Tables) / Sample: Former Colonies	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Two-Stage Least Squares / Instrument: Log European Settler Mortality						
Genetic distance to the United States		-0.626 (2.283)	-2.232 (2.530)	-1.333 (3.292)	-1.122 (3.408)	1.491 (4.123)
Years of schooling, 1960-2000		0.496 <sup>***</sup> (0.065)	0.444 <sup>***</sup> (0.060)	0.513 <sup>***</sup> (0.079)	0.532 <sup>***</sup> (0.082)	0.602 <sup>***</sup> (0.117)
AR confidence interval		[0.38, 0.65]	[0.34, 0.59]	[0.36, 0.70]	[0.37, 0.72]	[0.40, 0.97]
Panel B: First Stage for Years of Schooling, 1960-2000						
Genetic distance to the United States		-7.302 (4.899)	-7.687 (7.587)	0.867 (9.059)	-0.085 (9.126)	-5.938 (9.369)
Log European settler mortality		-1.400 <sup>***</sup> (0.213)	-1.464 <sup>***</sup> (0.300)	-1.082 <sup>***</sup> (0.273)	-0.993 <sup>***</sup> (0.237)	-0.743 <sup>***</sup> (0.258)
R <sup>2</sup> (first stage)		0.573	0.606	0.741	0.754	0.808
F-stat (first stage)		43.19	23.78	15.72	17.60	8.31
Geographical controls	-	-	Yes	Yes	Yes	Yes
Continent fixed effects	-	-	-	Yes	Yes	Yes
Legal origin fixed effects	-	-	-	-	Yes	Yes
Major religion shares	-	-	-	-	-	Yes

Table 3.6 (Continued)

	(1)	(2)	(3)	(4)	(5)	(6)
Panel C: Ordinary Least Squares						
Genetic distance to the United States	-13.452 <sup>**</sup> (2.556)	-3.441 <sup>*</sup> (1.932)	-2.469 (2.698)	0.186 (3.244)	0.198 (3.383)	0.998 (4.319)
Years of schooling, 1960-2000		0.387 <sup>***</sup> (0.044)	0.354 <sup>**</sup> (0.038)	0.377 <sup>***</sup> (0.048)	0.378 <sup>**</sup> (0.049)	0.376 <sup>***</sup> (0.055)
Observations	57	57	57	57	57	57
Geographical controls	-	-	Yes	Yes	Yes	Yes
Continent fixed effects	-	-	-	Yes	Yes	Yes
Legal origin fixed effects	-	-	-	-	Yes	Yes
Major religion shares	-	-	-	-	-	Yes

Notes: Panel A report the result of the second stage of the instrumental variable regression, where average years of schooling is instrumented with log of European settler mortality. Panel B reports to the results of the corresponding first stage, and Panel C report the result of Ordinary Least Squares regressions. Geographical controls are log of the ancestry adjusted timing of Neolithic Transition, log percentage of arable land, a landlock dummy, and the absolute value of latitude. Robust standard errors are reported in parentheses. Data definitions and sources are presented in Appendix C. <sup>\*</sup> Significant at 1 percent, <sup>\*\*</sup> Significant at 5 percent, <sup>\*\*\*</sup> Significant at 10 percent.

In Table 1.7 I use the log of population density in 1500 in columns 1-3 and the percent of European settlement in 1900 in columns 4-6 as instruments for social infrastructure. Engerman and Sokoloff (2011) suggest that the density of indigenous populations at the time of colonization determined whether the colonists could obtain the desired level of labor from the existing population and through this, affected the need for mass European migration and settlement. Similarly, AJR (2002) use log of population density in 1500 as an instrument for institution and argue that colonizers generally didn't settle in those region that were relatively rich in natural resources and were densely populated at the time of colonization (e.g. Aztec and Inca empires), and followed an extractive strategy to exploit those regions, thereby creating a "reversal of fortune". Percent European settler in 1900 (approximately the end of the colonial era) is a proxy of the effect of colonization on the colonized area and as mentioned in Section 5.1, is also used by AJR (2001) as an instrument for institutions.

Panels A and B of Table 1.7 present the result of the second and the first stage of the IV strategy, respectively. Panel A shows that the reported result in Table 1.5 does not depend on the use of log settler mortality as instrument, i.e., the coefficient on genetic distance to the United States is not statistically significant and social infrastructure is significant at the 1-percent level and its magnitude is comparable to the reported results of Panel A of Table 1.5. In all of the regressions, AR 95 percent confidence interval is bounded and does not contain zero. The first stage F-statistics (Panel B) suggest that, with an exception of column (1), these regressions do not suffer from weak instrument problem. Panel C reports the p-value of the corresponding  $\chi^2$  test where social infrastructure is instrumented with log settler mortality in conjunction with log population density in 1500 (columns 1-3) and percent European settler in 1900 (columns 4-6). In all columns, the  $p$ -values are sufficiently high, which is further evidence in favour of the validity of the exclusion restrictions of Tables 1.5 and 1.7.

Table 1.7: IV Regression of Income per Capita / Instrumented Variable: Social Infrastructure

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent Variable: Log of Real GDP per Capita, 2000 (Penn World Tables) / Sample: Former Colonies						
Panel A: Two-Stage Least Squares						
Genetic distance to the United States	-2.652 (3.002)	-0.058 (4.055)	2.260 (3.172)	-2.454 (3.046)	-0.922 (3.613)	3.146 (3.119)
Social infrastructure	6.700 <sup>...</sup> (1.695)	7.080 <sup>...</sup> (1.572)	5.226 <sup>...</sup> (1.049)	6.442 <sup>...</sup> (1.415)	6.288 <sup>...</sup> (1.336)	4.128 <sup>...</sup> (0.830)
AR confidence interval	[4.2, 13.3]	[5.0, 13.2]	[3.7, 8.9]	[4.5, 11.1]	[4.4, 10.1]	[2.1, 6.7]
Panel B: First Stage for Social Infrastructure, 1986-1995						
Genetic distance to the United States	-1.321 <sup>...</sup> (0.364)	-0.119 (0.587)	0.119 (0.651)	-0.518 (0.350)	-0.022 (0.534)	-0.479 (0.521)
Log population density, 1500	-0.043 <sup>...</sup> (0.017)	-0.049 <sup>...</sup> (0.016)	-0.062 <sup>...</sup> (0.018)			
European settlement, 1900				0.004 <sup>...</sup> (0.001)	0.005 <sup>...</sup> (0.001)	0.007 <sup>...</sup> (0.002)
R <sup>2</sup> (first stage)	0.445	0.421	0.697	0.410	0.453	0.751
F-stat (first stage)	6.68	9.12	11.73	18.85	14.75	15.57
Observations	64	64	64	64	64	64
Geographical controls	-	Yes	Yes	-	Yes	Yes
Continent fixed effects	-	-	Yes	-	-	Yes

Table 3.7 (Continued)

	(1)	(2)	(3)	(4)	(5)	(6)
Panel C: Overidentification Test - Including Log European Settler Mortality						
<i>p</i> -value (from $\chi^2$ test)	[0.87]	[0.41]	[0.83]	[0.95]	[0.79]	[0.87]
Observations	64	64	64	64	64	64
Geographical controls	-	Yes	Yes	-	Yes	Yes
Continent fixed effects	-	-	Yes	-	-	Yes

Notes: Panel A report the result of the second stage of the instrumental variable regression, where social infrastructure (1986-1996) is instrumented with the log of population density in 1500 in columns 1-3, and with the percent of European settler in 1900 in columns 4-6. Panel B reports to the results of the corresponding first stage. Panel C report the result from overidentification test, where log of European settler mortality is also used as an instrument for social infrastructure. Geographical controls are the log of ancestry adjusted timing of Neolithic Transition, log percentage of arable land, a landlock dummy, and absolute latitude. Robust standard errors are reported in parentheses. Data definitions and sources are presented in Appendix C. ... Significant at 1 percent, \* Significant at 5 percent, \*\* Significant at 10 percent.

Overall, the estimates presented in Tables 1.5/1.7 show that, once the effect of other factors that European brought to their colonies is accounted for, genetic distance to the technological frontier does not have a significant explanatory power for contemporary comparative development.

### 1.6.3 Spolaore and Wacziarg's Instrumental Variable Strategy

To control for the possible endogeneity of genetic distance to the United States, that “arises from the pattern of colonization of the New World starting after 1500” (SW, 2009 p.502), SW use genetic distance to Western Europe in 1500 as an instrument for contemporary genetic distance to the United States. They argue that since genetic distance is highly persistent, genetic distance to Western Europe satisfies the condition for a good instrument. The problem with SW's instrumental variable strategy, however, is that the correlations between genetic distance to Western Europe in 1500, continents initial biogeographical conditions (Figure 1.2), and log European settler mortality (Figure 1.4), lead to mechanical violation of their exclusion restriction. This is because SW do not properly control for the pre-colonial heterogeneity in natural endowment of continents and do not have any proxy of the effect of European colonialism in their IV regressions. Thus, their instrument is correlated with contemporary economic performance through channels other than their first stage.

To avoid the aforementioned problem, I include log of European settler mortality in the IV regression for the sample of former colonies.<sup>38</sup> In the world sample, adding a fixed effect for sub-Saharan Africa and percent European descent restores SW's exclusion restriction. Panels A and B of Table 1.8 report the results for the former colonies sample and the world sample, respectively.

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<sup>38</sup>Note that Figures 3-1 and 3-2 show that former colonies were relatively similar in their initial biogeographical conditions and the timing of transition to agriculture. Therefore, the baseline specification for this sample does not include geographic fixed effect.

Table 1.8: IV Regression of Income per Capita / Instrumented Variable: Genetic Distance to the United States

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent Variable: Log of Real GDP per Capita, 2000 (Penn World Tables)						
Instrument: Genetic Distance to Western Europe, 1500						
Panel A: Two-Stage Least Squares / Sample: Former Colonies						
Genetic distance to the United States	-8.169 <sup>**</sup> (3.578)	0.183 (3.896)	8.828 (6.322)	8.039 (6.932)	7.822 (7.248)	11.436 (10.639)
Log European settler mortality		-0.727 <sup>***</sup> (0.109)	-0.479 <sup>***</sup> (0.126)	-0.340 <sup>***</sup> (0.132)	-0.338 <sup>***</sup> (0.129)	-0.263 <sup>**</sup> (0.130)
AR confidence interval		[-6.8, 8.7]	[-1.9, 24.1]	[-4.9, 22.6]	[-5.7, 23.0]	[-10.0, 34.6]
F-stat (first stage)	181.79	99.71	40.61	55.15	49.51	18.35
Observations	67	67	67	67	67	67
Geographical controls	-	-	Yes	Yes	Yes	Yes
Continent fixed effects	-	-	-	Yes	Yes	Yes
Legal origin fixed effects	-	-	-	-	Yes	Yes
Major religion shares	-	-	-	-	-	Yes

Table 3.8 (Continued)

	(1)	(2)	(3)	(4)	(5)	(6)
Panel B: Two-Stage Least Squares / Sample: The World						
Genetic distance to the United States	-15.518 <sup>***</sup> (2.103)	-2.887 (3.416)	0.282 (3.791)	3.769 (3.403)	5.334 <sup>*</sup> (3.057)	4.190 (3.165)
Percent European descent		0.011 <sup>***</sup> (0.003)	0.014 <sup>***</sup> (0.003)	0.027 <sup>***</sup> (0.006)	0.030 <sup>***</sup> (0.005)	0.030 <sup>***</sup> (0.006)
sub-Saharan fixed effect		Yes	Yes	Yes	Yes	Yes
AR confidence interval	[-19.6,-11.4]	[-9.6, 3.7]	[-7.1, 7.9]	[-2.8, 10.4]	[-0.6, 11.3]	[-1.9, 10.3]
F-stat (first stage)	710.02	132.30	78.05	358.38	411.25	190.17
Observations	134	134	134	134	134	134
Geographical controls	-	-	Yes	Yes	Yes	Yes
Continent fixed effects	-	-	-	Yes	Yes	Yes
Legal origin fixed effects	-	-	-	-	Yes	Yes
Major religion shares	-	-	-	-	-	Yes

Notes: Panel A report the result of the second stage of the instrumental variable regression for the sample of former colonies and the world sample, respectively, genetic distance to the United States is instrumented with genetic distance to Western Europe in 1500. Geographical controls are log of the ancestry adjusted timing of Neolithic Transition, log percentage of arable land, a landlock dummy, and the absolute value of latitude. Robust standard errors are reported in parentheses. Data definition and sources are presented in Appendix C. <sup>\*\*\*</sup> Significant at 1 percent, <sup>\*\*</sup> Significant at 5 percent, <sup>\*</sup> Significant at 10 percent.



Consistent with SW's finding, the coefficients on genetic distance to the United States in column (1) - where the confounding factors are not included in the regressions- are significant at 5 percent and 10 percent in Panels A and B, respectively. Column (2) adds log settler mortality (Panels A and B) and a dummy for sub-Saharan Africa (Panel B) and shows that genetic distance to the United States does not have a statistically significant effect on income per capita. The remaining columns show that these results remain robust to controlling for other historical correlates of contemporary development. Therefore, consistent with previous results and in sharp contrast to SW, these IV regressions demonstrate the lack of causal link from genetic distance to economic performance.

#### 1.6.4 Genetic Distance and Economic Performance In the Long-Run

This subsection examines the within country variation in genetic distance and economic performance over the the long-run. The idea is to ask whether it is more likely for a country to *become* relatively richer as it *becomes* genetically closer to the world technological frontier. If SW's key hypothesis is correct, one would expect to see that, for example, former colonies that got genetically closer to Western Europeans (and consequently to the United States) over the past 500 years, to be relatively richer today compared to their genetically-remote counterparts, as a result of the change in their populations' genetic characteristics.

Figure 1.8 plots the change in the log of real income per capita against the change in genetic distance in the sample of 43 former colonies that got genealogically *closer* to Anglo-American population over the past 500 years.<sup>39</sup> The slope of the fitted line is significant at -22.250 (standard error=5.586). Therefore, to a first approximation, SW's barrier hypothesis is seemingly correct. However, the long-run association between these two variables refers not only to the potential effect of a reduction in the biological differences between former colonies and Western Europeans on development, but also to the effect of colonization on the development paths of former colonies through non-genetic channels (e.g., institutions). Therefore, the estimated slope of the fitted line could be inconsistent. To see this more clearly, assume that

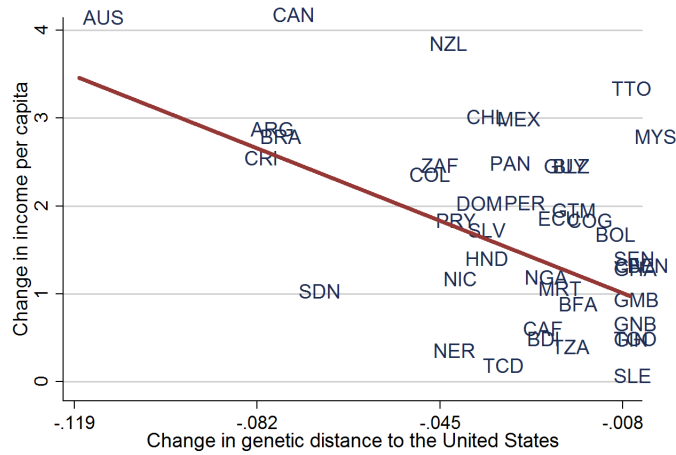
$$Y_t = \alpha D_t + \delta^Y + \epsilon_t^Y \quad \text{and} \quad D_t = \delta^D + \epsilon_t^D$$

where  $Y_t$  and  $D_t$  are the levels of income per capita and genetic distance at time  $t \in \{1500, 2000\}$ , respectively, and  $\delta^Y$  and  $\delta^D$  are fixed differences in the levels of income and genetic distance.  $\epsilon_t^Y$  and  $\epsilon_t^D$  are error terms. The change in income and genetic distance over the past 500 years can then be written as:

$$Y_{2000} - Y_{1500} = \alpha \Delta \epsilon^D + \Delta \epsilon^Y$$

<sup>39</sup>A close inspection of the sample of 65 countries that got genetically closer to Western Europeans over the past 500 years reveals that 54 out of 65 of these countries, or 86 percent of this sample, are former colonies. Non-colonies that got genetically closer to Anglo-American populations are Estonia, Ethiopia, Kazakhstan, Kyrgyzstan, Latvia, Liberia, Lithuania, Suriname, and Thailand. The sample used in Figure 4-5 includes only a subset of these countries for which I have data on proxies of colonization strategies, and therefore includes only former colonies. Also, regressions performed but not presented here suggest that the change in genetic distance does not possess a significant explanatory power for the change in income in countries that moved genetically away from Western Europeans over the past 500 years. For these reasons, in this subsection I focus on the sample of 43 former colonies that became genetically closer to their colonizers over the past 500 years.

Figure 1.8: Change in Income per Capita and Genetic Distance to the United States, 1500-2000



Notes: The regression represented by the fitted line yields a coefficient of -22.250 (standard error=5.586), N=43, R<sup>2</sup>=0.28.

where  $\Delta\epsilon^Y = \epsilon_{2000}^Y - \epsilon_{1500}^Y$  and  $\Delta\epsilon^D = \epsilon_{2000}^D - \epsilon_{1500}^D$ . The slope of the fitted line in Figure 4-4 is the OLS estimate of  $\alpha$ . Standard arguments imply that the probability limit of this OLS estimate is

$$\text{plim } \hat{\alpha} = \alpha + \frac{\text{Cov}(\Delta\epsilon^Y, \Delta\epsilon^D)}{\text{Var}(\Delta\epsilon^D)} \quad (1.3)$$

Therefore, the OLS estimator for  $\alpha$  is consistent if and only if  $\text{Cov}(\Delta\epsilon^Y, \Delta\epsilon^D)=0$ . However, the empirical evidence presented so far suggest the existence of large and common shocks, caused by colonization, affecting former colonies' genetic distance to the United States and their income per capita in opposite directions. This means that  $\text{Cov}(\Delta\epsilon^Y, \Delta\epsilon^D) < 0$ . Hence, equation (1.3) implies that there will be a downward bias in the OLS estimate of  $\alpha$ .<sup>40</sup>

In practice, one has to control for colonial shocks to genetic distance and economic performance. The empirical evidence presented before suggests that European settler mortality, population density in 1500, and the extent of European settlement in former colonies could be used for this purpose. Table 1.9 presents the results of OLS estimation of  $\alpha$ , with and without proxies of colonization strategies. Panel A reports estimates when the change in genetic distance is calculated as the difference between the current match of weighted  $F_{ST}$  genetic distance to the United States and the  $F_{ST}$  genetic distance (between plurality groups) to Western Europe in 1500. Panel B shows estimates where the current match of weighted  $F_{ST}$  genetic distance to the United Kingdom is used as the measure of contemporary genetic distance.

Column (1) of both panels is the simple regression of the change in income on the change in genetic distance. The estimated coefficients on genetic distance are quantitatively very large and

<sup>40</sup>The argument regarding the inconsistency of the OLS estimator of  $\alpha$  is valid if first, the colonial shocks to genetic distance and economic performance have happened during the period in which the data is observed (between 1500 and 2000), and, second, if these shocks have a persistent effect on both variables. Both conditions hold in this case. See Acemoglu et al. (2008) for more details.

