“Essays on Institutions and Economic Growth”

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Country Size and the Rule of Law: Resuscitating Montesquieu

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Abstract

The political impact of country size has been a frequently discussed issue in social science. In accordance with the general hypothesis of Montesquieu, this paper demonstrates that there is a robust negative relationship between the size of country territory and a measure of the rule of law for a large cross-section of countries. We outline a model featuring two main reasons for this regularity; firstly that institutional quality often has the character of a local public good that is imperfectly spread across space from the capital to the hinterland, and secondly that a large territory usually is accompanied by valuable rents that tend to distort property rights institutions. Our empirical analysis further shows some evidence that whether the capital is centrally or peripherally located within the country matters for the average level of rule of law.

Keywords: country size, rule of law, institutions, development, Montesquieu.

JEL Codes: N40, N50, P33.

"It is in the nature of a republic that it should have a small territory; without that, it could scarcely exist. In a large republic, there are large fortunes, and consequently little moderation of spirit...

In a large republic, the common good is sacrificed to a thousand considerations; it is subordinated to various exceptions; it depends on accidents. In a small republic, the public good is more strongly felt, better known, and closer to each citizen..."

(From *The Spirit of Laws*, C.L. Montesquieu, 1750, Book VIII)

1 Introduction

We demonstrate that there is a robust negative relationship between the size of country territory and the strength of rule of law for a large cross-section of

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countries. We also show that the internal location of the capital matters for the geographical spreading of institutions. In the spirit of Montesquieu, we argue that there are two basic reasons for these results; firstly that large countries tend to be endowed with sizeable potential rents that distort the incentives of the regime, and secondly that the rule of law has the character of a local public good that is imperfectly broadcast from the country capital to the hinterland.

The importance of country size for social development has been a topic among political philosophers for centuries. Both Plato and Aristotle preceded Montesquieu arguing that small nations like the Greek city states were naturally superior to larger entities and that a country's entire territory should not be larger than that it could be surveyed from a hill. Likewise, Rousseau later claimed that small states prosper "...simply because they are small, because all their citizens know each other and keep an eye on each other, and because their rulers can see for themselves the harm that is being done and the good that is theirs to do..." (Rousseau, quoted in Rose, 2005).

The opposite argument, that the diversity of preferences and the effects of fractionalization are more easily handled within large countries, was proposed by both David Hume and James Madison.[1] Later influential works like Dahl and Tufte (1973) and Alesina and Spolaore (2003) have tended to think of the problem as encompassing a trade-off where small countries have advantages in terms of democratic participation and preference homogeneity, whereas smallness on the other hand implies higher per capita costs of non-rival public goods, a small internal market, and that small countries easily might be partitioned or swallowed by larger countries with a greater military capacity. The latter argument appears to have been particularly relevant for the European continent (Tilly, 1990).

Within the economics discipline, the relationship between country size and economic performance has not rendered a lot of attention. Early endogenous growth models like Romer (1990) and Aghion and Howitt (1992) included a prediction that larger countries should grow faster because they had a larger pool of potential innovators. On the whole, these early models did not receive strong empirical support.[2] Alesina et al (1998) show that large countries tend to have large governments and that they are less open to trade than smaller countries. Using the level of the population as the measure of country size, Rose (2005) fails to find any systematic effect of size on a range of institutional and economic

[1] See Dahl and Tufte (1973), Alesina and Spolaore (2003), and Rose (2005) for reviews of the older literature.

[2] Kremer's (1993) extreme long-run analysis of population growth on different continents is sometimes viewed as giving some support to the 'scale-effect' prediction, but it was effectively refuted by the evidence in Jones (1995) and led to the development of growth models without scale effects.

performance variables. Similarly, Knack and Azfar (2003) argue that empirical studies that have shown a negative relationship between corruption and population size have suffered from sample selection bias and that the relationship disappears when a broader sample is used. Dahl and Tufte (1973) is probably the most comprehensive study of the importance of country size and is one of few studies that actually considers country area as a potential determinant of economic outcomes.

A few articles focus on the endogenous determination of country size. In Friedman (1977), it is assumed that the size of tax revenues increases with country territory and that tax revenue-maximizing rulers therefore invest in extending their territory. In the end, this process will actually result in an equilibrium where rulers maximize their joint potential net revenue. In Alesina and Spolaore (1997, 2003), country size is endogenously determined as a result of a trade-off where large countries have economies of scale in public goods provision but a greater degree of preference heterogeneity. Wittman (2000) extends this framework by allowing for migration between countries in the spirit of Tiebout (1956).