Table 1.9: Income and Genetic Distance Over the Past 500 Years

Dependent Variable: Change in Real GDP per Capita, 1500-2000					
	(1)	(2)	(3)	(4)	(5)
Panel A: Change in genetic distance (the United States - Western Europe in 1500)					
Change in genetic distance, 1500-2000	-22.250... (5.586)	-6.055 (4.391)	-2.931 (6.533)	0.974 (4.806)	3.935 (5.604)
Log European settler mortality		-0.612... (0.104)			-0.356... (0.110)
Log population density, 1500			-0.492... (0.109)		-0.039 (0.117)
Percent European settler, 1900				0.034... (0.004)	0.022... (0.005)
Observations	43	43	43	43	43
R <sup>2</sup>	0.279	0.633	0.460	0.668	0.754
Panel B: Change in genetic distance (the United Kingdom - Western Europe in 1500)					
Change in genetic distance, 1500-2000	-15.749... (3.684)	-5.630... (3.118)	-4.692 (5.112)	0.629 (3.824)	3.110 (4.409)
Log European settler mortality		-0.590... (0.108)			-0.431... (0.119)
Log population density, 1500			-0.392... (0.124)		-0.078 (0.104)
Percent European settler, 1900				0.032... (0.005)	0.018... (0.006)
Observations	46	46	46	46	46
R <sup>2</sup>	0.293	0.635	0.404	0.562	0.717

*Notes:* Countries in the sample in both panels are former colonies that got genetically closer to Americans and Western Europeans over the past 500 years. In Panel A, change in genetic distance is calculated as difference between the current match of weighted  $F_{ST}$  genetic distance to the United States and genetic distance to Western Europe (between plurality groups) in 1500. In Panel B, change in genetic distance is calculated as difference between the current match of weighted  $F_{ST}$  genetic distance to the United Kingdom and genetic distance to Western Europe (between plurality groups) in 1500. Data on change in income per capita over the past 500 years is taken from Acemoglu, Johnson, Robinson, and Yared (2008). Robust standard errors are reported in parentheses. Data definition and sources are presented in Appendix C. ... Significant at 1 percent, .. Significant at 5 percent, · Significant at 10 percent.

significant at the 1-percent level. Column (2) adds log of European settler mortality. This induces dramatic reductions in the genetic distance coefficient and make this variable statistically insignificant in Panel A, and significant at 10 percent in Panel B. Column (3) controls for log population density in 1500. This completely removes the statistical association between the change in genetic distance and the change in economic performance in both panels. Similarly, controlling for the extent of European settlement in 1900 (column 4) reduces the magnitude of the effect of the change in genetic distance to the point of statistical insignificance. Finally, column (5) includes all of the three proxies of the common shocks simultaneously, and shows that those former colonies that became genetically closer to the world technological frontier over the past 500 years did not become richer because of it.

## 1.7 Concluding Remarks

The recent empirical literature on the fundamental causes of economic development refers to the effect of deep-rooted genetic factors on the prosperity of nations. This paper argues that there is no causal relationship between genetic distance to the technological frontier and economic performance. The reason is that the two fundamental determinants of contemporary genetic distance to the United States - the pattern of the separation of Homo sapiens from each other during their migration out of Africa, and the extent of European settlement in their former colonies during the colonial era - are not independent of the geographic distribution of the pre- and the post-colonial determinants of economic performance. More specifically, I show that: a) the prehistoric ecological prerequisites for good economic performance (Diamond, 1997) were absent in those societies that were genetically far from Western Europeans, and b) during the colonial era Europeans generally didn't settle in those former colonies that were genetically remote from them, and instead imposed extractive institutions to exploit the natural and the human resources of those regions (e.g. sub-Saharan Africa).

I show that controlling for confounding factors in (a) and (b) completely removes the statistical association between genetic distance to the technological frontier and economic performance. To be more specific, I demonstrate that, in a sample that includes both former colonies and non-colonies, the association between genetic distance and economic performance is not robust to controlling for a dummy for sub-Saharan Africa and proxies of the influence of Western Europe during the colonial era (either measures of contemporary institutions, share of European descent, or absolute latitude). Further, in the sample of former colonies, controlling for log of European settler mortality at the time of colonization removes the statistical association between genetic distance and income per capita. The results remain robust once I control for institutions and/or human capital instrumented with log of European settler mortality or log of population density in 1500. Fixed effect estimates also suggest that those former colonies that became genetically closer to Western Europeans over the past 500 years did not become richer because of it. My results are in stark contrast to Spolaore and Wacziarg (2009, 2012, 2013) and provide further empirical support for Acemoglu et al. (2001, 2002) and Glaeser et al. (2004).

By providing strong empirical support for *institutional* explanations of the causes of economic

development, this study contributes to a better understanding of the fundamental causes of development, especially the literature on the effect of European colonialism on comparative development, and sheds light on recent controversial claims regarding the effect of deep-rooted genetic factors on the prosperity of nations. For example, Ashraf and Galor (2013) use genetic distance between population to construct their measure of “predicted genetic diversity”, and show that sub-Saharan Africa’s high genetic diversity and Latin America’s low genetic diversity are not conducive for development. However Ashraf and Galor (2013) do not address the endogeneity of institutions and human capital in sub-Saharan Africa and Latin America, and, therefore, overestimate the effect of genetic diversity on contemporary economic development.

## 1.8 Appendix A: Additional Tables

### 1.8.1 Bilateral Regressions

As mentioned in Section 2, SW argue that *if* their key hypothesis is correct, i.e., if genetic distance to the United States is a barrier to the diffusion of development from the world technological frontier, then a measure of relative genetic distance from the United States should have more explanatory power for contemporary income per capita, compared to a measure of absolute genetic distance. They define the absolute genetic distance between countries  $i$  and  $j$  as  $G_{ij}^D$ , which refers to the expected elapsed time since population of countries  $i$  and  $j$  shared a common ancestor; and the relative genetic distance from the United States as  $G_{ij}^R = |G_{i,US}^D - G_{j,US}^D|$ , where  $D_{i,US}$  and  $D_{j,US}$  denote genetic distance of country  $i$  and  $j$  to the United States, respectively. SW follow a bilateral approach in their econometric analysis and calculate income differences between all 9316 pairs of countries (based on 137 countries) in their sample, and show that, in regressions that use the absolute value of income differences ( $|Y_i - Y_j|$ ) as the dependent variable, the magnitude of the effect of  $G_{ij}^R$  is bigger than  $G_{ij}^D$ . They take this difference in the magnitude of the effect of relative and absolute genetic distance on income differences as evidence in favour of the validity of their key hypothesis.

Note that this paper’s argument regarding the endogeneity of genetic distance to the technological frontier applies to both of SW’s measures of genetic distance. For example, my argument implies that both the relative and the absolute genetic distance between pairs of colonies, and also the absolute and the relative genetic distance between any pair involving a former colony and a non-colony are affected by the extent of European settlement during the colonial era. Therefore, without explicitly addressing the simultaneous effect of colonization on genetic distance and economic performance, the estimated effect of both the relative and the absolute genetic distance on income per capita is biased and inconsistent.<sup>41</sup>

In this section I estimate the effect of relative genetic distance on pairwise income differences in the sample of former colonies, controlling for the differences in European settler mortality. The dependent variable is the absolute value of income differences between 2278 pairs of countries (based on 68 countries in the sample of former colonies). All of the other independent variables of

<sup>41</sup>See Section 4 and footnote 25 for a formal argument.

the model are calculated as pairwise differences. As noted in SW, a problem with bilateral specification is the spatial correlation resulting from the construction of the dependent variable. To address this problem, I follow SW and rely on two-way clustering of standard errors (see Cameron, Gelbach, and Miller, 2006 for more information).

Table 1.10 presents the results. Column (1) relative genetic distance is the only independent variable, and its coefficient is significant at 1 percent. Note that this coefficient is comparable to the reported result in SW (Table III-column (4), p.496), they report a coefficient of 6.357 (standard error=0.996) for a sample that includes both former colonies and non-colonies. Column (2) adds the absolute differences in log of European settler mortality. The coefficient on genetic distance remains significant at 5 percent, but its magnitude decreases by 43 percent. Column (3) includes the geographical controls and shows that the relative genetic distance is now statistically insignificant. Column (4) suggests that this result do not change once I control for the difference in major religion shares. Overall, the results of bilateral analysis are consistent with my argument in Section 3 and further confirm the empirical results of Section 5.

Table 1.10: Bilateral Regression of Income per Capita

Dependent Variable: Log Real GDP per Capita, 2000 / Sample: Former Colonies				
	(1)	(2)	(3)	(4)
Relative genetic distance	6.458*** (1.945)	3.689** (1.563)	1.512 (1.484)	1.392 (1.456)
Log European settler mortality (absolute difference)		0.437*** (0.066)	0.358*** (0.062)	0.362*** (0.061)
Log Neolithic transition timing (absolute difference)			0.445* (0.233)	0.440* (0.231)
Log arable land area (absolute difference)			0.077*** (0.027)	0.078*** (0.027)
Latitude (absolute difference)			0.010** (0.005)	0.010** (0.005)
Percent Protestant (absolute difference)				0.001 (0.003)
Percent Catholic (absolute difference)				0.002 (0.001)
Percent Muslim (absolute difference)				0.001 (0.002)
Observations	2278	2278	2278	2278
R-squared	0.069	0.270	0.317	0.323

*Notes:* Relative genetic distance is the absolute value of the difference in the genetic distance of countries to the United States. Two-way clustered standard errors are reported in parentheses. Data definition and sources are presented in Appendix C.

\*\*\* Significant at 1 percent.

\*\* Significant at 5 percent.

\* Significant at 10 percent.

## 1.8.2 Albouys' Preferred Sample

Table 1.11: OLS Regression of Income per Capita, Albouys' Preferred Sample

Dependent Variable: Log of Real GDP per Capita, 2000 / Sample: Former Colonies						
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A - Technological Frontier: The United States						
Genetic distance to the United States	-13.148 <sup>***</sup> (4.288)	-4.072 (3.111)	1.390 (5.496)	3.309 (5.176)	3.598 (5.373)	1.683 (6.415)
Log European settler mortality		-0.564 <sup>***</sup> (0.074)	-0.454 <sup>***</sup> (0.147)	-0.385 <sup>*</sup> (0.185)	-0.384 <sup>*</sup> (0.183)	-0.374 <sup>*</sup> (0.197)
Observations	26	26	26	26	26	26
R <sup>2</sup>	0.277	0.623	0.691	0.892	0.894	0.898
Panel B - Technological Frontier: The United Kingdom						
Genetic distance to the United Kingdom	-8.567 <sup>**</sup> (3.422)	-1.704 (2.522)	3.693 (3.740)	6.395 (3.690)	6.387 (3.856)	5.705 (7.011)
Log European settler mortality		-0.557 <sup>***</sup> (0.080)	-0.399 <sup>**</sup> (0.139)	-0.299 <sup>*</sup> (0.169)	-0.302 <sup>*</sup> (0.169)	-0.299 (0.194)
Observations	25	25	25	25	25	25
R <sup>2</sup>	0.204	0.584	0.690	0.886	0.887	0.887
Panel C - Technological Frontier: Germany						
Genetic distance to Germany	-11.622 <sup>***</sup> (3.712)	-2.260 (3.155)	5.025 (5.263)	4.185 (4.646)	5.192 (4.809)	3.931 (5.491)
Log European settler mortality		-0.587 <sup>***</sup> (0.093)	-0.462 <sup>***</sup> (0.146)	-0.409 <sup>**</sup> (0.146)	-0.396 <sup>**</sup> (0.138)	-0.364 <sup>**</sup> (0.159)
Observations	27	27	27	27	27	27
R <sup>2</sup>	0.270	0.606	0.700	0.898	0.902	0.903
Geographical controls	-	-	Yes	Yes	Yes	Yes
Continent fixed effects	-	-	-	Yes	Yes	Yes
Legal origin fixed effects	-	-	-	-	Yes	Yes
Major religion shares	-	-	-	-	-	Yes

*Notes:* In all three panels, the measure of genetic distance is the current match of weighted  $F_{ST}$  genetic distance. Geographical controls are absolute value of latitude, percentage of tropical land, and a dummy variable taking value of 1 if a country is landlocked. Continent fixed effect are dummies for Africa, Asia, and Other continents with America being the omitted group. Countries included in Panel A are Algeria, Bangladesh, Canada, Congo, Egypt, Gambia, Ghana, India, Indonesia, Jamaica, Kenya, Madagascar, Malaysia, Mali, Malta, Mexico, New Zealand, Nigeria, Senegal, Sierra Leone, South Africa, Sri Lanka, Sudan, Trinidad and Tobago, Tunisia, and The United States. In Panel B, due to lack of data on genetic distance, The United States is excluded from the sample. Panel C adds Vietnam to the sample of countries in Panel A.

<sup>\*\*\*</sup> Significant at 1 percent. <sup>\*\*</sup> Significant at 5 percent. <sup>\*</sup> Significant at 10 percent.



## 1.9 Appendix B: Colonization, Genetic Distance, and Economic Performance

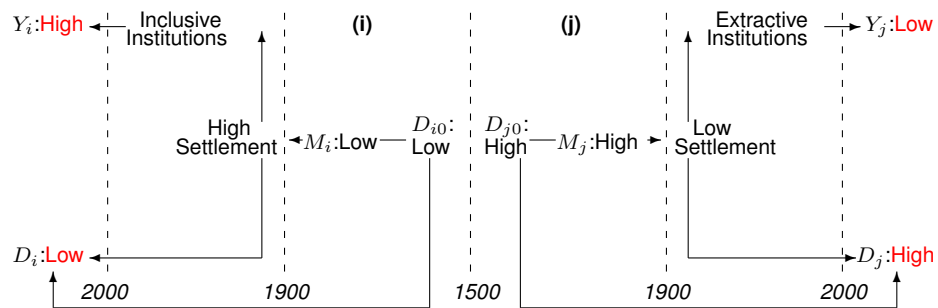
Figure 1.9 illustrates the argument of Section 3.2, diagrammatically. Take two hypothetical countries,  $i$  and  $j$ , with country  $i$  having a lower genetic distance to Western Europe in 1500 ( $D_{i0} < D_{j0}$ ). The panel at the left-hand side of the dashed line marked by 1500 refers to the historical path of country  $i$ , and the panel at the right-hand side of this line refers to the historical path of country  $j$ . In both panels, the direction of arrows refers to the direction of causal effect between variables. Remember that Figure 1.4 suggests that, *on average*, Europeans faced a higher mortality rates in former colonies with higher genetic distance to Europeans in 1500. Therefore, the lines connecting genetic distance in 1500,  $D_{k0}$ , to European settler mortality,  $M_k$  for  $k=\{i, j\}$ , refer to this positive correlation (therefore on average  $M_i < M_j$ ). The arrows connecting settler mortality ( $M$ ) to institutions and contemporary economic performance ( $Y$ ) reconstruct AJR's argument regarding the colonial origins of comparative development: Europeans settled with more (less) intensity in those geographic regions in which they had lower (higher) rate of mortality, installed inclusive (extractive) institutions that led to good (bad) contemporary economic performance.

Map 2 and Figure 1.5 refer to the effect of colonization on the contemporary genetic distance of former colonies to the United States. Take country  $i$  for example. Low rate of European mortality in this country ( $M_i$ :Low) resulted in relatively high settlement by Europeans during colonization period. This would result in country  $i$  to be currently genetically closer to Western Europe and the United States ( $D_i$ :Low). The exact opposite argument holds for country  $j$ , resulting in  $D_j$  to be bigger than  $D_i$ . Finally, since genetic distance is a measure persistence of in nature (the correlation between contemporary genetic distance to the United States and genetic distance to Western Europe in 1500 is 0.8) two arrows directly connect  $D_{i0}$  and  $D_{j0}$  to  $D_i$  and  $D_j$ .

Therefore, if one estimates the effect of genetic distance on contemporary income per capita in an equation like  $Y_k = \alpha + \beta D_k + x_k' \gamma + \epsilon_k$  for  $k=\{i, j\}$ , where  $\alpha$  and  $\epsilon_k$  are the intercept and the error term respectively, and  $x_k$  is the vector of all other covariates of income (for example the set of control variables used in SW), the estimated coefficient,  $\beta$ , will be negative and possibly large. This is because the pairs  $(Y_i, Y_j)$ :(High,Low) and  $(D_i, D_j)$ :(Low,High) move in opposite directions. Further, this correlation should remain robust to controlling for various historical, geographical, linguistic, and religious controls as long as  $x_k$  does not include variables that are proper proxies of the effect of colonization on genetic distance and economic performance.

Figure 1.9 shows that, without addressing the simultaneous effect of colonization on genetic distance and economic performance, the effect of all other factors that are related to colonization and affecting economic development (e.g. institutions or human capital) are embedded in the genetic distance of populations to the United States. In other words,  $\text{Cov}(D_k, \epsilon_k) \neq 0$  for  $k=\{i, j\}$ . Therefore, a causal interpretation of the effect of genetic distance on economic performance is not valid in this case.

Figure 1.9: Simultaneous Effect of Colonization on Genetic Distance and Economic Performance



Notes:  $D_{i0}$  and  $D_i$  refer to genetic distance of population of country *i* to Western Europe and the United States in 1500 and 2000, respectively.  $M_i$  refers to European settler mortality rate in country *i*, and  $Y_i$  refers to contemporary economic performance e.g., income per capita of country *i*.

## Chapter 2

# The Dynamics of State Repression

### 2.1 Abstract

This paper studies the effect of economic development on the likelihood of state repression. The poor are credit constrained and might demand redistribution of wealth. The elite could respond to the demands made by the poor either by concession or repression. The relative cost of repression depends on the wealth gap between social classes and is endogenously determined. The model suggests that the likelihood of state repression depends on both the *level* and the *distribution* of wealth. I show that if the wealth of the poor class grows relatively fast along the equilibrium path, it becomes less likely for the elite to repress the poor regardless of the feasibility of upward class mobility. On the other hand, even if upward class mobility is possible, but if there is little growth opportunity for the poor, the likelihood of state repression might increase along the equilibrium path. Thus, the model suggests that the association between income per capita and the likelihood of state repression could be non-monotonic. Semi-parametric estimations of the effect of income per capita on measures of state repression provide some evidence which is consistent with the theoretical insight.

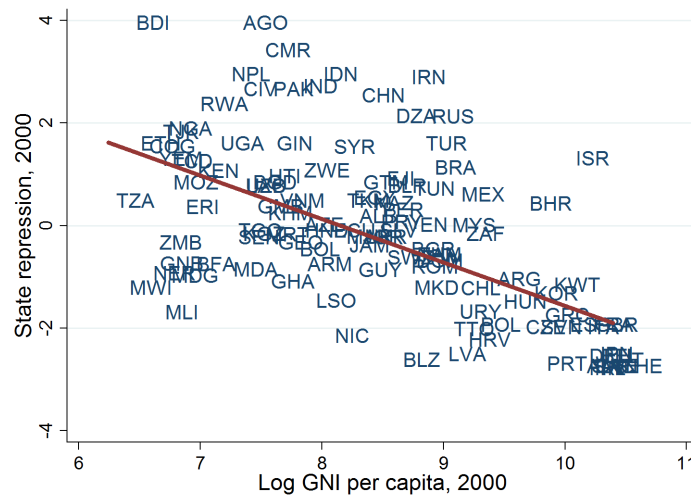
### 2.2 Introduction

What is the effect of economic development and its associated socio-political changes on state repression? The answer to this question, both in the empirical literature and in the popular press, is that more developed countries have both a higher respect for human rights and less repressive governments.<sup>1</sup> Figure 2.1 illustrates this argument graphically: it shows a negative correlation between the first principal component of various measures of state repression ( The Amnesty International and the U.S. State Department measures of Political Terror Scale (PTS), The Cingranelli and Richards index of physical integrity, and The Freedom House index of civil liberties ) and the log

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<sup>1</sup>See for example, Henderson 1991, Landman and Larizza 2009, McKinlay and Cohan 1975, 1976, Mitchell and McCormick 1988, Park 1987, Poe and Tate 1994, 1999, Soysa and Binningsbo 2009, and Davenport 2007 for a survey of the literature.

Figure 2.1: State Repression and Income per Capita in the World, 2000



Notes: The regression represented by the fitted line yields a coefficient of  $-0.849$  (standard error= $0.109$ ),  $N=115$ ,  $R^2=0.34$ . The measure of state repression is the first principal component of four indices of state repression: Amnesty International and the U.S. State Department measure of Political Terror Scale (PTS), Cingranelli and Richards index of physical integrity, and Freedom House index of civil liberties. The first principal component takes values between  $-2.7$  and  $3.97$ , where higher values referring to more repressive states. These measures are highly correlated with each other and their first principal component is relatively equally distributed among them. See Section 4 for more detailed discussion of the indices of state repression.

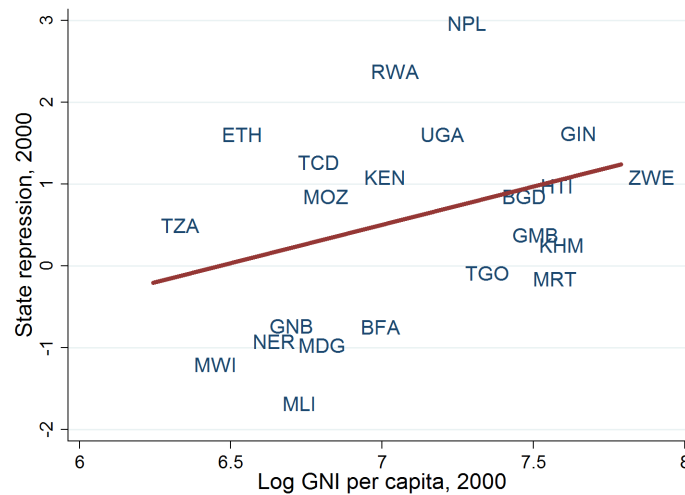
real GNI per capita of 115 countries in 2000, and suggests that there is a monotonically decreasing relationship between economic development and the occurrence of state repression across the globe.

There are, however, numerous examples of countries experiencing periods of intense state repression *during* the process of modernization. Almost all of rapidly developing economies of East Asia either started the process of modernization with highly authoritarian and repressive states (e.g., South Korea and Singapore), or are currently experiencing relatively high levels of state repression (e.g., India and China). In the Middle East, both the Shah of Iran and Kemal Ataturk of Turkey modernized their economies amid mass repression of the relatively poorer and often more conservative segments of their populations. Modernization and structural adjustment in Latin America too were often intertwined with military coups and violation of populations' human rights. Such counterexamples can be seen even in the contemporary cross-country relationship between economic development and state repression: Figure 2.2 plots the extent of state repression against log of real GNI per capita in the low-income countries and suggest a *positive* association between income and repression.<sup>2</sup>

This paper aims to provide a better explanation of the association between economic development and the occurrence of state repression. To this end, I propose a model of endogenous

<sup>2</sup>The low income countries are defined according to World Bank classification and are the ones for which data on the measure of state repression and income per capita is available. These are Burkina Faso, Bangladesh, Ethiopia, Guinea, Guinea-Bissau, Haiti, Kenya, Cambodia, Madagascar, Mali, Mozambique, Mauritania, Malawi, Niger, Nepal, Rwanda, Chad, Togo, Tanzania, Uganda, Zimbabwe.

Figure 2.2: State Repression and Income per Capita in the Low Income Countries, 2000



Notes: The regression represented by the fitted line yields a coefficient of 0.936 (standard error=0.467),  $N=22$ ,  $R^2=0.12$ . The measure of state repression is the first principal component of four indices of state repression: Amnesty International and the U.S. State Department measure of Political Terror Scale (PTS), Cingranelli and Richards index of physical integrity, and Freedom House index of civil liberties. The first principal component takes values between -2.7 and 3.97, where higher values referring to more repressive states. These measures are highly correlated with each other and their first principal component is relatively equally distributed among them. See Section 4 for more detailed discussion of the indices of state repression.

inequality in which there is a redistributive conflict between two different groups: a rich class who controls the state repressive apparatus and a poor class who might demand redistribution.<sup>3</sup> In the absence of any imperfection in the capital market, redistribution might be relatively unattractive for the poor, because they can borrow and invest in profitable projects (e.g., their human capital) without engaging in direct conflict with the rich. If the poor classes are credit constrained, however, then redistribution might become relatively attractive to them. In deciding whether to respond to the redistributive demands by repression or concession, the rich compare the payoff of repression against the payoff of concession. The *relative* cost of repression turns out to depend on the wealth gap between the two classes and is endogenously determined. The model suggests that both the average income *level* and its *distribution* together affect the incentive of the ruling class to use repression.

The model suggests that the effect of economic development on state repression depends on the ease and the extent of upward class mobility and different classes' growth opportunities along the equilibrium path. For example, when the borrowing constraint is always binding for the poor class, a case referred to as *class society*, and when the poor class faces relatively low opportunities for growth, income inequality increases along the equilibrium path. This exacerbates the redistributive conflict between the two classes and increases the likelihood of repression along the equilibrium path. However, a rigid class structure does not necessitate repression. If the growth rate of the

<sup>3</sup>Alternatively, one can define the identity of social classes based on their ethnicity, religion, etc., as long as these alternative identities translates into visible differences in wealth and income between different classes.

wealth of the poor class is relatively high (because they are relatively farther from their steady state compared to the rich class), then the extent of the redistributive conflict between social classes decreases along the equilibrium path and so does the likelihood of state repression.

On the other hand, in a *classless society* - one in which the borrowing constraint is relaxed at some point along the equilibrium path - the effect of economic development on state repressive tendencies could be non-monotonic. This is because, a binding borrowing constraint combined with low growth opportunity for the poor class implies that the income distribution becomes more unequal at the early stages of development. Therefore, it becomes more likely for the rich to respond to demands for redistribution by repression. But, as the poor accumulate enough wealth and as the borrowing constraint is relaxed, the likelihood of state repression decreases. This means that the association between economic development and the likelihood of state repression follows an inverted U-shape.

The empirical part of the paper provides evidence regarding the validity of the aforementioned theoretical argument. I show that in a sample of 115 countries from 1979 to 2002, the relationship between income inequality (measured by capital share) and repression is positive and statistically significant. Furthermore, semiparametric estimation of the association between income per capita and measures of state repression shows an inverse U-shaped relationship between the two variables. Both results are consistent with the theoretical insight of the paper.

The paper is organized as follows: Section (2) reviews the related literature, Section (3) presents the model and the analysis of its dynamics, Section (4) provides the empirical evidence, and Section (5) concludes.

## 2.3 Related Literature

The literature on state repression follows the logic of modernization theory by reformulating it as “simple poverty thesis” which maintains that “The poorest countries, with substantial social and political tensions created by economic scarcity, would be most unstable and thus most apt to use repression in order to maintain control” (Mitchell and McCormick, 1988). Almost all empirical research on state repression finds a negative and statically significant relationship between income per capita and repression (see for example Henderson 1991, Landman and Larizza 2009, McKinlay and Cohan 1975, 1976, Mitchell and McCormick 1988, Park 1987, Poe and Tate 1994, 1999, Soysa and Binningsbo 2009, and Davenport 2007 for a survey of the literature)<sup>4</sup>. Therefore, the simple poverty thesis is a re-statement of the modernization hypothesis and the positive association between income per capita and democracy (see Acemoglu et al. 2008 and 2009, Lipset 1959, Przeworski and Limongi 1997, and Robinson 2006).

As mentioned before, however, a problem with this thesis is that it is unable to explain many historical instances of intense state repression alongside with relatively rapid process of growth in income per capita in some countries. Therefore, it is not surprising that Davenport (2007), in his survey of the literature on state repression observed that:

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<sup>4</sup>This negative and statistically significant relationship between income and political violence is in fact a common feature in empirical research on state repression and on civil war, see for example Fearon and Laitin (2003), Collier and Hoeffler (2004), Øtsby (2008) for civil war literature.

Although the significance of the economy is straightforward, what is interesting is the lack of discussion it receives. Glancing at this research, one repeatedly comes across measures of gross national product (GNP) ... in every model estimated. But one does not find a detailed discussion of why economic development wields an influence or why GNP measures this feature adequately. This is problematic in repression research, as in the civil war literature, because the influence of GNP is consistently negative; poorer countries tend to repress more. The precise reason for the finding, however, is unclear. (2007, p.14)

In this situation a formal model that characterizes when and under what condition economic development will reduce or intensify the repressive tendencies of the state, might be helpful in clarifying the empirical evidence. Therefore, this paper contributes to the state repression literature by developing a formal model that describes how repression is related to both the level and the distribution of income in society.

The economic framework of the paper borrows from the literature on the effect of economic development on inequality. Examples are the works of Aghion and Bolton (1997), Banerjee and Newman (1993), Galor and Zeira (1993), and Matsuyama (2000, 2006). These models try to pin down conditions under which income might trickle down from haves to have-nots and cause inequality to disappear over time. A main feature of these models is that when the capital market is imperfect and the poor class faces some sort of borrowing constraint, inequality between the poor and the rich class might not disappear but could instead increase over the course of development. In most of these models, rich classes could become richer over time partly due to the cheap labor provided by large number of poor workers. Thus, most of these models exhibit some sort of path dependence i.e. agents' initial wealth determines whether they are borrowing constrained and consequently trapped in poverty, or not (see Matsuyama (2011) and Piketty (2000) for excellent literature reviews and Acemoglu (2008) for a textbook treatment). The economic framework used in this paper is borrowed from Matsuyama (2011) and is a simple version of Galor and Zeira (1993). The main modification is that I explicitly allow for social conflict between poor and rich classes over the distribution of wealth, and formally model the reaction of the rich class to the redistributive demands made by the poor. This enables me to specify how state repression might be affected by both the level and the distribution of income, and to distinguish between their effects.

The effect of inequality on political conflict has been the subject of debate among scholars since the introduction of *grievance-based theories* (Gurr 1968, 1970). According to these theories, social grievances are the fundamental cause of political violence. Thus, more grievances in general, and inequality among different social groups in particular, would lead to an increase in political violence (see Buechler 2004, and Shadmehr 2011, for reviews). These theories, however, are under attack by advocates of the political process approach for ignoring the intrinsic subtleties of collective action by different groups involved in political conflict.<sup>5</sup> According to *political process theories*, it is the strategic calculation of actors involved in collective action rather than structural factors such as inequality that affect likelihood and intensity of political conflict and violence. The empirical evidence

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<sup>5</sup>See for example McAdam 1999, McAdam et al. 2004, McCarthy and Zald 1973, 1977, Muller et al. 1991, Tarrow 1998, Tilly 1978, 2004, Tilly and Tarrow 2007, Zald and McCarthy 2003.

for both theories mostly comes from the determinants of civil war and often produce ambiguous and contradicting results.<sup>6</sup> The empirical literature on state repression, however, mostly ignore the potential effect of grievances in general, and inequality in particular.<sup>7</sup> The empirical results that I present shows a positive and statistically significant effect of capital share on state repression and provide further evidence in favour grievance-based theories.

Finally, The formal model of social conflict used in this paper borrows and relates to Acemoglu and Robinson's (2006) model of democratization, as well as two studies by Harms and Zink (2003). Acemoglu and Robinson's (2006) seminal work presents a formal model of conflict between rich and poor class in society and specifies how the conflict over redistribution of resource could affect the political institutions and the likelihood of democratization. The model presented in this paper is very similar in essence to their analysis, but a point of departure from their model is that here inequality is endogenously determined.<sup>8</sup> Harms and Zink (2003) study the interaction between rich and poor in a framework in which inequality is endogenously determined. The main difference here is that I explicitly model the state reaction to demands for redistribution by citizens, a feature that allows me to model the effect of income level and distribution on repression.

## 2.4 Model

### 2.4.1 The Economy

Consider an economy consisting of a continuum of infinitely lived dynasties. There is a single numeraire good which can either be consumed or invested. Agents reproduce asexually and total population is normalized to one in each period. Each agent is born into either a rich or a poor dynasty and lives for one period and a dynasty is linked by inheritance. At period zero, a fraction  $\delta < 1$  of population are rich and the remaining  $1 - \delta$  are poor. At the beginning of each period agent receives an endowment of  $w_t^i$  with  $i \in \{P, R\}$  from her parents, where  $P$  and  $R$  refers to poor and rich respectively. All agents earn an income of  $y$  during a period, so the difference in inheritance is the only source of heterogeneity among agents.<sup>9</sup> Agents' utility is given by  $u_t = c_t^{1-\beta} w_{t+1}^\beta$ , which means that in each period they allocate their wealth to consumption  $c_t$  and bequest  $w_{t+1}$ .

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<sup>6</sup>For example, Reviewing the early empirical evidence on the effect of inequality on civil war, Lichbach (1989) concludes that the empirical evidence is inconclusive and ambiguous. More recently, Fearon and Laitin (2003) and Collier and Hoeffler (2004), have not found any evidence confirming the effect of inequality on civil war. Cederman, Weidmann and Gleditsch (2011), Esteban, Mayoral and Ray (2012), Nepal, Bohara and Gawande (2011), Østby (2008), however, find evidence in favour of the effect of inequality on conflict and civil war.

<sup>7</sup>In the early literature, Henderson (1991) is an exception and shows a positive effect of inequality on repression but his study is based on regional comparison rather than statistical analysis using micro or macro data. More recently, Landman and Larizza (2009) study the effect of inequality on violation of human rights by the government and their findings show that both land and income inequality have a positive and causal effect on state repression. Their study, however, relies on "fixed effect vector decomposition" or FEVD estimation method, originally suggested by Plmper and Troeger (2007), which is a questionable method as suggested by Breusch et al. (2011) and Greene (2011).

<sup>8</sup>Based on Acemoglu and Robinson's (2006) mode, Shadmehr (2011) also provide theoretical and empirical evidence in favour of the effect of inequality on repression. However, in his model too, inequality is exogenous and therefore he does not explain the effect of income on repression.

<sup>9</sup>This can be interpreted as agents being homogeneous in ability and heterogeneous in opportunity. The results do not change if one allows for heterogeneity in both ability and opportunity (see for example Matsuyama, 2011).



During each period, agents (regardless of whether they are rich or poor) have two options regarding how to allocate their wealth. They can either lend their bequest at the market rate  $r$ , which results in a return of  $rw_t$  and an end of period wealth of  $y + rw_t$ . Or they can invest in a project which requires a fixed cost of investment  $F$  and yields  $R$  in return (the project could be investing in education or any type of skill for example). Therefore, the end of period wealth of an agent who invests in the project is  $y + R + r(w_t - F)$ . In what follows I assume that  $R > rF$ , which means that the present value of the return is higher than the fixed cost of the project. This assumption guarantees investment in the project is indeed profitable for the agent.

The only barrier for an agent to invest in the project is lack of ability to borrow, which is a result of capital market imperfection. The simplest way to introduce such imperfection is to assume that agent can pledge only a fraction  $\lambda \in (0, 1)$  of the return of the project for repayment.<sup>10</sup> Knowing this, the lender is willing to lend up to the present value of this fraction to the borrower or  $F - w_t \leq \frac{\lambda R}{r}$ , which results in a borrowing constraint:

$$w_t \geq F - \frac{\lambda R}{r} = w_c \quad (2.1)$$

The borrowing constraint implies that to be able to invest in the project an agent should be endowed or acquires a certain level of wealth  $w_c$ .<sup>11</sup> In each period  $t$  agents maximize their utility  $u_t = c_t^{1-\beta} w_{t+1}^\beta$  which, given (2.1), results in a bequest rule:

$$w_{t+1} = \begin{cases} \beta(y + rw_t) & \text{if } w_t < w_c \\ \beta(y + rw_t + (R - rF)) & \text{if } w_t \geq w_c \end{cases} \quad (2.2)$$

Therefore, if  $w_t < w_c$ , agent wealth converges to  $w_L^* = \beta y / [1 - \beta r]$ , and if  $w_t \geq w_c$ , the agent is wealthy enough to participate in the project and her wealth converges to  $w_H^* = \beta(y + R - rF) / [1 - \beta r]$  in the steady state. I assume that initially, the distribution of wealth is such that only the rich could invest in the project so  $w_0^R > w_c$  and  $w_0^P < w_c$ . In other words the initial condition is such that only the poor are borrowing constrained. To have room for growth I assume that agents' initial wealth to be less than the long-run steady state level or  $w_0^R < w_H^*$  and  $w_0^P < w_L^*$ . Combination of these two assumptions on the rich class initial wealth requires that  $w_H^* > w_c$ , a sufficient but not necessary condition for this to hold is  $\lambda > r$ . Assumption (1) summarized all of these aforementioned conditions on the initial and steady state level of wealth of the poor and the rich.

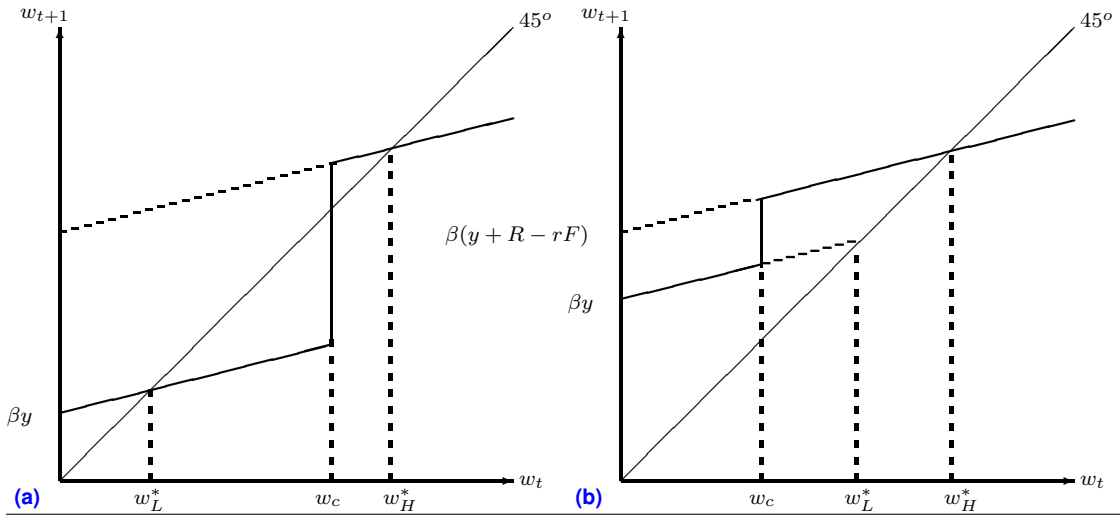
**Assumption 1.**  $w_c < w_0^R < w_H^*$ ,  $w_0^P < w_L^*$ , and  $w_0^P < w_c$

With this assumption, we can distinguish between two different scenarios. First, when  $w_L^* < w_c$ , we have a situation where the poor class, even in the long run, are not able to accumulate enough wealth to be able to participate in the project. I refer to this case as *class* society, since class differences are permanent and upward (class) mobility is not feasible. Second, when  $w_L^* \geq w_c$  poor class's wealth cross the the threshold level of wealth  $w_c$  and the borrowing constraint is relaxed in a

<sup>10</sup>A very simple, intuitive way to justify the way imperfection introduced in this model is to assume that the project is specific to the borrower and requires her service. Without borrower service the return on the project is only a fraction of what it is with her service. This in turn increases the borrower bargaining power and she can renegotiate the repayment obligation with the lender to accommodate this fact (See Matsuyama, 2011).