The generality of the endogenous borders literature has been questioned by Herbst (2000).[3] Although the endogenous borders literature is useful for understanding the European experience or developments over the very long run, it appears to have less to offer an analysis of politics in former colonies where borders were usually fixed by colonial powers and subsequently rarely changed. Indeed, Herbst argues that the exogenously given and more or less random configuration of borders in Africa must be a central feature in comparative analyses of African politics.

In this article, we show that the size of country territory is negatively associated with a range of institutional measures such as rule of law, political stability, and corruption when using a sample of all countries in the world. We recognize however that boundaries are potentially endogenous and therefore restrict our analysis to former colonies whose borders were exogenously determined by the colonial powers. In a theoretical section, we argue that country size has two effects: Firstly, that a large territory means a larger absolute value of expected rents from lands and mines and that this stock of appropriable treasures makes self-interested autocratic rulers less interested in upholding strong private prop-

[3] In Herbst's (2000, p 141) own words: "...the intertia of the national experience and the incentives posed by international structures and norms that have developed over time combine to make the demarcation of the state a non-issue in most countries most of the time. Here, I differ greatly from writings by economists who seek to find the optimal number of states by assuming that states cooperate to design themselves in a way that will maximize 'their joint potential net revenue' [Friedman] or who believe that the size and shape of states is determined on the basis of majority votes motivated by precise calculations of economic interests [Alesina and Spolaore]"

erty rights and protection against expropriation. Secondly, we propose (in the spirit of the emerging literature on 'new economic geography') that the strong concentration of power in the capitals of former colonies implies that public goods like the rule of law diffuse according to a spatial decay-function so that the levels felt in the hinterland are much weaker than in the capitals. This problem should be further exacerbated in countries where the capital is non-centrally located.

As the base sample for testing our hypotheses, we use data from 127 former colonies which - unlike most of the previous literature on colonialism - arguably contains all large and small countries that were ever colonized. We show that the size of country territory has a very robust negative impact on our measure of the rule of law, even after controlling for distance from the equator, openness to trade, settler mortality, ethnic fractionalization, colonial origin, continental dummies, and a number of other variables. We also show that country territory appears to have a stronger association with rule of law than the level of the population. This fact, together with the general endogeneity of population size to institutions, suggest to us that country territory is a more appropriate indicator of country size than population. Unlike any other study that we are aware of, we further construct two indicators of the peripherality of the capital. As hypothesized, it turns out that when we hold country territory and some other controls constant, the strength of rule of law decreases with our size-neutral measure of the peripherality of the capital. Our interpretation of these results is that exogenously determined country territory has been a major impediment to the creation of strong institutions in large countries like Indonesia, Sudan, and Algeria, whereas it has been highly beneficial to small countries like Bahrain, Martinique, and Singapore.

Since the strength of rule of law is a kind of institutional variable, our approach is obviously highly related to the growing empirical literature on the determinants of institutional strength (Hall and Jones, 1999; Acemoglu et al, 2001, 2002; Rodrik et al, 2004). In the spirit of Glaeser et al (2004), we think of property rights institutions and the rule of law as a variable that governments actually can influence, at least in the medium run. In the theory section, an important assumption is that post-colonial regimes are capable and willing to undertake institutional change, although the impact of such policies depend on the colonial and pre-colonial institutional environment. This type of modelling therefore distinguishes our approach somewhat from works in the tradition of Douglass North such as Acemoglu et al (2001, 2002) where institutional persistence from colonial times is a central element.

The article is organized as follows: In section two, we give a general outline of the statistical correlations between country size and various indicators of institutional quality. In section three, we develop a theoretical framework for understanding the linkages between size and institutions. In section four, we provide the main empirical investigation using the reduced sample of former colonies. Section five concludes the exposition.

2 Country Size, Institutions, and Economic Development

2.1 Country Size and Institutional Quality

Country size is negatively associated with a range of measures of institutional quality. In Table 1, we use six different measures as dependent variables, capturing various types of institutions that are believed to be central for economic development. The six indicators are *Rule of Law*, *Political Stability*, *Voice and Accountability*, *Government Effectiveness*, *Regulatory Quality*, and *Corruption* for the year 2004, collected by Kaufmann et al (2005) (for a description of all variables, see the Data Appendix). As our measure of country size, we use *LogArea*, which shows the logged value of the total area of a country (including lakes and rivers) in square kilometers. The sample includes just above 200 countries, some of which are very small like Macau and Singapore.