<sup>11</sup>Note that as capital market becomes less perfect (or as  $\lambda$  decreases),  $w_c$  increases which makes a binding borrowing constraint more likely.

Figure 2.3: Wealth Dynamic



Panel (a): The wealth dynamic of class society,  $w_L^* < w_c < w_H^*$ . Panel (b): The wealth dynamic of classless society,  $w_c < w_L^* < w_H^*$

finite time. I refer to this case as *classless* society, since in a finite time class differences vanish and inter-generational class mobility is attainable. Note that together, equation (2.2) and assumption (1) imply that the dynamic of wealth for the two classes is given by the following first order difference equations:

$$w_t^P = \begin{cases} |_{t < \tau} [w_L^* - \alpha^t(w_L^* - w_0^P)] \\ |_{t \geq \tau} [w_H^* - \alpha^t(w_H^* - w_c)] \end{cases} \quad (2.3)$$

$$w_t^R = w_H^* - \alpha^t(w_H^* - w_0^R) \quad (2.4)$$

where  $\alpha = \beta r < 1$  and in equation (2.3)  $\tau$  refers to the index of time where the wealth of poor class cross the threshold  $w_c$  for the first time and the borrowing constraint is relaxed. Note that assumption (1) ensures that the wealth of both classes is increasing over time or  $\partial w_t^i / \partial t > 0$  for  $i = \{P, R\}$ . This in turn implies that the average or per capita wealth  $\bar{w}_t$  is increasing over time. Figure 3.1 illustrates the dynamic of wealth in a class and classless society. Panel (a) refers to the case where  $w_L^* < w_c$  or in other words, there is a mobility trap and the dynamic of poor class wealth is determined solely by the first term on the RHS of equation (2.3). Panel (b) is the case where  $w_L^* \geq w_c$ , where the class differences disappears in the long-run and the poor class' wealth dynamic is governed by the first term on RHS of equation (2.3) up to the point  $t < \tau$  for some finite  $\tau$  and by the second term afterwards.

Note that this model analyses the wealth dynamic of a single household in isolation and there is no interaction among agents, for example through labour market. This means that the dynamic here does not depend on the share of households above or below the threshold level of wealth  $w_c$ . This simplification makes the dynamics significantly easier to follow and is to a great extent without loss of generality.<sup>12</sup>

<sup>12</sup>The results of this model are robust to introduction of some sort of interaction between households through labour market as shown in Galor and Zeira (1993) or Banerjee and Newman (1993), and besides, the dynamic and comparative static of the results of this "single dynasty" model is a subset of more general "multiple dynasties with variable threshold"

## 2.4.2 Social Conflict

In each period, beside their decision on how to allocate their wealth, the poor can mobilize and demand redistribution. For simplicity and without loss of generality, the distortion caused by wealth redistribution is ignored. I assume that the rich control the state and its repressive apparatus and therefore, are the political elite.<sup>13</sup> If the rich class concedes to the redistributive demands made by the poor, the sum of endowments of that period is confiscated and redistributed among population and in that period everyone receive  $\bar{w}_t = (1 - \delta)w_t^P + \delta w_t^R$ . Instead of concession, the rich might decide to respond to the poor class's demand by repression. Repression is costly for both groups. If the rich elite decide to use state repressive apparatus to reduce the pressure for redistribution, they have to give up  $k_t$  units of their wealth and this cost will be shared equally among their members. So the payoff from repression for a rich agent would be  $w_t^R - k_t/\delta$ .<sup>14</sup> The poor class will lose all their wealth in that period and their payoff is normalized to zero.<sup>15</sup> If there is no demand for redistribution, there will be no repression and both groups accept the market outcome and consume a fraction  $1 - \beta$  of their endowments  $(w_t^P, w_t^R)$  in that period.<sup>16</sup>

An important assumption here is that there is asymmetric information regarding the cost of repression: rich elites have complete information about  $k_t$  since they control the government and have access to a bureaucracy that assesses this cost. While the poor citizens are not very well informed about this cost and are only aware of the its distribution  $F$ , which is a twice differentiable cumulative distribution function defined over non-negative real numbers. This asymmetric information is entered into the model by assuming that  $k_t$  is realized after the poor class decision regarding mobilization and before the rich reaction to demands for redistribution.<sup>17</sup> With this premise the timing of events in each period is as follows:

1. Agents receive their inheritance  $w_t$ .
2. The poor class decides whether to mobilize and demand redistribution not knowing the cost of repression  $k_t$ . If the poor do not mobilize the game ends and the market outcome realizes.
3.  $k_t$  is realized .

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models that allow for interaction of the households through labour market channel on the one hand and the endogenous adjustment of the wealth threshold to interactions between households on the other hand. See Matsuyama (2011) for a complete classification of the models of endogenous inequality with imperfect capital market and the discussion of their implications for dynamic of inequality.

<sup>13</sup>A simplifying assumption here is that the poor class never become a part of political elite irrespective of their wealth status. Therefore, this model does not study the possibility of transition to more democratic form of government and enfranchisement of the poor.

<sup>14</sup>The cost of repression refers to the financial cost using repressive apparatus for monitoring and punishment and possible damages to productive capacity if the economy (such as human, social, and physical capital). The magnitude of this cost is determined by the economic structure, government repressive capacity, geography, geopolitical consideration, international atmosphere and strategic considerations such as the strength of coalitions among political elites. For discussion of cost of repression and the factors affecting it see among others Acemoglu and Robinson (2006), Davenport (2007b, 2007c) and Shadmehrer (2011).

<sup>15</sup>More precisely, if repression happens in any period, the poor withhold their income  $y$ , so that they are not stuck in the trivial steady state forever. Since all agents (poor or rich) have the same income  $y$ , it is dropped from analysis altogether.

<sup>16</sup>If there is no demand for redistribution of wealth, repression is a strictly dominated strategy for the rich.

<sup>17</sup>Alternatively one can assume that this cost realized at the beginning of the game, but only the rich are informed about its value.

4. The rich class decides whether to respond to redistributive demands by repression or concession.
5. Agents decide about investing in the project and consume a fraction  $1 - \beta$  of their wealth and pass the remaining fraction  $\beta$  to their children.

We can solve this game by backward induction. At the last stage of the game, after the poor's decision to mobilize and after the realization of the cost of repression, the rich decide whether to repress or concede. They prefer repression to concession if the payoff of repression is strictly more than the payoff of concession or if  $w_t^R - k_t/\delta > \bar{w}_t$ . Bringing  $\bar{w}_t$  to the left hand side and  $k_t$  to the right hand side we can re-write this inequality as:

$$k_t < \hat{k}_t = s(\delta)(w_t^R - w_t^P) \quad (2.5)$$

where  $s(\delta) = \delta(1 - \delta)$ . Inequality (2.5) means that the rich prefer repression to concession if the cost of repression  $k_t$  is below some threshold, which depends on the wealth gap between the rich and the poor. Note that repression becomes more attractive to the rich if the wealth gap between the two social classes increases. In what follows I refer to the wealth gap between the two group  $(w_t^R - w_t^P)$  as *inequality*.

At the first move of the game, when the poor class decides about demanding redistribution, they are not aware of the realized value of  $k_t$  but only know its distribution  $F$ . So, they know that if  $k_t < \hat{k}_t$  their payoff from mobilization is zero and on the other hand if  $k_t \geq \hat{k}_t$ , they can increase their wealth through redistribution. Let  $X_t = Probability(k_t \geq \hat{k}_t)$  denotes the probability that repression does not happen in the equilibrium. The poor class expected payoff from demanding redistribution is  $X_t \bar{w}_t$ . When deciding whether to demand redistribution or not, poor agents compare this expected payoff to the market outcome which is  $w_t^P$ . Thus they mobilize if and only if

$$X_t \bar{w}_t > w_t^P$$

by replacing for  $\bar{w}_t$  and after some manipulations, we can write the above inequality as:

$$\hat{k}_t = s(\delta)(w_t^R - w_t^P) > \frac{1 - X_t}{X_t} (1 - \delta) w_t^P \quad (2.6)$$

Note that the effect of an increase in inequality on poor agents' decision is not clear. Intuitively there are two offsetting effects: On the one hand, higher inequality, by increasing the left hand side of the inequality (2.6), makes redistribution more attractive for the poor and makes mobilization more likely. On the other hand, higher inequality decreases  $X_t$  and makes repression relatively more attractive to the rich, and anticipating this, the poor become less eager to demand redistribution. The final outcome depends on which of these two effects dominates. Theorem 1 summarizes these results.

**Theorem 1.** *In the social conflict game described above, there is a unique Perfect Bayesian Equilibrium such that:*

- a) *If inequality (2.6) does not hold, the poor accept the market outcome and there will be no repression or redistribution in equilibrium.*

b) If inequality (2.6) does not hold holds, the rich will repress the poor and avoid redistribution whenever  $k_t < \hat{k}_t$  and make a concession otherwise.

The next section studies the dynamic of repression by analysing how the state repressive tendencies,  $Pr(k_t < \hat{k}_t)$ , changes along the equilibrium path. Note that first, the following analysis studies the evolution of this probability conditional on the poor demanding redistribution (otherwise there is no incentive for repression) and second, the dynamics are studied from ex-ante point of view i.e. the focus is on the probability of repression given that there hasn't been any repression along the equilibrium path thus far.

### 2.4.3 The Dynamics of Repression in a Class Society ( $w_L^* < w_c$ )

Since  $w_0^P < w_L^* < w_c$  and  $w_c < w_0^R < w_H^*$ , the initial wealth gap between the two classes  $w_0^R - w_0^P$  never disappears and wealth differences prevails over time. In other words, this situation corresponds to a case with no inter-generational mobility: while the wealth of both classes is increasing over time (Figure 3.1, Panel a), the poor class will remain *relatively* poor, since their wealth level will never pass the threshold  $w_c$  to enable them to invest in the project. Whether such a society becomes more repressive or not depends on the evolution of inequality. To see this formally, note that repression is preferred to concession whenever  $k_t < \hat{k}_t = s(\delta)(w_t^R - w_t^P)$  (equation 2.5 and inequality ??), therefore, the evolution of the probability of state repression or  $Pr(k_t < \hat{k}_t)$  depends on the evolution of the threshold level of repression  $\hat{k}_t$  which itself depends on the evolution of inequality or  $(w_t^R - w_t^P)$ . Thus, by substituting from equations (2.3) and (2.4) in  $w_t^R - w_t^P$ , we can specify the dynamic of the threshold cost of repression as:

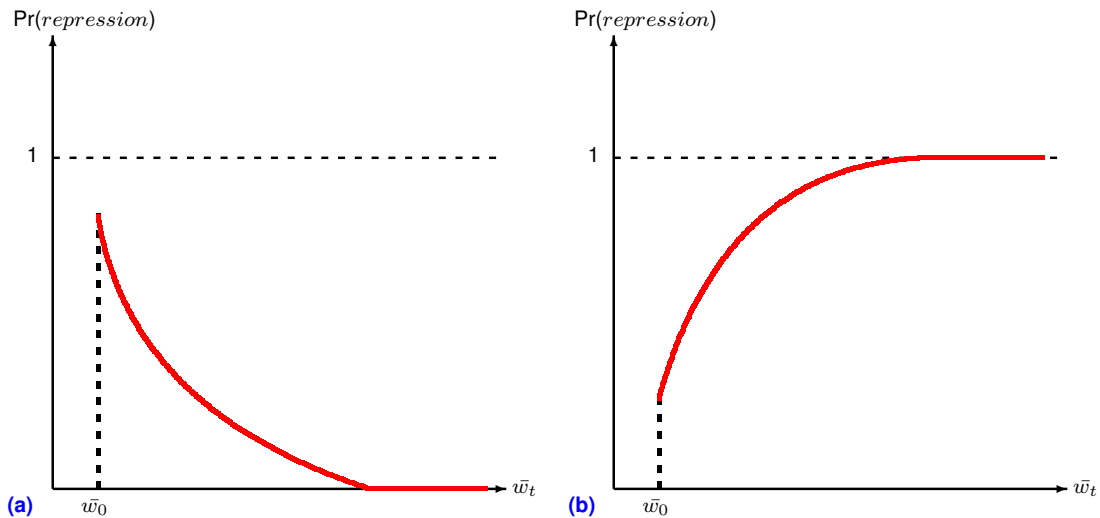
$$\partial \hat{k}_t / \partial t = s(\delta) \alpha^t \ln \alpha [(w_L^* - w_0^P) - (w_H^* - w_0^R)] \quad (2.7)$$

Two different scenarios could be distinguished from each other. First, if  $(w_H^* - w_0^R) < (w_L^* - w_0^P)$ , or if the distribution of the initial wealth of the rich and the poor is such that the rich are closer to their steady state than the poor, then the growth rate of rich agents' wealth is smaller than poor agent's growth rate - due to diminishing returns on wealth or investment - and based on equation (2.7),  $\hat{k}_t$  decreases as the economy develops or as  $\bar{w}_t$  increases.<sup>18</sup> So in this case the likelihood of repression or  $Pr(k_t < \hat{k}_t)$  is decreasing along the equilibrium path. Panel (a) of Figure 3-) illustrates this case. The horizontal axis is  $\bar{w}_t$  which, in our model refers to both per capita and total income and is increasing over time, and the vertical axis is  $Pr(k_t < \hat{k}_t)$  or the probability of repression. So here the dynamic, in the spirit of the modernization theory, suggests something similar to the simple poverty thesis (Mitchell and McCormick, 1988; Poe and Tate, 1994), i.e., as the economy develops, the attractiveness of repression falls for the rich and it becomes less likely that they respond to the poor redistributive demands by repression. Hence one might expect to see a monotonically decreasing relationship between income per capita and repression.

Second, if  $(w_H^* - w_0^R) > (w_L^* - w_0^P)$ , the wealth of rich class is growing faster and inequality is increasing along the equilibrium path. In this case the likelihood of repression  $Pr(k_t < \hat{k}_t)$  is

<sup>18</sup>According to equations (2.3) and (2.4) the growth rate of the wealth of the poor and the rich classes is given by  $\partial w_t^P / \partial t = -\alpha^t \ln \alpha (w_L^* - w_t^P)$  and  $\partial w_t^R / \partial t = -\alpha^t \ln \alpha (w_L^* - w_t^R)$ , respectively. Since  $\alpha = \beta r < 1$  and  $(w_H^* - w_0^R) < (w_L^* - w_0^P)$ ,  $\partial w_t^P / \partial t > \partial w_t^R / \partial t$  for all  $t$ .

Figure 2.4: The Dynamics of Repression in a Class Society



Panel (a): Development into a non-repressive state;  $w_H - w_0^R < w_L - w_0^P$ . Panel (b): Development into a repressive state;  $w_H - w_0^R > w_L - w_0^P$ .

increasing over time which results in a persisting class conflict. This situation depicted in panel (b) of Figure 2.4. Note that we can rewrite the condition that characterizes evolution into a repressive state as  $(w_H^* - w_L^*) > (w_0^R - w_0^P)$ , and this inequality means that a class society eventually develops a repressive political institutions if the distribution of wealth in the steady state is more unequal than the initial distribution. This case corresponds to Brrington Moore's (1966) argument that the path to modernization might lead to more repressive political institutions such as communism and fascism rather than democracy. In his view, whether the modernization process brings about fascism or communism depends on inherited feudal institution and organization of agriculture of a society, an argument which could be related to the importance of initial conditions and growth potential of different classes as suggested by the model. This case also resembles Marx's argument regarding the dual nature of the process of capitalism in which wealth accumulation inevitably intensifies class conflict and results in the repression of the proletariat by the bourgeoisie.<sup>19</sup> The difference here is that this process is not inevitable: a class society with limited or no mobility potential does not correspond to a repressive one per se. What is required for a class society to become more repressive along the equilibrium path is relatively limited growth potential for the poor.<sup>20</sup>

<sup>19</sup>In his response to the French anarcho-socialist Pierre-Joseph Proudhon's *The Philosophy of Poverty*, Marx argues: From day to day it thus becomes clearer that the production relations in which the bourgeoisie moves have not a simple, uniform character, but a dual character; that in the selfsame relations in which wealth is produced, poverty is also produced; that in the selfsame relations in which there is a development of the productive forces, there is also a force producing repression; that these relations produce bourgeois wealth i.e., the wealth of the bourgeois class only by continually annihilating the wealth of the individual members of this class and by producing an ever-growing proletariat. (Marx, "The Poverty of Philosophy", 1847.)

<sup>20</sup>Note that  $(w_H^* - w_0^R)$  and  $(w_L^* - w_0^P)$  could be interpreted as the growth potentials of the two classes.

### 2.4.4 The Dynamics of Repression in a Classless Society ( $w_L^* \geq w_c$ )

Here  $w_0^L < w_c < w_L^*$  and  $w_c < w_0^R < w_H^*$ . Therefore, the poor eventually accumulate enough wealth and the borrowing constrain is relaxed along the equilibrium path. Panel (b) of Figure 3.1 illustrates this case. Remember from the previous section that  $\tau$  is the index of time when the wealth of poor class cross the threshold level  $w_c$ . Therefore, the dynamic of the probability of repression is given by:

$$\partial \hat{k}_t / \partial t = s(\delta) \{ |_{t < \tau} \alpha^t \ln \alpha [(w_L^* - w_0^P) - (w_H^* - w_0^R)] + |_{t \geq \tau} \alpha^t \ln \alpha (w_0^R - w_c) \} \quad (2.8)$$

Again, if  $(w_H^* - w_0^R) < (w_L^* - w_0^P)$  or if the rich are closer to their steady state, the first term on the right hand side of equation (8) is positive and since the second term is always positive ( $w_0^R > w_c$ ), the probability that repression occurs is decreasing along the equilibrium path or  $\partial \hat{k}_t / \partial t < 0$ . In this situation the association between income and repression is similar to what suggested by the modernization theory and the result regarding the evolution of inequality is similar to the first scenario considered for a class society above. However, note that here class differences disappears over time and inter-generational class mobility is feasible while in a class society the distribution of income remains polarized. Panel (a) of Figure 2.5 illustrates this case.