As Table 1 shows, the coefficient for *LogArea* is negative and highly significant for all six dependent institutional variables. *LogArea* has its strongest impact on *Rule of Law* and *Political Stability.* In the latter case, *LogArea* alone explains roughly 25 percent of the variation, which we think is a quite remarkable result but perhaps not surprising. It seems for instance natural that a large country is more likely to host rebel movements than small ones. However, the fit is substantially improved when we include *Latitude*, which measures absolute distance from the equator in latitude degrees, and dummies for *Sub-Saharan Africa* and *Neo-Europe* where the latter captures the influence of four outliers United States, Canada, Australia, and New Zealand. Especially the first three countries are anomalies in our investigation since they are very large countries far from the equator with good institutions.[4] The coefficient for *Neo-Europe* is highly significant in all columns, as is the coefficient for *Latitude,* whereas the coefficient for *Sub-Saharan Africa* is always negative and mostly significant. *Latitude* is often included in empirical investigations of this kind and is believed to capture geographical, agricultural, and disease-related factors (Hall and Jones, 1999; Acemoglu et al, 2001; Olsson and Hibbs, 2005). Figure 1 shows the partial

[4] These four countries are indeed treated as outliers in most of the literature on former colonies and are sometimes excluded for that reason.

scatter plot between *LogArea* and *Rule of law* (controlling for *Latitude* and the two regional dummies).

The reduced form regressions in Table 1 show that country size seems to be strongly correlated with various types of institutional quality. However, the estimates do not tell us much about the causal mechanisms behind the results. Indeed, we suspect that the precise causal mechanism depends on what particular institutional variable we are considering. Therefore, we will henceforth focus more deeply on the variable that has attracted the greatest interest in the literature - *Rule of law* - which for instance covers central aspects like the strength of property rights.

2.2 Institutions and Economic Development

A further motivation for our interest in the determinants of *Rule of law* is that the cluster of institutions that the variable proxies for has been found to have a strong impact on levels of economic development, as demonstrated for instance by Rodrik et al (2004). Although we are primarily interested in the link between country size and institutions, we take a short detour in Table 2 to further emphasize the causal effect of institutional quality on countries' economic prosperity. It is a well known fact that OLS estimations of the effect of institutions on income levels suffer from reverse causality-problems. Table 2 therefore shows *GDP per capita* in 2004 as the dependent variable with *Rule of law* as an endogenous variable. This follows in the much celebrated instrumental variable tradition that started with Hall and Jones (1999) and Acemoglu et al (2001).

The novelty compared to previous studies is that we introduce *LogArea* as an instrument for institutions. Columns 1-2 of Panel B in Table 2 shows the first-stage estimates where we regress *Rule of law in 2004* on *LogArea* alone and on the exogenous controls for the whole world in the same way as earlier. In columns 3-4, Panel B, we switch to a former colony sample, as used in much of the literature. The main result is that *LogArea* has significant first-stage estimates and that R^2 is high when joined with the three controls in columns 2 and 4. The second-stage estimate for *Rule of law* is further always strongly significant.

In columns 5-6, we briefly check whether the picture changes when we use Acemoglu et al's (2001) *Log Settler Mortality*-variable as the excludable instrument and *LogArea* as a conditioning variable. Panel B shows that the first-stage estimates are significant for both *Log Settler Mortality* and *LogArea*. The second-stage estimates for *LogArea* are positive but insignificant, indicating that the exclusion restriction that we made use of in columns 1-4 seems to be safe. In other words, *LogArea* only appears to have an indirect impact on income levels through institutions. It is further noteworthy that *LogArea* has a number of advantages as an instrument in this type of estimations, for instance a superior data availability and measurement precision.[5]

2.3 Is Country Size Endogenous?

There is however also the issue concerning the potential endogeneity of country size. In the theoretical model of Alesina and Spolaore (1997), country size is endogenously determined as a result of a trade-off between economies of scale in public goods provision and preference heterogeneity among the population. All else equal, large countries tend to have low costs per capita of public goods (like rule of law) but also people in the periphery who would prefer a different government policy. If this model is correct, then it would be inappropriate to include *LogArea* as an exogenous variable as in Tables 1 and 2.

The generality of Alesina and Spolaore's view on country formation has been questioned by Herbst (2000). Although the type of process envisaged by Alesina and Spolaore probably well describes developments in Europe and parts of Asia where country formation has been going on for centuries or even millennia, it is less apparently relevant for the former colonies in America and Africa that received independence much more recently. Herbst (2000) argues that for Africa in particular, the size and number of countries was organized in a more or less random manner during the infamous Berlin conference of 1885. First of all there was relatively little a priori information for boundary creators due to a lack of traditional boundaries as well as natural geographic boundaries. Ultimately, the Berlin conference made it possible to claim sovereignty over an area regardless of the ability to administer the area. Therefore, there was no discrimination enabling only the more powerful colonizers to claim large areas. The logic of the partition was primarily to serve European strategic interests and the colonial powers more or less ignored existing state structures and ethnic boundaries (Pakenham, 1991).[6] Indeed, the wider effects of the random nature of African borders has been a major topic among Africanists (Davidson, 1992; Englebert et al, 2002). The endogeneity of borders can also be questioned for the other former colonies, although there are some examples of country break-ups after independence.[7]

[5] We will not take the discussion of the IV-approach any further since it is not our main interest. See Glaeser et al (2004) for a recent critical overview of the literature.

[6] In Jackson and Rosberg's (1985, p 46) words: "The boundaries of many countries, particularly but by no means exclusively in French-speaking Africa, were arbitrarily drawn by the colonial powers and were not encouraging frameworks of unified, legitimate, and capable states."

[7] Well-known incidences of break-ups of colonies include the formation of India, Pakistan, and Bangladesh in 1949 and of Colombia, Venezuela, and Ecuador in 1830. However, all the

The implication of the discussion above is that while it might be problematic to consider country size as fully exogenous in Europe and parts of Asia, this should not constitute a serious problem for former colonies. In the further theoretical and empirical analysis, we will therefore only consider the relationship between country size and rule of law in countries that were previously colonized.

3 A Theoretical Framework

In the model below, we aim to describe certain features of the political economy and institutional environment of a former colony with exogenous, randomly distributed borders instituted by the previous colonial power.[8] The size of country territory is imagined to have two effects on the average level of rule of law: Firstly, a direct 'broadcasting-effect' that derives from many formal institutions' character of a local public good originating in the country capital. Secondly, an indirect 'rent seeking-effect' such that larger countries tend to be endowed with a larger amount of primary sector rents, which in turn decreases government incentives towards maintaining strong property rights.

3.1 The Broadcasting Effect

We propose that rule of law has the basic character of a local public good that emanates from the capital of the country and where the effective level of the good declines with geographical distance from the capital. As noted above, we see a number of reasons for making this assumption.

Firstly, it is a very common assertion in the literature that both executive and legislative power in the newly independent colonies tended to originate almost exclusively from the capitals (Bates, 1981; Herbst, 2000). Following the old colonial logic, whoever controlled the capital was usually also internationally recognized as the legitimate regime. Given the lack of democracy and the rarity of strong regional identities or federal states, the maintenance of rule of law remained highly centralized.[9]

Secondly, a large literature in economic geography has clearly demonstrated that there are significant costs of geographical distance (Venables, 2005). For

countries mentioned had their break-up in conjunction with or very soon after independence and post-colonial developments have therefore had at most a very small impact on border formation.

[8] The model is not at all intended to capture the situation in the Neo-European former colonies. As in the empirical section, the historical trajectories of Australia, Canada, New Zealand, and the United States are anomalies to the theory below.

[9] There are of course exceptions to this generalization. India is a well-known example of a democratic country with strong regional autonomy.

instance, Keller (2002) shows that the benefits from technology externalities are halved every 1,200 kilometers from the center of origin. Arzaghi and Henderson (2005) have recently suggested that similar costs of distance apply for other public goods. A recurring theme in the development literature is how the 'broadcasting of power over space' in former colonies is associated with significant challenges, particularly in Africa (Herbst, 2000). Public goods like the legislation and enforcement of property rights are most strongly felt in and around the capital among the elite groups that control the state and its functions. In this sense, we argue that institutions tend to be local public goods in a similar way as for instance knowledge production and R&D.