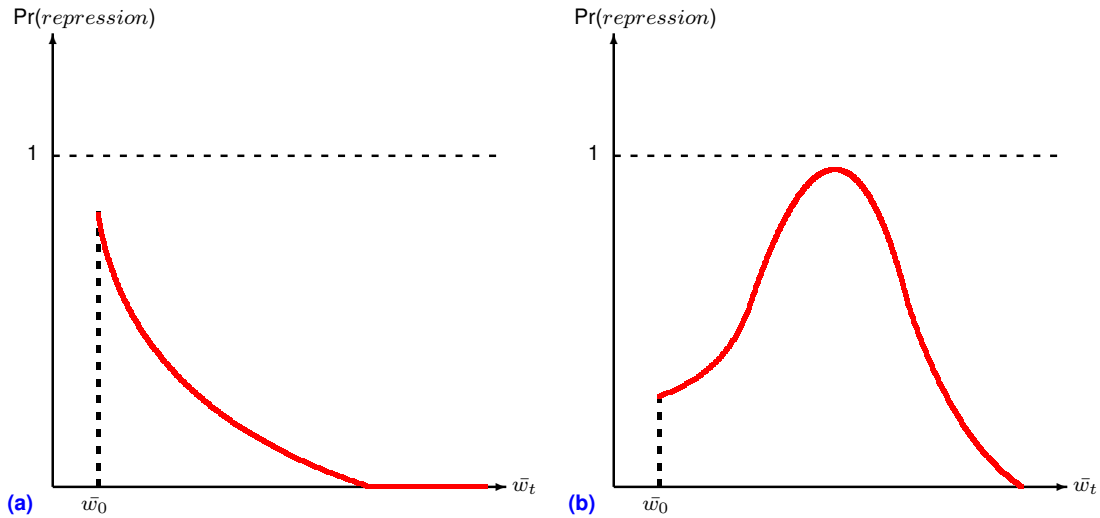
If on the other hand  $(w_H^* - w_0^R) > (w_L^* - w_0^P)$ , the growth rate of the wealth of the rich class is higher and the initial wealth gap grows over time. In this case as long as  $t < \tau$  inequality is increasing and when  $t \geq \tau$  the poor have accumulated enough wealth and the borrowing constraint is not binding, and at this point the evolution of inequality is drive solely by the second term on the right hand side of equation (8). Since this term is always negative, inequality is decreasing over time. Note that here as long as  $t < \tau$ , the growth rate of the wealth of rich is higher, but for  $t \geq \tau$ , the growth rate of the wealth of the poor becomes higher.<sup>21</sup> Therefore this case produce a relationship between inequality and development which is similar to Kuznets (1955) argument and the likelihood of repression  $Pr(k_t < \hat{k}_t)$  follows an inverted U shape path along the equilibrium path. Therefore, in this case political institutions of a classless society undergo two distinct phases: at the early stage, while both class are getting wealthier in absolute sense, the wealth of rich class is growing faster and the class differences magnifies. At this stage the likelihood of repression is increasing. But at later stages of development, the poor becomes wealthy enough to invest for example in their human capital and at this point their wealth starts to grow faster and the class structure starts to disappears and with it the repressive tendencies of the state.

This case is similar to Huntington (1968) and Nagel (1974) arguments that political instability and violence is most likely when a country is at the middle of the process of modernization. Panel(b) of Figure 2.5 illustrates this situation. The increasing part of the likelihood of repression refers to  $t < \tau$ , when the poor are borrowing constrained and the growth rate of the wealth of the rich is higher. The decreasing part of the function refers to  $t \geq \tau$ , when the borrowing constraint is not binding and the poor class's wealth starts growing faster. The following proposition summarize the results about the dynamic of repression:

**Proposition 1.** The Dynamics of State Repression

<sup>21</sup> For  $t < \tau$ ,  $|\partial w_t^R / \partial t| = \alpha^t \ln \alpha (w_H^* - w_0^R)$  which is higher than  $|\partial w_t^P / \partial t| = \alpha^t \ln \alpha (w_L^* - w_0^P)$ . While for  $t \geq \tau$ ,  $|\partial w_t^R / \partial t|$  is lower than  $|\partial w_t^P / \partial t| = \alpha^t \ln \alpha (w_H^* - w_c)$ .

Figure 2.5: The Dynamics of Repression in a Classless Society



Panel (a): Development into a non-repressive state;  $w_H - w_0^R < w_L - w_0^P$ . Panel (b): Society goes through two different phases of repression;  $w_H - w_0^R > w_L - w_0^P$ .

The likelihood of state repression is an increasing function of inequality defined as  $w^R - w^P$ , and the effect of economic development on repression depends on how the process of development affect the distribution of wealth, in particular:

1) If  $w_H - w_0^R < w_L - w_0^P$  (if the rich class are closer to their steady state that the poor), then regardless of whether or not there is a mobility trap, repression becomes less likely as society develops. In this case there is a monotonically decreasing relationship between income level and repression.

2) If  $w_H - w_0^R > w_L - w_0^P$  (if the poor class are closer to their steady state that the rich), then:

a) If upward mobility is not feasible even in the steady state ( $w_L^* < w_c$ ), then repression becomes more likely along the equilibrium path. in this case the association between income level and probability of repression is monotonically increasing.

b) If upward mobility is feasible ( $w_L^* \geq w_c$ ), the society experience two different phases of the state propensity to repress along the equilibrium path, i.e., there is an inverse U-shaped relationship between the level of income and the probability of state repression.

The next section empirically examines the validity of the theoretical results.

## 2.5 Empirical Evidence

### 2.5.1 Data and Descriptive Statistics

The theoretical model suggests that first, repression is more likely when current inequality is high since the cost of redistribution for the rich is relatively higher in such a society. I examine this claim by including two measures of inequality in regressions with different measures of state repression



as the dependent variable. Second, the model suggests that association between income level and repression might be increasing, decreasing or inverse U-shaped depending on a country growth potential for different classes (which depends on distribution of wealth at the beginning of the process of development and in the steady state) and class mobility (whether or not there is a mobility trap). To the best of my knowledge a comprehensive measure for growth potential of different income groups and an index that measure the extent of class mobility for enough countries to make statistical inference feasible, does not exist.<sup>22</sup> An alternative way is to estimate the relationship between state repression and income in a non-parametric setting. The idea behind non-parametric specification is to relax any prior on the functional form and to let the sample in hand determines the actual shape of the relationship between variables.<sup>23</sup> This approach is particularly suitable for the current problem since if one expects that for some countries in the sample the association between income and repression is positive, for some negative, and for some hump shaped, then it is very likely that the non-parametric specification return a non-linear functional form. And this could be interpreted to be indirectly in favor of the theoretical results.

**The Dependent Variable:** There are at least four comprehensive measure of state repression available. These are Political Terror Scale (PTS), which consists of data from the U.S. state department and Amnesty International, Cingranelli and Richards human rights data (CIRI), and Freedom House measure of civil liberties. Note that all of these measures are to a great extent compatible with the underlying concept of state repression suggested by the formal model.<sup>24</sup> I use the PTS of the U.S state department for my *primary* specification. PTS measures physical integrity rights violations worldwide from 1976 till 2010 and it classifies all countries based on five categories or Political Terror Scale Levels, which are defined below:

**Level 5:** Terror has expanded to the whole population. The leaders of these societies place no limits on the means or thoroughness with which they pursue personal or ideological goals.

**Level 4:** Civil and political rights violations have expanded to large numbers of the population. Murders, disappearances, and torture are a common part of life. In spite of its generality, on this level terror affects those who interest themselves in politics or ideas.

**Level 3:** There is extensive political imprisonment, or a recent history of such imprisonment. Execution or other political murders and brutality may be common. Unlimited

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<sup>22</sup>The extent of class mobility is measurable using the “inter-generational earnings correlation (IGEC)” which measures correlation between the earnings of a generation and its subsequent one, but as mentioned above a comprehensive IGEC measures that cover enough countries over sufficient time periods to make statistical inference feasible is not available. There are some evidence, however, that developing countries have generally a higher IGEC, which is an evidence of low inter-generational mobility and more rigid class structure in these countries. See for example Behrman, Gaviria, and Szekely (2001), Dunn (2007), and Mulligan (1997) regarding measuring IGEC in developing countries and in the U.S.

<sup>23</sup>For example, a simple OLS estimation is based on the “average” of the data and by itself is incapable of uncovering any non-monotonic or non-linear effect of regressors or regressand.

<sup>24</sup>The model suggests that repression could be the proper response to some sort of opposition to the state when inequality is high. Whether this opposition connote to purely redistributive class conflict or more serious confrontation between government and opposition (such as mass mobilization and a in the limit a threat of revolution), if the state react by using repressive apparatus (or any combination of police, security and military forces) against opposition, one would expect to see some degree of violation of personal integrity of at least a part of opposition. Note that this definition of repression is in line with the definition suggested by most scholars, see Davenport (2000) and (2007a), Goldstein (1978), Tilly (1978).

detention, with or without a trial, for political views is accepted.

**Level 2:** There is a limited amount of imprisonment for nonviolent political activity. However, few persons are affected, torture and beatings are exceptional. Political murder is rare.

**Level 1:** Countries under a secure rule of law, people are not imprisoned for their view, and torture is rare or exceptional. Political murders are extremely rare.

Since my model refers to the probability of state repression rather than actual repression, I construct a new binary measure of repression that classifies a country as repressive and takes the value of 1 if the state department PTS is equal to or higher than 3, and takes the value of zero otherwise.<sup>25</sup> The choice of the cutoff point is natural since level 3 is the situation where there is extensive repression by the state, and below this level, repression is limited and sporadic.<sup>26</sup>

A valid concern here is that whether the choice of dependent variable and its modification have an affect on the validity and generality of the results. For example, one might suspect that a model that uses the data from other sources such as Amnesty International PTS, Cingranelli and Richards data, or Freedom House civil liberties index, would return similar results. specially since these variable are highly correlated with each other. To answer this concern, I combine all of the aforementioned measures - PTS (state department, Amnesty International), CIRI, and Civil Liberties indices- and use their "Principal Component(s)" as the dependent variable in a second specification. Note that Table 2.1 suggests that these measures are highly correlated, therefore using their principal components is a reasonable strategy.<sup>27</sup> Table 2.2 shows that principal components of the four measure of state repression. Only the first component has an eigenvalue bigger than one and it bears almost 66 percent of the information in the data. Table 2.3 shows that the contribution of the measures of repression to the first component is relatively equal. Therefore, I use the first principal component of these measures as the dependent variable in a second specification.<sup>28</sup>

**Independent Variables:** Remember that inequality (2.5) suggests that as inequality - defined as the absolute differences in wealth between the social classes - increases, repression becomes more likely. Therefore, to empirically test for this prediction in a cross-country setting, one needs a measure of absolute inequality, for example between the top 1-10 percent and the rest of the population. Unfortunately, a comprehensive cross-country measure of absolute inequality is not readily available. The alternative strategy adopted in this paper is to rely on conventional measures of relative inequality such as Gini coefficient and capital share which are readily accessible. To this end. I use an estimated Gini index developed by University of Texas Inequality Project (UTIP). This variable is an "Estimated Household Income Inequality"(EHII) based on a linear regression of

<sup>25</sup>Remember that repression or concession on the part of the rich requires some degree of mobilization by the poor to demand redistribution which might not happen even if the inequality is high, for example because the poor anticipate that any demand would be met with sever repression or perhaps because they lack the necessary organizational capacity for collective action. In other words inequality (6) might not be binding even if the wealth distribution is very unequal.

<sup>26</sup>This modification leads to loss of information but has some advantages: first, it allows the econometric specification to refers to probability of repression which is more compatible with the theoretical results, second, it makes the interpretation of the results easier and more meaningful compare to a model with polychotomous dependent variable, and third, it might help to reduce the measurement error which could be sever in these types of data.

<sup>27</sup>Cingranelli and Richards's personal integrity index is inverted to become comparable and consistent with the other three measures.

<sup>28</sup>The first principal component is a continuous measure with the minimum value of -2.7694 and the maximum of 4.7339.

Table 2.1: Correlations Between Human Rights Scales

Source	State Department	Amnesty International	CIRI	Freedom House
Index	PTS	PTS	Physical Integrity	Civil Liberties
PTS (SD)	1			
PTS (AI)	0.7913	1		
Physical Integrity	0.6396	0.6088	1	
Civil Liberties	0.5434	0.4636	0.3518	1

All correlations are significant at 0.01 level

Table 2.2: Principal Components/Correlation

Component	Eigenvalue	Proportion
Comp.1	2.6216	0.6554
Comp.2	0.6967	0.1472
Comp.3	0.4485	0.1121
Comp.4	0.2330	0.0583

Number of Observations: 2266

Deininger and Squire (1996) Gini coefficient on a Theil measure of industrial pay inequality and other relevant socio-economic information. Since measures of industrial pay inequality are readily available, this EHI measure is much more comprehensive than the original Deininger and Squire (1996) data. UTIP data covers a large set of countries from 1963 till 2002. Second, I use capital share, the proportion of value added in industrial sector accruing to capital owners, gathered by Ortega and Rodriguez (2006). As suggested by Acemoglu and Robinson (2006), when conflict is between rich and poor, the capital share might be a good measure of inequality since the poor classes drive their income mostly from their labor and don't have access to capital market. Therefore high capital share refers to higher concentration of wealth among the rich classes and is a sign of high inequality.<sup>29</sup> Ortega and Rodriguez (2006) data has about 3500 observations covering 116 countries between 1960 and 2000 and was constructed from data collected by the United Nations Industrial Development Organization (UNIDO). I use GNI per capita in purchasing power parity from World Development Indicator (WDI) as a proxy for development. In what follows I refer to GNI per capita as income per capita.

**Other Control Variables:** Almost all statistical analysis on state repression find that democracies are less repressive and an outbreak of civil war increases the likelihood of state repression (Davenport, 2007). Therefore, all regressions include a dummy variable which takes the value of 1 if the Polity IV score of a country is above 6 and takes 0 otherwise and a dummy variable which takes the value of 1 if a country has experienced civil war with at least 25 battle-related death in a specific year and takes 0 otherwise. This variable is taken from Uppasala/PRIO dataset on civil war. Other control variables are a lagged dependent variable, log of population and an index of ethno-linguistic fractionalization. The lagged dependent variable controls for serial correlation, captures factors omitted in the model and conceptually refers to the fact that repression might be deeply

<sup>29</sup>A possible problem with capital share, however, could be that it covers only the industrial sector and might not be good representative of the whole economy, especially for developing countries (Houle, 2009).

Table 2.3: Principal Components (eigenvectors)

	Component 1
PTS (SD)	0.5585
PTS (AI)	0.5378
Physical Integrity	0.4742
Civil Liberties	0.4171

Table 2.4: Summary Statistics

	Mean	Std. Dev	Min	Max	Obs
Repression (PTS-binary)	0.1503	0.3575	0	1	4310
Repression (The first principal component)	0.0000	1.6119	-2.7694	4.7339	2266
Income (log/per capita)	8.1159	1.1262	5.7053	10.933	3625
Gini Index (UTIP)	41.0378	7.1074	19.81	64.34	2085
Capital Share	0.6502	0.1330	0.2926	0.9269	1971
Democracy (dummy)	0.4155	0.4928	0	1	3312
Civil War (dummy)	0.1789	0.3833	0	1	3309
Population (log)	15.5571	1.8631	10.309	20.9704	4264
Fractionalization	0.4234	0.2741	0.0041	0.9250	3621

rooted property of political institutions and might change slowly over time. Note that in Section 2.4 I analysed the likelihood of state repression from ex-ante point of view, and, therefore, a possible concern here could be that the inclusion of lagged dependent variable is not justified by the theoretical model. However, regressions performed but not presented here suggest that the shape of the association between income per capita and measures of state repression is not affected by the inclusion of lagged dependent variable. Population is taken from World Bank (2012) and its inclusion is necessary to correct for the fact that our dependent variables are based on event count and do not control for population size. Fractionalization index is taken from Fearon and Laitin (2003) and is included to capture the fact that countries with high degree of fractionalization among population might experience more intense conflict among societal groups which may provoke more political violence and repression.<sup>30</sup>

Table 2.4 presents summary of the variables. The time span of the sample is bounded from below by the availability of PTS data, which is available for most countries from 1979 onward, and from above by the availability of data on inequality, which is available till 2002.

## 2.5.2 Empirical Strategy and Results

The first specification uses the binary PTS index as the dependent variable. This calls for a probit or logit model, which are proper specifications for binary dependent variable. Therefore the first specification estimates the following dynamic semi-parametric probit model:

$$Pr(R_{it} = 1 | R_{it-1}, \Psi_i) = \Phi(\gamma R_{it-1} + s(y_{it-1}) + \alpha \theta_{it-1} + X_{it-1} \beta + \mu_t) \quad (2.9)$$

Where  $R_{it}$  is the measure of repression (here the binary PTS) and  $R_{it-1}$  is its lagged value.  $\Psi_i$  refers to the matrix of all other regressors.  $\Phi$  is the cumulative distribution function of standard

<sup>30</sup>This variable is not statistically significant determinant of conflict in some empirical research, see for example Lee et al. (2004) and Walker and Poe (2002).

normal distribution.  $y_{it-1}$  is income per capita and  $s$  is a smooth function to be determined.  $\theta_{it-1}$  is the measure of inequality (capital share or Gini) and  $X_{it-1}$  is the matrix of controls.  $\mu_t$  is a vector of time dummies.<sup>31</sup> All independent variables are lagged once to control for simultaneity bias and in all specification the standard errors are clustered to control for correlation across observations.<sup>32</sup>

There are two ways to estimate equation (2.9). First, we can estimate (2.9) by regressing  $R_{it}$  on a polynomial of  $y_{it-1}$  and the rest of regressors, and the degree of the polynomial determines the shape of functional form between income and repression. This can be easily done using standard software such as Stata. One possible concern about this method is that it might not be flexible enough to capture the exact shape of the relationship. A way to avoid this problem is to estimate equation (2.9) as a “Generalized Additive Model” (GAM), which approximates the smooth function  $s$  using splines and is relatively more flexible compared to a polynomial regression.<sup>33</sup> I employ both methods but since the results are quite similar, I report the results for polynomial regression and for graphical illustration, I use the results obtained from both methods. Table 2.5 presents the result of the estimation of equation (2.9).

Column (1) of Table 2.5 excludes inequality and is parametric in income and is included to make the comparison of estimations based on equation (2.9) with the literature easier (e.g. Poe and Tate; 1994 and 1999). As expected, lag dependent variable is highly significant and its effect is positive. Income and democracy are negatively correlated and civil war and population are positively correlated with repression. The effect of fractionalization is negative but not significant. Column (2) includes the capital share and income squared. Capital share has the expected sign but not significant and the coefficient on income and income square are positive and negative respectively. These coefficients suggest an inverse U-shaped relationship between income and repression.<sup>34</sup> Column (3) includes UTIP Gini-index. The result is quite similar to column (2) and coefficients on income and income squared suggest an inverse U-shaped relationship. Inequality has the expected sign and is significant at 10 percent level. Columns 1-3 include all countries in the sample and a possible problem with this is that one might suspect that the results are affected by the presence of a group wealthy, democratic and developed countries that have relatively lower inequality and historically good scores of human rights, and are better represented in the sample due to better quality of data for both dependent and independent variables. For this reason, columns (4) and (5) of Table 2.5 repeat the specifications of columns (2) and (3) but this time excluding high-income OECD countries.<sup>35</sup> The results are very similar to results obtained for columns (2) and (3).

<sup>31</sup>Time dummies control for trends over time, for example the end of Cold War or changes in global policies. Without these dummies the regression may pick the world-wide trends in development and state repression.

<sup>32</sup>I am aware of the limitation of cross-country comparison and pooled panel data method, specially in terms of causal interpretation. This method ignores unobserved heterogeneity, endogeneity, and possibility of reverse causality and therefore I am reluctant to attribute any causal interpretation to the empirical results. A problem that prevented me to include the unobserved heterogeneity in the estimations is the lack of enough within country variation in the most of right hand side variables, such as inequality, the index of democracy, and ethno-linguistic fractionalization.

<sup>33</sup>GAM estimation is performed in R using Simon’s Wood (2010) mgcv package. The estimation method is Penalized Maximum Likelihood (PML), using probit link and thin plate splines. This package allows for automatic knot selection via minimizing the mean square error. See Rupert et al. (2003) for a survey of semi-parametric methods.

<sup>34</sup>Regression performed but not presented here shows that income cubed is not significant and its inclusion render all other terms of the polynomial insignificant. This suggests that the proper functional form is quadratic.

<sup>35</sup>Counties excluded are The United States and Canada, New Zealand, Australia and Japan, Austria, Belgium, Great Britain, Denmark, Finland, France, Germany, Ireland, Israel, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Switzerland, Sweden.

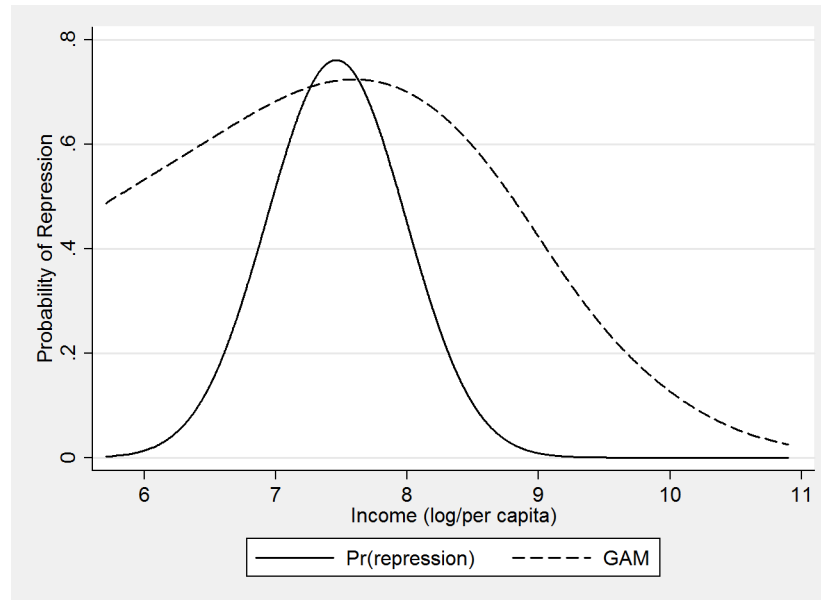
Table 2.5: Dynamic Probit Regressions

Dependent Variable: Repression <sub>t</sub> measured as PTS/binary					
Countries	(1) All	(2) All	(3) All	(4) Developing	(5) Developing
Repression <sub>t-1</sub>	1.696*** (0.091)	1.482*** (0.122)	1.631*** (0.128)	1.419*** (0.124)	1.564*** (0.130)
Income <sub>t-1</sub>	-0.302*** (0.061)	4.677*** (0.882)	4.491*** (0.995)	5.207*** (1.080)	4.735*** (1.086)
Income (square) <sub>t-1</sub>		-0.318*** (0.058)	-0.301*** (0.063)	-0.351*** (0.072)	-0.315*** (0.070)
Inequality (Capital Share) <sub>t-1</sub>		0.536 (0.500)		0.692 (0.564)	
Inequality (Gini) <sub>t-1</sub>			0.019* (0.010)		0.0179* (0.011)
Democracy <sub>t-1</sub>	-0.470*** (0.109)	-0.315** (0.140)	-0.414*** (0.139)	-0.267* (0.145)	-0.362** (0.142)
Civil War <sub>t-1</sub>	0.787*** (0.141)	0.898*** (0.200)	0.897*** (0.200)	0.863*** (0.205)	0.842*** (0.208)
Population <sub>t-1</sub>	0.203*** (0.039)	0.270*** (0.039)	0.319*** (0.055)	0.312*** (0.040)	0.361*** (0.060)
Fractionalization <sub>t-1</sub>	-0.288 (0.192)	-0.106 (0.227)	-0.172 (0.237)	-0.064 (0.243)	-0.109 (0.243)
Observations	2750	1795	1622	1417	1242
Pseudo R-squared	0.504	0.567	0.609	0.566	0.609

Robust standard errors in parentheses

\*\*\* p&lt;0.01, \*\* p&lt;0.05, \* p&lt;0.1

Figure 2.6: Economic Development and the Probability of State Repression



Notes: Predicted probabilities of the solid line are extracted from column (3) of Table 2.5. The dashed line refers to a corresponding GAM column with thin plate splines as smooth function.

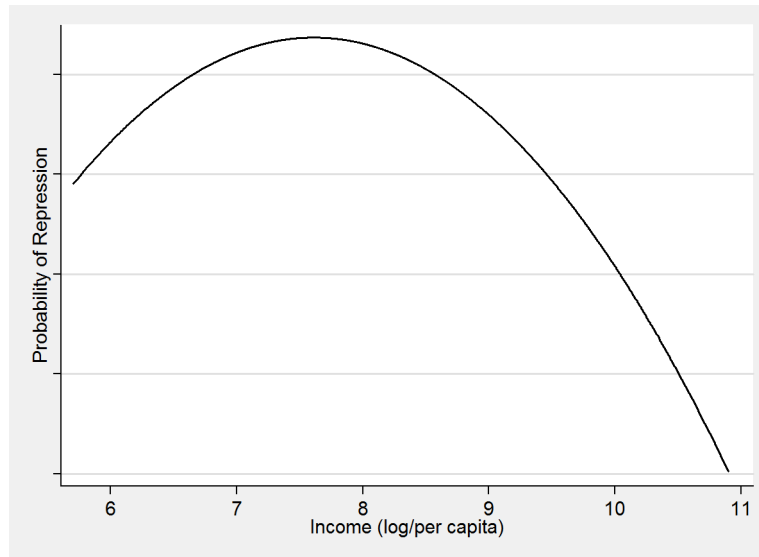
Capital share has the expected sign but not significant, Gini index has a positive effect and significant at 10 percent level and the coefficient on income and income squared suggest an inverse U-shaped relationship between income and probability of repression. Figure 2.6 illustrates the predicted probabilities of repression extracted from the regression similar to column (3) of Table 2.5 and a corresponding GAM model with thin plate splines as smooth function.<sup>36</sup>

This figure suggests that repression is most likely when income is at the intermediate levels, a case which resembles panel (b) of Figure 2.5 and corresponds to a situation where the borrowing constraint is relaxed along the equilibrium path and class mobility is feasible in finite time. This is evidence against simple poverty thesis (which maintains a monotonically decreasing association between income and repression) and is in favor of the argument made by Samuel Huntington (1968) that political violence is most likely when a country is at the middle of the process of modernization. The turning point of the repression function presented by the solid line (polynomial regression) is when log income per capita reaches 7.47 which is approximately equal to 1737 dollars.<sup>37</sup> So in this sample, countries with income below turning point has experienced a positive marginal effect of income on probability of repression or in other words, had become more repressive along the equilibrium path.

<sup>36</sup>Note that since the estimation method and the smooth function of polynomial model and GAM model are different, these two methods produce different predicted outcome for same values of income. In this case predicted probabilities of GAM model were higher than those obtained with dynamic probit model. Therefore, these probabilities are re-scaled so that they are comparable to each other. These modification is inconsequential since we are merely interested in the shape of the functional form between income and repression.

<sup>37</sup>This corresponds for example to income per capita of Cameroon or Mauritania in 2000.

Figure 2.7: Economic Development and the Probability of State Repression



Note: Predicted probabilities of the solid line are extracted from column (3) of Table 2.6.

**Robustness Check.** The second specification uses the principal component of the four aforementioned measures of state repression (Table 2.1) as the dependent variable. Since this is a continuous measure the model is linear and can be easily estimated with Ordinary Least Square in the following specification:

$$R_{it} = R_{it-1} + s(y_{it-1}) + \alpha\theta_{it-1} + X_{it-1} + \mu_t + \epsilon_{it} \quad (2.10)$$

Where  $R_{it}$  is the principal component,  $s$  is a smooth function to be determined, and  $\epsilon_{it}$  is the error term.  $\theta_{it-1}$  is the measure of inequality (capital share or Gini) and  $X_{it-1}$  is the matrix of controls.  $\mu_t$  is a vector of time dummies. Table 2.6 presents the result of the estimation of equation (2.10) and suggests that the results presented in Table 2.5 are robust to change in the dependent variable. The coefficients on income and income squared in columns 2-5 of Table 2.6 suggest an inverted U-shape association between income and repression. Capital share has the expected sign but not statistically significant, and Gini coefficient has a positive effect and significant at the 1-percent level.<sup>38</sup> Figure 2.7 illustrates the the likelihood of state repression extracted from a regression similar to column (3) of Table 2.5 and similar to Figure 2.6, shows an inverted U-shape relationship between income per capita and repression.

<sup>38</sup>Since Principal Component Analysis (PCA) reveals the internal structure of the four dependent variables in a way that best explain the variance in the data, one advantage of the second specification (equation 11) over dynamic probit model (equation 10) is that in the former, the dependent variable has incorporated more *useful* information, and as a result, all standard errors are significantly lower and estimations are more efficient.



Table 2.6: OLS Regressions

Dependent Variable: Repression <sub>t</sub> /The First Principal Component					
Countries	(1) All	(2) All	(3) All	(4) Developing	(5) Developing
Repression <sub>t-1</sub>	0.750*** (0.020)	0.691*** (0.030)	0.722*** (0.030)	0.648*** (0.030)	0.667*** (0.029)
Income <sub>t-1</sub>	-0.126*** (0.027)	1.740*** (0.332)	1.224*** (0.370)	1.872*** (0.474)	1.315*** (0.376)
Income (square) <sub>t-1</sub>		-0.119*** (0.022)	-0.080*** (0.023)	-0.126*** (0.031)	-0.083*** (0.023)
Inequality (Capital Share) <sub>t-1</sub>		0.008 (0.204)		0.136 (0.241)	
Inequality (Gini) <sub>t-1</sub>			0.013*** (0.004)		0.013*** (0.004)
Democracy <sub>t-1</sub>	-0.223*** (0.048)	-0.165*** (0.060)	-0.254*** (0.060)	-0.164** (0.063)	-0.270*** (0.062)
Civil War <sub>t-1</sub>	0.255*** (0.076)	0.324*** (0.096)	0.244*** (0.090)	0.356*** (0.096)	0.264*** (0.092)
Population <sub>t-1</sub>	0.082*** (0.0150)	0.110*** (0.019)	0.109*** (0.021)	0.139*** (0.019)	0.148*** (0.022)
Fractionalization <sub>t-1</sub>	-0.078 (0.074)	0.016 (0.097)	0.046 (0.096)	0.053 (0.117)	0.114 (0.109)
Observations	1782	1180	1017	982	829
R-squared	0.789	0.809	0.831	0.711	0.747

Robust standard errors in parentheses

\*\*\* p&lt;0.01, \*\* p&lt;0.05, \* p&lt;0.1

## 2.6 Concluding Remarks

This paper provides a theoretical model to study the effect of economic development on state repression. I argue that an imperfection in capital markets might cause a poverty trap for the poor and eliminate their ability to get out of poverty without redistribution of wealth. Demand for redistribution may result in a conflict between the rich and the poor and depending on the cost of repression, the rich might respond with repression rather than policy concession. The model implies that both the average or per capita income level and the distribution of income are associated with the state repressive tendencies. In particular, the rich class has more incentive to repress the poor when the distribution of income or wealth is highly unequal, since in such society redistribution is relatively more costly to the rich. Furthermore, the relationship between income level and repression depends on the growth opportunities for different classes and on whether or not the poor class is mobility trapped. The growth opportunities for different classes depends on the distance between their initial and steady state level of wealth, and the existence of the mobility trap is determined by the extent of the imperfection in the capital market.

For example, I show that if the borrowing constraint is binding for the poor even in the steady state, and if the growth opportunity for the poor is relatively small along the equilibrium path, the state propensity to repress increases over the course of development. In this situation one might expect to see a positive association between income level and state repression over time. On the other hand, it is also possible for a society to experience different intensity of state repression over the course of development. This happens if the growth opportunities for lower classes are relatively small at the beginning of the process of development but overtime the poor class accumulate enough wealth and the borrowing constraint is relaxed in finite time. This situation generates an inverse U-shaped relationship between the level of income and the probability of state repression.

The empirical evidence confirms the theoretical insight of the model: cross country evidence suggest that inequality is positively and significantly correlated with repression and the relationship between income and probability of repression follows an inverted U-shape path. These results contributes to the literature on state repression, as well as the modernization literature and the literature on the effect of inequality on political conflict. The empirical association between inequality and repression complements the literature on the effect of inequality and political conflict. While the estimated inverted U-shape relationship between income level and repression goes against “the simple poverty thesis” of the literature on state repression (Mitchell and McCormick, 1988, Poe and Tate, 1997). After all, historically some scholars have argued that modernization and industrialization could lead to less democratic and more repressive forms of government. For example, based on Europe’s experience in 19th and 20th century, Moore (1966) has argued that democracy is only one of the paths of modernization, and the others are fascism and communism (both of which could be more repressive compared to democracy). Similarly, Ardent (1958) saw the rise of modern dictatorships such as Nazi Germany as a by-product of industrialization and argued that a main feature of these modern dictatorship is that “terror is no longer used as a means to exterminate and frighten opponents, but as an instrument to rule masses of people who are perfectly obedient” (1958, p.6). Marxist theories also identify a close connection between capitalist modes of production and repression of the proletariat by the bourgeoisie. The theoretical model incorporates most of these

arguments and characterizes the condition that could give rise to each of them. Finally, the empirical evidence presented here is in favor Samuel Huntington's (1968) argument that political violence is most likely when a country is at the middle of the process of modernization.

Besides, the theoretical and the empirical results of the paper might be helpful for governments and organizations dealing with human rights issues in developing countries. For example, one of the concerns of international organizations and Western governments regarding China is the high level of human rights violation and the Communist party repressive policies. As an example, upon considering a signing a free trade agreement with China, Canadian government and political activists inside Canada have expressed concerned about the violation of human rights by the Chinese government. So far China's answer to this concerns has been "let us develop", which implies that they believe that overtime, and as a result of development these issues will be automatically solved.<sup>39</sup> The model and empirical evidence presented here might be helpful in understanding whether the process of economic development in China and other developing countries eventually lead to less repressive and more democratic governance or not. The argument here is that such a process is not automatic and to a great extent depends on the details of economic structure and policies pursued by governments. In short, the effect of economic development on political institutions depends on which groups are relatively benefiting more from this process.

There is, however, a great room of improvement and exciting areas for further research. For example, the model of social conflict presented in Section 3 simply assumes that faced with pressure to redistribute wealth, the ruling class have two options: repression or concession. While real world examples show that in practice governments use both repression and concession, sometime simultaneously, to deal with pressures that threaten their political stability. Incorporating this fact results in a richer repression dynamic. Also note that the paper assumes that the share of population that control the state and its repressive apparatus ( $\delta$ ) does not change over time. This assumption allows me to abbreviate from considering the possibility of democratization following mass mobilization and significantly simplifies the analysis. Although the main message of the model - that the association between economic development and the likelihood of state repression needs not to be monotonically decreasing - will not be affected if one relaxes this assumption, explicitly modelling different types of concession might be another useful dimension for extension. For example, Acemoglu and Robinson (2006) assume that there are two types of concession: policy concession and more equal distribution of political rights. Extending the social conflict game in this direction could be helpful in clarifying the dynamics of democratization. From empirical point of view, this paper relies on cross-country comparison. This method, can not go beyond correlation between variables and is not suitable for drawing a *causal* interpretation. More elaborate statistical frameworks and employing micro-data is helpful for answering questions regarding causal effect of income and inequality on repression.

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<sup>39</sup>For example, in response to critics made by the government of Canada regarding human rights violation in China, Zhang Junsai, China's ambassador to Canada, replied: "Give us a break. You know? Let us develop. We have done no harm to your country. We see all this improvement. You should recognize improvement and development". Cited in The Globe and Mail, Sep. 22, 2012; accessible at: <http://www.theglobeandmail.com/news/politics/china-calls-for-free-trade-deal-with-canada-within-a-decade/article4561149/>.

## Chapter 3

# Efficient Market Segmentation

### 3.1 Abstract

We study an infinite horizon duopoly with identical firms and homogeneous consumers. Firms choose price and effort while consumers care about price and quality – a noisy function of the unobserved effort level exerted by the firm. We study the tension between this moral hazard problem and the potentially positive effects on efficiency generated by competition. We show that there exists an equilibrium with market segmentation, in which only one of the firms always exerts high effort, thereby producing goods with higher expected quality. This equilibrium may be Pareto superior to the one in which both firms exert high effort.

### 3.2 Introduction

Maintaining a reputation for producing high-quality goods is important in certain markets, such as markets for experience goods. Consumers are willing to pay a premium for a higher quality good, but they can only assess the quality of a good after consuming it. In these markets, a seller benefits from being perceived as a high quality producer. For example, in the market for education parents may be willing to pay a high tuition if their child gets a high-quality education. Parents can rely on a public history: for example, on signals about the quality of previous students, such as past placement records. However, the quality of the education provided to their own child will only be available after graduation – or even several years later. Many other markets exhibit the same features, such as health care, aviation, fine dining, Internet and phone service providers, computer operating systems, smart phones, and many other service providers in general.

However, one often observes that in these markets some firms have always had a reputation for high quality, while others have always had one for lower quality, even though they may exhibit the same technology. For example, the smart phone industry has an oligopolistic market structure with Apple and Samsung as the dominant high quality producers competing with each other and also with several other smaller producers such as Nokia, HTC, LG, and Sony, whose product, while are less expensive, generally perceived to be of lower quality. In other oligopoly markets, for example

branded personal computers and internet service providers, one can also observe some sort of market segmentation based on quality (and price). In this paper we provide a theory of endogenous market segmentation and study the implication of this market structure for social welfare.

Specifically, we consider an infinite horizon model in which two firms with identical technologies face a continuum of short-lived homogeneous consumers every period. A consumer buys at most a single product per period from one of the firms. The utility of the consumer depends on the price paid and the quality of the good bought. We assume that the consumers must buy the goods before they can experience their quality, which is a noisy signal of the unobservable effort chosen by the firm. Effort can be low and costless or high, which we assume to be costly. In this setting, consumers' beliefs are valuable: the more they believe that the good will be of high quality, the higher the price that the firm is able to charge. We will focus on equilibria in which firms fully extract the surplus of the consumers. In the benchmark case of a single firm in the market, we show that no equilibrium with full-extraction exists in which the firm always exerts the costly high effort. The intuition is that if such an equilibrium existed, the consumers would believe that with probability one the firm exerts high effort, thus any bad outcome would be attributed to noise. This, in turn, would generate incentives for the firm to exert low effort, which is a contradiction.

In our model, firms' incentive for reputation building comes from two different sources. The first source stems from competition over the market share based on product quality between the two firms. Loosely speaking, if the fear of losing consumers to competitors after providing a low-quality good exceeds the costs of exerting high effort, firms might have incentives to sustain their reputation.<sup>1</sup> The second source is the possibility of tacit collusion – which enable the firms to avoid price war and maintain the premium which is necessary to cover the cost of exerting effort. Combining these two forces with unobservable effort, we show that there is an equilibrium in which goods with high expected quality are always produced. With two competing firms and when tacit collusion is possible, the consumers' behavior may discipline the firms, despite the moral hazard problem. The intuition for this is that if consumers punish low quality – which can occur even under high effort – by switching firms, this may generate the necessary incentives for firms to always exert high effort.<sup>2</sup>

Next, we show that the two aforementioned forces (competition over quality and tacit collusion over prices) might also generate equilibrium with market segmentation. Here, one firm specializes in the high-quality goods (in expectation), while the other firm produces the low expected quality good and maintains an inferior reputation. Consumers know this in equilibrium and they will only buy from the lower quality firm if they pay lower prices. We show that when cost of exerting effort is at some intermediate values and when the market base of the firm with superior reputation is large, the equilibrium with market segmentation can, in fact, Pareto dominate the equilibrium in which both firms always exert high effort. The simple intuition for this result is that the equilibrium with market segmentation avoids the replication of the fixed cost of exerting effort by the firms (which

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<sup>1</sup> A simple intuition is provided in the seminal work of Klein and Leffler (1981), who focused on equilibria in which once the firm produces low-quality goods, it is out of the market. In their case, if the firm is sufficiently patient, it may choose to never provide low-quality goods. In their model, contrary to ours, quality is not a stochastic function of effort. When it is – and if its inverse relation has full support – their intuition no longer holds; otherwise all firms would eventually be out of the market.