Thirdly, even if the broadcasting of institutions had been smooth across geography, it is usually the case that the sympathy for the ruling elite and its laws decrease with distance from the capital. Alesina and Spolaore (1997) make a similar assumption but with the size of the population rather than geographical distance as the source of preference discordance. In any case, distance from the capital should be negatively associated with the strength of law enforcement and with the willingness of local people to comply with the rules endorsed by the elite in the capital.

In order to formalize this idea, let us imagine that the strength of rule of law in the capital of country i is given by a variable z_i. Let us also imagine, as in Alesina and Spolaore (1997), that the size and location of countries in the world can be described as non-overlapping intervals on the real line where $s_i > 0$ is the size of country i and where $[l_i, l_i + s_i] \subset \mathbb{R}_+$ defines the unique country location with $l_i > 0$ as the 'coordinate' for the left-hand side border.[10] The capital of the country, in turn, is located at a point $c_i \in [l_i, l_i + s_i]$. Obviously, if the capital is located exactly in the middle of the country, it will be found at $c_i = l_i + s_i/2$. The geographical distance from the capital to some location $l_{i,j} \in [l_i, l_i + s_i]$ within country i is described by the term $d_{i,j} = |l_{i,j} - c_i| \in [0, s_i]$ (see Figure 2 for a graphical illustration).

A central assumption of our model is that the size distribution of former colonies was determined by a random, exogenous process. The former assumption is of course an important departure from the endogenous borders-models by Friedman (1977) and Alesina and Spolaore (1997) but is well in line with the literature on the history and political development of ex-colonies (Herbst, 2000; Englebert et al, 2002). We further make the implicit assumption that within countries, the population is uniformly distributed.

As discussed above, we postulate that the strength of rule of law diminishes

[10] The one-dimensional nature of country size is used for simplicity. As shown by Alesina and Spolaore (1997), modelling size as two-dimensional significantly increases the complexity of calculations without any intuitive gains.

with distance from the capital according to a spatial decay-function

$$z_{i,j} = z_i \left(1 - a_i d_{i,j}\right) \tag{1}$$

where $z_{i,j}$ is the level of rule of law at location $l_{i,j}$ and where $a_i > 0$ is a parameter describing the marginal decline in institutional quality over space. The level of a_i is assumed to be such that $a_i s_i < 1$.[11]

If we define the average distance to the capital within a country as $\bar{d}_i$, we can calculate this measure as a weighted average

$$\bar{d}_i = \frac{\left(c_i - l_i\right)^2 + \left(l_i + s_i - c_i\right)^2}{2 s_i}. \tag{2}$$

This distance function can assume two extreme values. The first is given by the situation when the capital is located exactly in the middle of the country so that $c_i = l_i + s_i/2$. In this case, simple algebra shows that $\bar{d}_i = \frac{s_i}{4}$. In the other extreme case with the capital located at either of the two borders, we will have that $\bar{d}_i = \frac{s_i}{2}$. We can thus describe average distance more generally as

$$\bar{d}_i = \frac{\left(1 + q_i\right) s_i}{4} \tag{3}$$

where $q_i \in [0, 1]$ is a size-neutral index of the 'peripherality' of the capital where a high q_i indicates a location near (or at) a border and where a low q_i means a location near (or at) the center of the country.

3.2 The Rent Seeking-Effect

The level of institutional quality in the capital z_i is to a large extent given by the colonial and pre-colonial history of the country, as argued by North (1990), Acemoglu et al (2001, 2002) and others. However, in the general spirit of Glaeser et al (2004) and the model in Congdon Fors and Olsson (2005), we argue that the institutional setup was partly also a choice variable for the post-colonial regimes.

In order to capture both of these features, we make a distinction between historical (pre-colonial and colonial) property rights institutions with an average strength of x and endogenously determined current (post-colonial) institutions z. After independence, discontinuous breaks with the colonial regime were often made, which is the reason why we think of x and z as different variables. However, as will be shown, the choice of z will partly depend on the historical

[11] This condition is imposed to ensure that $z_{i,j} > 0$ at all $l_{i,j}$. The same type of spatial decay-function for public goods is used by Arzaghi and Henderson (2005). 'Iceberg' functions in spatial economics and in the 'new economic geography' is discussed for instance by Krugman (1998).

level x.