<sup>2</sup> Other authors have obtained similar results, showing that competition may generate incentives for firms to always exert high effort. However, those models include incomplete information, and therefore consumers do not get the high quality good (in expectation) every period. We discuss some of these models below.

hurts efficiency).

Since we study a dynamic duopoly model with imperfect information, our paper is related to the literature on reputation for quality and the literature that study strategic interaction between firms, especially tacit collusion.<sup>3</sup> In the reputation literature, our paper is most closely related to the works of Mailath and Samuelson (2001), Holmstrom (1999), Hörner (2002). These papers study the effect of market structure on firm's incentive to maintain a good reputation in the presence of moral hazard problem. They show that, through threatening the market base of firms, competition can induce firms to exert effort and invest in their reputation. Therefore, the first source of incentive for firms to exert effort in our model - the fear of losing customers to the competitor after a realized bad outcome - is similar to the mechanism suggested in these studies. Two main differences between our model and the aforementioned studies are that first, we allow for the possibility of strategic interaction between firms and second, those models include incomplete information, and therefore consumers do not get the high quality good (in expectation) every period.

The studies by Dana and Fong (2011) and Kranton (2003) also emphasize on the role of tacit collusion in providing incentive for firms to produce high quality. For example, Dana and Fong (2011) show that the possibility of tacit collusion implies that firms in oligopoly might have stronger incentive to produce high quality products compared to perfectly competitive market, and Kranton (2003) suggests that by eliminating firms' profit margin, anti-trust laws could eliminate incentive to exert effort in a duopoly. Both studies, however, focus only on symmetric equilibria in which firms' strategies (regarding their reputation) is identical, while our focus is on asymmetric equilibria and the possibility of market segmentation based on quality and reputation. It is worth mentioning that our focus on asymmetric equilibria is not purely due to theoretical ambitions and as mentioned at the beginning of this section, many oligopolistic markets of experience goods exhibit some level of segmentation based on reputation. Understanding the forces behind these structures and its welfare implication could be important for policy-makers as well as academics.

To summarize, we have two main results. First, we show that there exists a pure strategy equilibrium in which both firms always exert high effort. In contrast to most models of dynamic moral hazard, ours does not include incomplete information. This implies that in this high effort equilibrium, consumers get the good with the highest expected quality every period. Second, we show that, under a range of parameters, there is also an equilibrium with market segmentation. Although consumers are homogeneous and firms are identical, there is an equilibrium in which one firm produces a good with high expected quality and gets a higher profit, whereas the other firm produces a lower expected quality good. This may Pareto dominate the high-effort equilibrium.

The paper is organized as follows. In Section 2, we describe the model and the equilibrium concept. Section 3 studies the market structure. Section 4 presents the comparison of equilibria in terms of efficiency. Section 5 concludes.

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<sup>3</sup>Bar-Isaac (2008) and Mailath and Samuelson (2006) provide an excellent survey of reputation literature, and Dana and Fong (2001) and Ivaldi et al. (2007) survey the literature on tacit collusion.

### 3.3 Model

Assume that two long-lived firms interact every period in an infinite horizon economy. Every period there is a mass of short-lived consumers that we normalize to one. Consumers do not have strategic incentives: they are assumed to be too small to affect the outcomes. Each consumer buys at most 1 good from one of the two firms. The consumer's utility depends on the quality of the good that he bought and on the price that he paid. The quality of the good can be either good or bad, we denote realized quality by  $\omega \in \{g, b\}$ . Consumers are risk neutral, identical and we assume a separable utility function. If the quality outcome is  $g$ , the consumer's utility at that period is assumed to be  $1 - p$ , where  $p$  is the price paid by the consumer, while if the outcome is  $b$ , his utility is assumed to be  $-p$ . Similarly to Mailath and Samuelson (2001), we will focus on equilibria in which the consumers pay their expected payoff from the quality on-equilibrium path.

Every period each firm is to choose a price,  $p \in [0, \infty)$ , and an effort level that can be low or high:  $e \in \{L, H\}$ . To exert high effort the firm must pay a fixed cost  $c > 0$ , while we normalize the cost of low effort to zero. We assume that besides the fixed cost of high effort, there are no extra costs in producing.<sup>4</sup> Firms discount the future using a discount factor  $\delta < 1$ . We assume that quality is not persistent: the quality of the good depends only on the current effort level, according to the probabilities described in the table below:

	$g$	$b$
$H$	$\alpha$	$1 - \alpha$
$L$	$\beta$	$1 - \beta$

where  $\alpha$  and  $\beta$  are independent random variables with  $1 \geq \alpha > \beta > 0$ , so that high quality goods are more likely under high effort level.<sup>5</sup> We also assume that  $\alpha - \beta > 2c$  so that two firms exerting effort is Pareto superior to the outcome in which both firms exert low effort. The realization of the quality is observed by everyone in the economy at the end of each period. A public history at time  $\tau$  is denoted by  $h_\tau = \{(\omega_{1,t}, \omega_{2,t}, p_{1,t}, p_{2,t})\}_{t=1}^\tau$ , and the set of all public histories in time period  $\tau$  is  $\mathcal{H}_\tau$ . Let  $\{\mathcal{H}_t\}_{t=1}^\infty$  be the set of all public histories.

Define a public strategy profile to be a strategy profile in which each player's actions in each period depend on the public history only. A behavioural public strategy of firm  $i$  at time  $t$  is defined as:

$$\sigma_{i,t} : \mathcal{H}_t \rightarrow \{H, L\} \times [0, \infty). \quad (3.1)$$

The strategy for each consumer is to choose a probability with which he buys from firm  $i$ , firm  $j$  or neither. If he doesn't buy from any of the two firms, his utility is assumed to be zero. His behavioural strategy is:

$$s_t : \mathcal{H}_t \times [0, \infty)^2 \rightarrow \{(s_i, s_j) \in [0, 1]^2 : s_i + s_j \leq 1\}. \quad (3.2)$$

<sup>4</sup> The assumption that the cost of exerting effort is fixed is common in the literature. Allowing for a variable cost leads to a richer dynamics but does not alter the equilibria and the comparative dynamics.

<sup>5</sup>The independence assumption implies that there is no externalities between firms with regard to effort, i.e., one firm exerting effort to produce high quality does not increase the chance of producing high quality products while exerting low effort for the other firm.

Let  $\sigma$  be the public strategy profile, which is a strategy for each firm, and each consumer. There are multiple Nash equilibria in this game, where at any equilibrium, firms maximize profits, and consumers maximize their utilities. We will concentrate on public equilibria.

**Definition 1** [*Perfect Public Equilibrium*]

A perfect public equilibrium is a public strategy profile  $\sigma$  such that for each  $t$  and every history  $h_t$ ,  $\sigma$  prescribes a Nash equilibrium in the infinitely repeated game starting at stage  $t$  after history  $h_t$ .

Our focus on public equilibria makes the analysis significantly easier. If, instead, consumers experience a private signal about firm's product quality, they might not be able to coordinate punishment when the realized quality is bad. Further, in this situation each consumer have to draw statistical inferences regarding the history of other players private signal to be able to estimate what they are going to do. Even if we focus on very simple strategies, this inference could become very complicated over time. Besides, private monitoring results in the equilibria to not to have a compact recursive structure. However, as shown in Compte (1998) and Kandori and Matsushima (1998), if one allows players to truthfully communicate their private signal, the equilibrium, which depends on the publicly observable messages, becomes very similar to the public monitoring case. In this spirit, Hörner (2002), in a model in which consumers privately observe the quality of products but are able to coordinate their actions through observing the consumer base of each firms, obtains an equilibrium concept very similar to ours.

The belief that the consumer has at the beginning of each period that the quality of the good produced by firm  $i$  is good, following history  $h_t$ , the prices  $p_i$  and  $p_j$  and given the strategy profile  $\sigma$ , will be denoted by  $\gamma_i(h_t, \sigma)$ .

In any Nash equilibrium, the demand of each consumer  $l$  for the good of firm  $i$  must satisfy the following conditions. First, if

$$\begin{aligned} \gamma_i(h_t, \sigma) - p_i &> \gamma_j(h_t, \sigma) - p_j, \text{ and} \\ \gamma_i(h_t, \sigma) - p_i &\geq 0, \end{aligned} \quad (3.3a)$$

then  $s_{l,i} = 1$  and  $s_{l,j} = 0$ ; while if

$$0 > \max_{k \in \{i,j\}} \gamma_k(h_t, \sigma) - p_k, \quad (3.3b)$$

then  $s_{l,i} = s_{l,j} = 0$ . Finally, if

$$\gamma_i(h_t, \sigma) - p_i = \gamma_j(h_t, \sigma) - p_j \geq 0, \quad (3.3c)$$

then  $s_{l,i} + s_{l,j} = 1$ . Denote  $q_i$  to be the total expected quantity bought from firm  $i$ :

$$q_i = \int_0^1 s_{l,i}(h_t, p_1, p_2) dl. \quad (3.4)$$

Consider first the case of a single firm in the economy. If we restrict attention to equilibria in which consumers pay their expected utility, as in Mailath and Samuelson (2001), there is no equilibria in which the firm exerts high effort every period. If at every period the consumers expect that the firm exerts high effort, then  $\gamma(h_t) = \alpha, \forall h_t \in \mathcal{H}_t$ . Then, the firm charges  $p = \alpha$  and all consumers buy.



The firms' expected continuation payoff of following this strategy profile is  $V(\sigma) = \frac{\alpha - c}{1 - \delta}$ . While if the firm deviates at a particular period, the expected payoff of deviation is  $V(\sigma') = \alpha + \delta \frac{\alpha - c}{1 - \delta}$  which is always higher than  $V(\sigma)$ . Therefore, high effort every period cannot be an equilibrium if the market has a single firm. We state this result below.

**Proposition 1** [*Single Firm: No high effort equilibrium*]

*With a single firm, there is no Nash equilibrium with full extraction in which the firm produces high quality with probability one every period.*

### 3.4 Market Structure

From now on we will consider the case of a market with two firms. The firms are ex-ante identical in costs and quality technology. However, they have clearly identifiable brands.

First, note that for any discount factor, there is always an equilibrium in which both firms always exert low effort. In particular, for myopic firms, the problem becomes simply a repetition of the static Bertrand model. For sufficiently patient firms, however, tacit collusion on a price higher than marginal cost is possible. This slightly more general result is shown below.

**Lemma 1** *For any price small enough,  $\forall \bar{p} \in [0, \beta]$ , there exists a perfect public equilibrium  $\sigma$  in which both firms always exert low effort and charge price  $p = \bar{p}$ , with the consumer beliefs being  $\gamma(h_t) = \beta$ , for any  $h_t \in \{\mathcal{H}_t\}_{t=0}^\infty$ , and consumer demand satisfying (3.3a), (3.3b), and (3.3c).*

**Proof.** Consider the strategy profile  $\sigma^*$ , in which firms exert low effort regardless of the history and charge price  $p = 0$  every period. Half of the unit mass of consumers buy from firm 1 and half buys from firm 2.  $\sigma^*$  is a perfect public equilibrium, since firms do not have an incentive to deviate: higher price leads to zero profit, as under  $\sigma^*$  any high quality will be interpreted by consumers as an outcome of low effort, so there are no incentives to exert high effort. Each consumer gets a payoff of  $U = \beta$ , regardless of the firm that he buys from. The expected payoff for each firm under  $\sigma^*$  is  $V = 0$ .

Now consider the following strategy profile: always exert low effort, regardless of the history, and charge  $p = \bar{p}$  following any history in which both firms have always charged  $\bar{p}$ . If the posted price has ever been different than  $\bar{p}$ , then switch to  $\sigma^*$  thereafter. Then,  $\sigma$  is an equilibrium if:

$$V(\sigma) = \sum_{t=1}^{\infty} \delta^{t-1} q(t) \bar{p} \geq \bar{p}.$$

this happens if and only if the equilibrium sequence  $\{q(t)\}_{t=1}^\infty$  is such that  $\sum_{t=1}^{\infty} \delta^{t-1} q(t) \geq 1$ . In particular, consider any stationary sequence in which  $q(t) = \bar{q} \in (0, 1)$ , such that  $\delta \geq \bar{q} \geq 1 - \delta$ . ■

For sufficiently patient firms and for a sufficiently low cost of exerting high effort, there is also an equilibrium in which both firms exert high effort every period. In this equilibrium, consumers get the good with highest expected quality every period.

**Proposition 2** [*High Effort Equilibrium*]

*For any  $\alpha$ , and  $\beta$  there exists a discount factor  $\bar{\delta} < 1$  and a cost  $\bar{c} > 0$  such that for any  $\delta > \bar{\delta}$  and*

any  $\bar{c} > c \geq 0$ , there exists a perfect public equilibrium in which both firms exert high effort every period and charge a price  $p = \alpha$ , on the equilibrium path.

**Proof.** Consider the following strategy for each firm. Exert high effort and charge  $p = \alpha$  every period as long as all previous periods have been such that both firms have always charged  $p = \alpha$ . If at any history at least one of the two firms has charged a price  $p \neq \alpha$ , then switch to  $\sigma^*$  described in lemma 1 above. Every period, consumers' expected utility is  $U = \alpha - p = 0$ . Given that the quality of the product produced by each firm is assumed to be a public signal, consumers can coordinate the behaviour on the past outcomes. Consider a strategy profile in which the quantity consumed from each of the two firms is a function of the previous period's observed quality. There are four possible outcomes every stage game  $\xi \in \{gg, gb, bg, bb\}$ , where the first term of each pair refers to firm 1's quality and the second term is firm 2's quality. Consider a symmetric strategy profile for consumers such that they 'punish' the firms that have just produced a worse outcome than their competitors:

$$q_1^{gb} = q_2^{bg} > q_i^{gg} = q_i^{bb} > q_1^{bg} = q_2^{gb}, \quad i = 1, 2, \quad (3.5)$$

with  $q_1^\xi + q_2^\xi = 1, \forall \xi$ .

Then, in equilibrium, the expected payoff of the firm depends solely on the previous state of the market. Here we state everything for firm 1, but both firms are identical.

$$V_\xi = q_1^\xi \alpha - c + \delta \left( \alpha^2 V_{gg} + \alpha(1-\alpha) V_{gb} + \alpha(1-\alpha) V_{bg} + (1-\alpha)^2 V_{bb} \right). \quad (3.6)$$

Note that the expected continuation payoff for each  $\xi$  differs only in the current payoff, which is given by the revenue. Given the restrictions in (3.5), we have that:  $V_{gb} > V_{gg} = V_{bb} > V_{bg}$ . Solving the system of four equations (3.6), we have that:

$$V_\xi = q_1^\xi \alpha + \frac{\delta}{1-\delta} \left( \alpha^2 q_1^{gg} + \alpha(1-\alpha) q_1^{gb} + \alpha(1-\alpha) q_1^{bg} + (1-\alpha)^2 q_1^{bb} \right) \alpha - \frac{c}{1-\delta}. \quad (3.7)$$

Suppose that a firm decides to deviate and exert low effort. This deviation will imply an immediate gain to the firm that deviates, since it is not paying the fixed cost of high effort. However, the deviation will affect the probability distribution over quality levels, which in turn implies less demand (and thus less revenue) for next period. The expected continuation payoff of such deviation when the market is at state  $\xi$  is denoted  $V'_\xi$  and given by:

$$V'_\xi = q_1^\xi \alpha + \delta (\beta \alpha V_{gg} + \beta(1-\alpha) V_{gb} + \alpha(1-\beta) V_{bg} + (1-\beta)(1-\alpha) V_{bb}). \quad (3.8)$$

which, similar to equation (6) can be re-written as:

$$V'_\xi = q_1^\xi \alpha + \frac{\delta}{1-\delta} \left( \beta \alpha q_1^{gg} + \beta(1-\alpha) q_1^{gb} + (1-\beta) \alpha q_1^{bg} + (1-\beta)(1-\alpha) q_1^{bb} \right) \alpha. \quad (3.9)$$

Such deviation will not be worth if  $V_\xi \geq V'_\xi, \forall \xi$ , which using (3.7) and (3.9) is equivalent to:

$$\alpha \left( q_1^{gg} - q_1^{bg} \right) + (1-\alpha) \left( q_1^{gb} - q_1^{bb} \right) \geq \frac{c}{\delta \alpha (\alpha - \beta)} \quad (3.10)$$

Given that both terms in the l.h.s. of (3.10) are positive, there must exist a  $\bar{c}$  small enough, such that for any  $c < \bar{c}$ , there is a perfect public equilibrium that satisfies (3.10). If (3.10) holds, firms don't find it profitable to exert low effort even though this would not change their brand value.

Fear of losing customers to the competitor, however, is not enough per se to induce firms to exert effort. This is because a price war between the two firms could eliminate the margin which is required to cover the cost of exerting effort. Therefore, to maintain a good reputation on-equilibrium, firms should be able to tacitly collude, which requires them to be relatively patient. Assume that if one the firms charges a price lower than  $\alpha$  to capture the market, then both firms will switch to  $\sigma^*$  thereafter. Thus, if the firm is sufficiently patient it will not find it profitable to do so. In particular, consider a deviation in which a firm charges a price that is slightly smaller than  $\alpha$ , and does not exert high effort that period. In the current period all consumers will buy from the deviating firm (lower prices, but same expected quality, given that their beliefs are the equilibrium beliefs). Both firms will revert to  $\sigma^*$  and earn a 0 continuation profit. This deviation will not be profitable if and only if:

$$\alpha \left(1 - q_1^\xi\right) \leq -c + \delta \left(\alpha^2 V_{gg} + \alpha(1 - \alpha) V_{gb} + \alpha(1 - \alpha) V_{bg} + (1 - \alpha)^2 V_{bb}\right).$$

For  $c$  sufficiently small, this condition is satisfied, for  $\delta$  sufficiently large, if we consider only equilibria in which

$$\left(\alpha^2 q_1^{gg} + \alpha(1 - \alpha) q_1^{gb} + \alpha(1 - \alpha) q_1^{bg} + (1 - \alpha)^2 q_1^{bb}\right) \alpha > c.$$

One example in which this condition holds is if  $q_1^{gg} = q_1^{bb} = \frac{1}{2}$ ;  $q_1^{gb} = 1$ ,  $q_1^{bg} = 0$  and  $\alpha(\alpha - \beta) > 2c$ . These conditions together with a sufficiently large discount factor  $\delta$ , will be such that (3.10) holds. This proposed sequence of  $\{q_t(\xi)\}_t$ , together with the proposed strategy for the firm form a perfect public equilibrium of this game. ■

In the equilibrium described above, firms exert high effort every period and charge  $p = \alpha$ . All consumers purchase the good every period,  $q_1^\xi + q_2^\xi = 1$ ,  $\forall \xi$ , and the expected quality of the goods that they buy is always the highest possible:  $\gamma = \alpha$ .

The market structure that arises in the equilibrium proposed above is one in which both firms are always exerting high effort. There can be, however, an equilibrium in the same market (i.e. with the same parameters) in which there is an endogenous market segmentation. In this equilibrium, one firm charges a high price and exerts high effort, while the other firm exerts low effort and charges a lower price. For such an equilibrium to exist, both firms must have incentives to follow the specified strategies. For the high effort firm, there must be an incentive for not exerting low effort, which is unobservable. This is the same idea as the previous proposition: the consumers must discipline the firms, through demand shifts after bad draws of outputs. For this to be true, a necessary condition is that the cost is not “too large” as we showed previously. On the other hand, if the punishment for low output is high and the cost is low enough, the firm exerting low effort may want to deviate and exert high effort, so the cost must not be “too low” either. Formally, for every discount factor, there exists a range of costs such that if the costs fall in the range, then an equilibrium with market segmentation exists. Moreover, if the cost falls outside of this range, then it is not possible to sustain such equilibrium with 1-memory strategies, i.e. strategies that depend only on last period’s market outcome  $\xi$ .

**Proposition 3 [Market Segmentation]**

Fix any parameters  $\alpha > \beta > 0$ , then, there exists a discount factor  $\bar{\delta} < 1$  and an interval  $[\underline{c}, \bar{c}]$  such

that for  $\delta > \bar{\delta}$  and  $c \in [\underline{c}, \bar{c}]$  a perfect public equilibrium exists in which at every period, one firm exerts high effort while the other firm exerts low effort:  $\gamma_1(h_t) = \alpha$  and  $\gamma_2(h_t) = \beta$  for every  $h_t \in \mathcal{H}_t$ .

**Proof.** Consider the strategy profile in which firm 1 exerts high effort and firm 2 exerts low effort and they tacitly collude on prices  $p_1 = \alpha$  and  $p_2 = \beta$ . After a history in which at least one firm has charged a price different than  $\alpha$  or  $\beta$ , then both firms switch to  $\sigma^*$ , i.e. exert low effort and charge a price of 0. There exists a discount factor  $\bar{\delta} < 1$  such that for any  $\delta > \bar{\delta}$ , neither of the two firms want to charge a different price.<sup>6</sup> We omit the argument, since it is very close to the proof of lemma 1.

We will restrict attention to 1-memory equilibria in which the consumers' behaviour are conditioned on the previous outcome of the market and follow (3.5). Consider the potential deviations of each firm on the effort level and note that these deviations will be undetected—since any quality outcome is consistent with the proposed perfect public equilibrium. On the equilibrium path, the expected continuation payoff of firm 1 is:

$$V_1(\xi) = q_1^\xi \alpha - c + \delta (\alpha \beta V_1(gg) + \alpha (1 - \beta) V_1(gb) + (1 - \alpha) \beta V_1(bg) + (1 - \alpha) (1 - \beta) V_1(bb)).$$

Define

$$W = \frac{\alpha}{1 - \delta} \left( \alpha \beta q_1^{gg} + \alpha (1 - \beta) q_1^{gb} + (1 - \alpha) \beta q_1^{bg} + (1 - \alpha) (1 - \beta) q_1^{bb} \right) - \frac{c}{1 - \delta},$$

then we can write:

$$V_1(\xi) = q_1^\xi \alpha - c + \delta W.$$

A deviation to low effort implies a payoff of:

$$V_1'(\xi) = q_1^\xi \alpha + \delta \alpha \left( \beta \beta q_1^{gg} + \beta (1 - \beta) q_1^{gb} + (1 - \beta) \beta q_1^{bg} + (1 - \beta) (1 - \beta) q_1^{bb} \right) - \delta c + \delta^2 W.$$

Thus, such an equilibrium will exist only if

$$V_1(\xi) \geq V_1'(\xi),$$

which after some algebra gives us:

$$\beta \left( q_1^{gg} - q_1^{bg} \right) + (1 - \beta) \left( q_1^{gb} - q_1^{bb} \right) \geq \frac{c}{\delta \alpha (\alpha - \beta)}. \quad (3.11)$$

The same argument from proposition (2) applies here.

It should also be the case that the firm exerting low effort does not have an incentive to deviate. Its expected continuation profit is given by:

$$V_2(\xi) = q_2^\xi \beta + \delta (\alpha \beta V_2(gg) + \alpha (1 - \beta) V_2(gb) + (1 - \alpha) \beta V_2(bg) + (1 - \alpha) (1 - \beta) V_2(bb)).$$

Solving the system of equations, gives us:

$$V_2(\xi) = q_2^\xi \beta + \delta \frac{\beta}{1 - \delta} \left( \alpha \beta q_2^{gg} + \alpha (1 - \beta) q_2^{gb} + (1 - \alpha) \beta q_2^{bg} + (1 - \alpha) (1 - \beta) q_2^{bb} \right),$$

<sup>6</sup> Note that we do not need to consider a joint deviation in price and quality, since, given the punishment strategy  $\sigma^*$ , covering the cost of high effort after a deviation in price is not possible.

whereas deviating to a high effort implies a payoff of:

$$V_2'(\xi) = q_2^\xi \beta - c + \delta (\alpha^2 V_2(gg) + \alpha(1-\alpha) V_2(gb) + (1-\alpha)\alpha V_2(bg) + (1-\alpha)(1-\alpha) V_2(bb)),$$

or, solving for the system of equations:

$$\begin{aligned} V_2'(\xi) &= q_2^\xi \beta - c + \delta \beta \left( \alpha^2 q_2^{gg} + \alpha(1-\alpha) q_2^{gb} + (1-\alpha)\alpha q_2^{bg} + (1-\alpha)(1-\alpha) q_2^{bb} \right) \\ &\quad + \delta^2 \frac{\beta}{1-\delta} \left( \alpha\beta q_2^{gg} + \alpha(1-\beta) q_2^{gb} + (1-\alpha)\beta q_2^{bg} + (1-\alpha)(1-\beta) q_2^{bb} \right). \end{aligned}$$

Thus, a necessary condition for equilibrium is that  $V_2(\xi) \geq V_2'(\xi)$ , which will happen if and only if:

$$\alpha \left( q_2^{gg} - q_2^{gb} \right) + (1-\alpha) \left( q_2^{bg} - q_2^{bb} \right) \leq \frac{c}{(\alpha-\beta)\delta\beta}. \quad (3.12)$$

If we concentrate on equilibria in which  $q_1^\xi + q_2^\xi = 1, \forall \xi$ , then the above condition is equivalent to:

$$\alpha \left( q_1^{gb} - q_1^{gg} \right) + (1-\alpha) \left( q_1^{bb} - q_1^{bg} \right) \leq \frac{c}{(\alpha-\beta)\delta\beta}. \quad (3.13)$$

In the example given above, for  $q_1^{gg} = q_1^{bb} = \frac{1}{2}$  and  $q_1^{gb} = 1 - q_1^{bg} = 1$ , we have that:

$$\frac{1}{2} \leq \frac{c}{(\alpha-\beta)\delta\beta} \Rightarrow c \geq \frac{(\alpha-\beta)\delta\beta}{2}.$$

whereas for the second condition:

$$\frac{1}{2} \geq \frac{c}{(\alpha-\beta)\delta\alpha} \Rightarrow c \leq \frac{(\alpha-\beta)\delta\alpha}{2}$$

Thus, for such an equilibrium to exist, it is sufficient to have that:

$$c \in \left[ \frac{(\alpha-\beta)\delta\beta}{2}, \frac{(\alpha-\beta)\delta\alpha}{2} \right].$$

■

### 3.5 Efficiency

To look at efficient outcomes, note first that the consumer surplus in the high effort equilibrium is  $U = \alpha - p = 0$ , whereas in the market segmentation equilibrium it is:  $U = \alpha - p_H = \beta - p_L = 0$ ; where the equality comes from the fact that the consumer is free to choose from which firm to buy from. Therefore, the equilibrium with market segmentation will Pareto dominate an equilibrium with both firms exerting high effort if the total surplus of the firms is higher. Let  $\Pi_1^{HL}$  and  $\Pi_2^{HL}$  denote the profit of the firm 1 and 2 in the market segmentation equilibrium, respectively. Also, let  $\Pi_2^{HH}$  and  $\Pi_1^{HH}$  be the firms' profit in the high effort equilibrium. We are looking for conditions under which the firms' surplus in the market segmentation case is higher than in the high effort equilibrium:

$$\begin{aligned} \Pi_1^{HL} + \Pi_2^{HL} &= \alpha\beta (\alpha q_1^{gg} + \beta q_2^{gg}) + \alpha(1-\beta) (\alpha q_1^{gb} + \beta q_2^{gb}) + (1-\alpha)\beta (\alpha q_1^{bg} + \beta q_2^{bg}) + \\ &\quad + (1-\alpha)(1-\beta) (\alpha q_1^{bb} + \beta q_2^{bb}) - c \\ &> \Pi_1^{HH} + \Pi_2^{HH} &= \alpha (\alpha^2 + \alpha(1-\alpha) + (1-\alpha)\alpha + (1-\alpha)^2) - 2c. \end{aligned}$$

this will happen if and only if:

$$\begin{aligned}
& \alpha\beta (\alpha q_1^{gg} + \beta (1 - q_1^{gg})) + \alpha (1 - \beta) (\alpha q_1^{gb} + \beta (1 - q_1^{gb})) + \\
& + (1 - \alpha) \beta (\alpha q_1^{bg} + \beta (1 - q_1^{bg})) + (1 - \alpha) (1 - \beta) (\alpha q_1^{bb} + \beta (1 - q_1^{bb})) \\
= & \beta + (\alpha - \beta) (\alpha\beta q_1^{gg} + \alpha (1 - \beta) q_1^{gb} + (1 - \alpha) \beta q_1^{bg} + (1 - \alpha) (1 - \beta) q_1^{bb}) \\
> & \alpha - c.
\end{aligned} \tag{3.14}$$

Define  $\theta$  to be the per period expected demand of firm 1. Formally:

$$\theta \equiv \alpha\beta q_1^{gg} + \alpha (1 - \beta) q_1^{gb} + (1 - \alpha) \beta q_1^{bg} + (1 - \alpha) (1 - \beta) q_1^{bb}.$$

Again, we will restrict attention to 1-memory perfect public equilibria, i.e. Nash equilibria in which all strategies depend only in the previous period's public state  $\xi$ . Then, using (3.14) we get that an equilibrium with market segmentation will be Pareto superior to the equilibrium in which both firms exert high effort if and only if:

$$\theta > \hat{\theta} = 1 - \frac{c}{\alpha - \beta}. \tag{3.15}$$

Note that as  $\alpha - \beta$  decreases, or as the relative efficiency of exerting effort falls, it becomes less likely that the market segmentation outcome Pareto dominates the high-effort outcome. This is because, relatively speaking, a fall in  $\alpha - \beta$  corresponds to a diminishing demand for the product of the firm with good reputation. On the other hand, as long as  $c \in \left[ \frac{(\alpha - \beta)\delta\beta}{2}, \frac{(\alpha - \beta)\delta\alpha}{2} \right]$ , an increase in  $c$  increases the likelihood that  $\theta > \hat{\theta}$ . This is because at intermediate range, the replication of the fixed cost in the high-effort equilibrium makes this equilibrium relatively less desirable. The intuition for this result is that, because of the fixed costs of effort, the efficient outcome would be one in which only one firm serves the entire market and exerts high effort every period. We have seen that this cannot be an equilibrium, though. Therefore, the equilibria in which both firms serve the market, but with high market concentration, i.e. with most consumers buying from the high effort firm, Pareto dominates the high effort equilibrium.

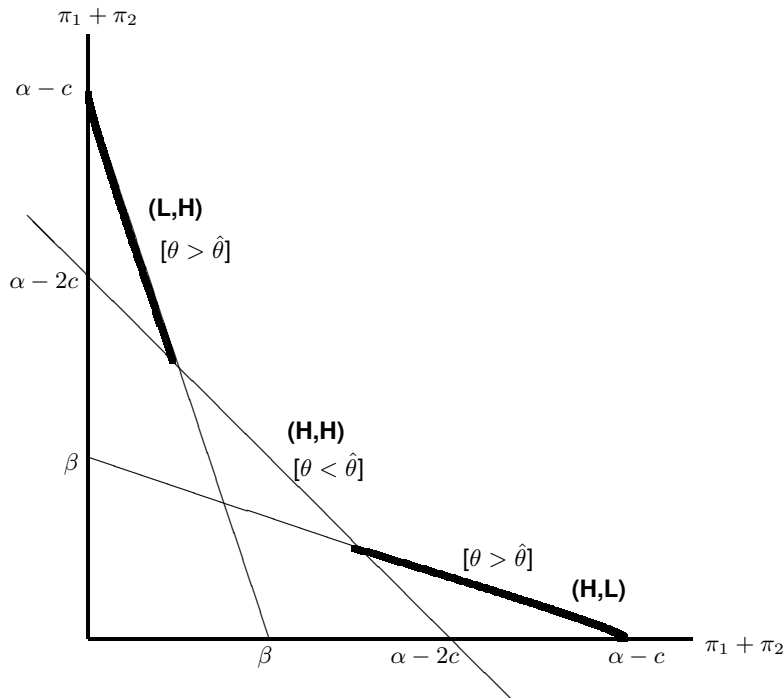
Figure 1 depicts the Pareto frontier from the pure strategy equilibria that we have considered in this paper and graphically presents the aforementioned argument. Each axis represents the sum per period expected profit of firms. The two lines labelled (H,L) and (L,H) represent the Pareto frontier of the equilibrium with market segmentation, and the line labelled (H,H) corresponds to the Pareto frontier of the high-effort equilibrium. As this figure suggests, the Pareto frontier of the market segmentation equilibrium is above the Pareto frontier of the high effort equilibrium when the market base of the firm with good reputation is relatively high (the parts highlighted by the thick line). These areas correspond to the situation where  $\theta > \hat{\theta}$ .

However, the existence of the equilibria with high level of market segmentation depends on the parameters as was shown in proposition 3. A formal derivation of the sufficient condition for the existence and the efficiency of the market segmentation equilibrium for a general case of  $q_1^{gb} = 1 - q_1^{bg} = q_2^{bg} = 1 - q_2^{gb} = x \in (0, 1]$  is presented in the appendix. Here we just introduce the results.

**Proposition 4 [Efficient Market Segmentation]**

If  $c \in [\underline{c}, \min\{\bar{c}, \hat{c}\}]$ , where  $\underline{c}$ ,  $\bar{c}$ , and  $\hat{c}$  are the threshold levels of  $c$  in inequalities (3.11), (3.13),

Figure 3.1: Pareto Frontier



and (3.15), respectively, then the market segmentation equilibrium exists and is Pareto superior compared to the high effort equilibrium.

### 3.6 Conclusion

In many oligopolistic markets of experience goods, such as health care, aviation, fine dining, Internet and phone service providers, computer operating systems, smart phones, and education, one often observes that some firms have always had a reputation for high quality, while others have always had one for lower quality, even though they may exhibit the same technology. In this paper we present a dynamic duopoly model with imperfect public monitoring to study endogenous market segmentation and its implications for social welfare.

In particular, we focused on the tension between the negative effects of moral hazard on reputation and the positive effects of competition over quality and the possibility of tacit collusion over price on reputation incentives. First, we showed that if the cost of effort is not prohibitively large, there exists an equilibrium in which both firms exert high effort every period. This equilibrium Pareto dominates the equilibrium in which firms never exert high effort. Thus, competition can generate the necessary incentives for reputation. Although this first result is not entirely new, we have shown a different channel through which it can occur. Buyers are always indifferent, a result from the Bertrand competition between the two firms, and can punish low quality by switching firms.

Most importantly, our main result is to show that for a particular range of parameters there is also an equilibrium in which one firm specializes in high expected quality goods and the other firm specializes in low expected quality goods. This equilibrium Pareto dominates the equilibrium in which

both firms exert high effort when the cost of exerting effort is at some intermediate range and when the market base of the firm with good reputation is relatively large.

In general, our result supports the view that competition is beneficial for efficiency, even (or specially) if it implies that one firm is very small and specializes in low-quality goods.

## Appendix

In this appendix, we will show the necessary conditions for existence of symmetric 1-memory perfect public equilibria with high level of market segmentation. The reason why this equilibria can only exist on a certain range of parameters is that the demand for each firm must exhibit some variance in order for the strategy profile to be sequentially rational for both firms. In other words, the high effort firm must be punished with a lower demand after a bad quality outcome, but at the same time, if the punishment is too harsh, it means that part of the time there is a high demand for the low effort firm, which hurts efficiency.

In particular, we are looking for strategies in which inequalities (11), (13), and (15) hold simultaneously. We will concentrate on symmetric 1-memory perfect public equilibria, i.e. when  $q_i^{gg} = q_i^{bb} = \frac{1}{2}$ ,  $i = 1, 2$  and  $q_1^{gb} = 1 - q_1^{bg} = q_2^{bg} = 1 - q_2^{gb} = x$ . Then inequalities (11) and (13) can be written as:

$$\begin{aligned} \beta \left( \frac{1}{2} - (1-x) \right) + (1-\beta) \left( x - \frac{1}{2} \right) &\geq \frac{c}{\delta\alpha(\alpha-\beta)} \\ \alpha \left( x - \frac{1}{2} \right) + (1-\alpha) \left( \frac{1}{2} - (1-x) \right) &\leq \frac{c}{(\alpha-\beta)\delta\beta} \end{aligned}$$

respectively, and We can re-write these conditions as:

$$\frac{1}{2} + \frac{c}{(\alpha-\beta)\delta\beta} \geq x \geq \frac{1}{2} + \frac{c}{\delta\alpha(\alpha-\beta)}, \quad (3.16)$$

thus, a necessary condition for this symmetric 1-memory strategy to be an equilibrium is:

$$c < \frac{\delta\alpha(\alpha-\beta)}{2}. \quad (3.17)$$

Using symmetric 1-memory strategies, we have that the level of market segmentation  $\gamma$  is given by:

$$\theta = \frac{\alpha\beta + (1-\alpha)(1-\beta)}{2} + \alpha(1-\beta)x + (1-\alpha)\beta(1-x).$$

Therefore we can write:

$$\begin{aligned} \theta &= \frac{\alpha\beta + (1-\alpha)(1-\beta)}{2} + \alpha(1-\beta)x + (1-\alpha)\beta(1-x) \\ &\geq \frac{\alpha\beta + (1-\alpha)(1-\beta)}{2} + \alpha(1-\beta) \left( \frac{1}{2} + \frac{c}{(\alpha-\beta)\delta\alpha} \right) + (1-\alpha)\beta \left( 1 - \frac{1}{2} - \frac{c}{\delta\alpha(\alpha-\beta)} \right) \\ &= \frac{1}{2} + \frac{c}{\alpha(\alpha-\beta)\delta} (\alpha(1-\beta) - \beta(1-\alpha)) \\ &= \frac{1}{2} + \frac{c}{\alpha\delta}. \end{aligned}$$

This level of market segmentation will be Pareto superior to the high effort equilibrium if:

$$\frac{1}{2} + \frac{c}{\alpha\delta} \geq \frac{\alpha - \beta - c}{\alpha - \beta},$$



which will be true if and only if:

$$\begin{aligned}(\alpha - \beta) \alpha \delta + 2c(\alpha - \beta) &\geq 2\alpha \delta (\alpha - \beta - c), \\ 2c(\alpha - \beta + \alpha \delta) &\geq \alpha \delta (\alpha - \beta).\end{aligned}$$

Thus, a sufficient condition for a 1-memory perfect equilibrium that Pareto dominates a high effort equilibrium is:

$$c \geq \frac{\alpha \delta (\alpha - \beta)}{2(\alpha - \beta + \alpha \delta)}. \quad (3.18)$$

Therefore, a symmetric strategy profile described above will be an equilibrium if and only if it satisfies (3.16) and the parameters are such that (3.17) and (3.18) hold at the same time.

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