We propose that autocratic post-colonial regimes typically faced a trade-off between fostering strong or weak property rights institutions, i.e. a high or a low level of z. Strong property rights and a pervasive rule of law tended to favor the growth of a modern, export-oriented manufacturing sector that was dependent on highly mobile foreign investments and capital. However, a strong rule of law also served as a significant constraint on the regime and made rent extraction from a primary sector more difficult.[12] The primary sector in our model includes industries such as agriculture as well as various types of mineral extraction, including oil. The common feature of these economic activities is that they rely on a highly immobile factor of production (land and mines) and therefore tend to be less sensitive to the institutional environment in the country.[13] Furthermore, there is generally a positive relationship between the magnitude of primary sector rents and the area of the country.[14]

We capture this reasoning formally by modelling a utility function for an autocratic ruling regime of the following appearance:

$$U_i = m\left(x_i, z_i\right) + b_i r\left(x_i, z_i, s_i\right) \tag{4}$$

The regime receives utility from private rents from manufacturing m and from a primary sector r. x_i measures the level of institutional quality given by colonial and pre-colonial history, whereas z_i indicates the endogenously created institutions after independence. The parameter b_i reflects the relative weight given to the primary sector in country i for historical or for power strategic reasons not explained by the model.[15]

In line with the discussion above, we assume that $\frac{\partial m(x_i,z_i)}{\partial z_i} = m_z > 0$ and that $\frac{\partial r(x_i z_i,s_i)}{\partial z_i} = r_z < 0$. In order to understand the intuition behind the signs of these derivatives, consider the following example. Imagine that under the prevailing property rights institutions, a regime in some former colony captures rents by randomly expropriating 5 percent of firm revenues in the two sectors

[12] We recognize of course that all former colonies are not characterized by non-democratic, self-interested rulers that maximize their own rents. However, we strongly believe that this generalization is more appropriate for this category of countries than it would be to include a benevolent social planner. Our model has some similarities to the chapter in Alesina and Spolaore (2003) featuring the optimization problem of a dictatorial 'Leviathan'.

[13] The least sensitive type of natural resource production is probably low tech mining of for instance alluvial diamonds and gold. Such mining has often prevailed in Africa even during periods of a general institutional collapse (Olsson, 2005). It should be acknowledged that certain types of natural resource production - like oil drilling and off-shore diamond mining - typically involves advanced technology and a dependency on foreign capital, as in the manufacturing sector.

[14] Casual observation certainly suggests that large former colonies like the United States, Brazil, DR Congo, Angola, and Nigeria are well endowed with natural resources.

[15] In Congdon Fors and Olsson (2005), it was argued that b_i gave an indication of the origins of the elite that came into power after independence. In many cases, this elite had very weak ties to the manufacturing sector and tended to favor the natural resource sectors.

in the name of the state but for personal gain. Let us further assume that total revenues in each of the two sectors initially are 100 units so that rents are 5 units in each sector. An improvement in property rights institutions then occurs which manifests itself in a lowering of the percentage of revenue expropriated in the two sectors from 5 to 4 percent. In the manufacturing sector, which relies on internationally mobile capital and investments, this good signal has a strong impact on total production that increases to 130. The effective level of rents therefore actually increases to become 5.2 units. In the primary sector, with highly immobile investments, production increases but only by a relatively small amount to 110 units. Effective primary sector rents fall from 5 to 4.4 units. In this representative example, manufacturing rents thus turn out to have a positive relationship with the strength of property rights, whereas the reverse is true in the primary sector.[16]

We further make the implicit assumption that natural resources are distributed randomly over space, which implies that the absolute level of expected primary sector rents increases with the territory of the country. In order to avoid extra notation, we capture this idea by simply assuming $\frac{\partial r(x_i,z_i,s_i)}{\partial s_i} = r_s > 0$. The same effect of space is not present in the manufacturing sector. All else equal, the utility of the regime thus always increases with territory.[17] The logic of the model further suggests that the marginal utility of extra territory should decrease with the strength of the rule of law since rent appropriation by the elite is more difficult if private property rights are strong, implying $\frac{\partial^2 r(x_i,z_i,s_i)}{\partial s_i \partial z_i} = r_{sz} < 0$.

The historical experience given by x_i shapes expectations about current behavior and exacerbates the marginal impact of a current institutional policy. In the numerical example above, the decrease in expropriation risk from 5 to 4 percent implied an increase in revenues with 30 units. In a country with favorable historical institutions, the reaction of an identical change in expropriation risk should be even greater, maybe increasing production to 150 and rents to 6 units. Likewise, production in the primary sector should be more responsive to a current institutional change, maybe increasing to 120 rather than to 110. Rents would then be 4.8 rather than 4.4. In other words, a stronger institutional heritage means that the positive marginal effect of increasing z_i increases with x_i in the manufacturing sector, whereas the negative marginal effect of increasing z_i decreases with x_i in the primary sector. Formally, this implies

[16] Note, however, that a rational rent-maximizing regime (with $b_i = 1$) would never choose to carry out this strengthening of institutions since the overall effect is a fall in rents from 10 to 9.6 units.

[17] If size had been a choice variable, all autocratic rulers in our model would thus have liked to increase the size of their country but would of course have been constrained by a similar desire among other dictatorial rulers, as in Friedman (1977).

that $\frac{\partial^2 m(x_i,z_i)}{\partial z_i \partial x_i} = m_{zx} > 0$ and $\frac{\partial^2 r(x_i,z_i,s_i)}{\partial z_i \partial x_i} = r_{zx} > 0$.

A key feature of our model further concerns the relationship between x_i and s_i. In line with the exogeneity of s_i discussed above, we argue that x_i had no impact on s_i, i.e. pre-colonial and colonial institutions did generally not affect the size distribution of countries. We recognize, however, that there could be a causal link from s_i to x_i such that the configuration of colonial institutions in the capital depended on the total size of colonial territory. It is not clear though what direction this influence would take among colonialists of different identity and in general we believe that the colonial rulers mainly cared about the situation in or near the capital.

Unlike in the framework of Alesina and Spolaore (1997), the choice variable in our model is the quality of a public good like the rule of law rather than country size. Another difference is that we do not believe that it is natural to assume economies of scale in public goods provision when area is the measure of country size. For simplicity, we also abstract from the costs of institutional change.[18] The only constraint facing the regime is that the rule of law must not fall below a certain reservation level $z^{\min}$. If it does, the people will overthrow the incumbent.

The ruling regime thus faces an optimization problem

$$\max_{z_i} \; m\left(x_i, z_i\right) + b_i r\left(x_i, z_i, s_i\right) \quad \text{subject to } z_i \geq z^{\min}.$$

If we disregard the possibility of a boundary solution, the (interior) equilibrium level of rule of law or property rights institutions z_i^* is implicitly given by the first-order condition $m_z + b_i r_z = 0$. In order to have an interior solution, it is further required that the second-order condition for maximum $m_{zz} + b_i r_{zz} < 0$ is satisfied. Straightforward implicit differentiation then shows that

$$\frac{\partial z_i^*}{\partial s_i} = \frac{-b_i r_{zs}}{m_{zz} + b_i r_{zz}}. \tag{5}$$

Since we have already established that the denominator must be negative, it will be the case that $\frac{\partial z_i^*}{\partial s_i} < 0$. We argue that this type of indirect negative relationship between institutional quality and territorial size is similar in spirit to what Montesquieu had in mind. We can also easily see that $\frac{\partial z_i^*}{\partial b_i} = \frac{-r_z}{m_{zz}+b_i r_{zz}} < 0$ and that $\frac{\partial z_i^*}{\partial x_i} = \frac{-m_{zx}-b_i r_{zx}}{m_{zz}+b_i r_{zz}} > 0$. These results might be summarized by writing $z_i^*\left(x_i, b_i, s_i\right)$.

The equations above imply that the average strength of rule of law in a

[18] The cost of institutional change is explicitly modelled in Congdon Fors and Olsson (2005). Naturally, costs of institutional change would imply that there is a bias toward keeping the institutions inherited from colonial days.

country i will be given by:[19]

$$\bar{z}_i = z_i^* \left(x_i, b_i, s_i\right) \cdot \left(1 - \frac{a_i \left(1 + q_i\right) s_i}{4}\right) \quad (6)$$

The central insight from this expression is that rule of law will diminish with country size via two potential channels. The first direct 'broadcasting-effect' comes about due to the imperfect enforcement of institutions over space. This effect can however be mitigated by a low marginal decline of institutional quality a_i and by a centrally placed capital (a low q_i). The second indirect 'rent seeking-effect' works via the level of primary sector rents that increases with country size and that tend to corrupt governmental institutional policy. The level of institutions will further be lower if the regime considers primary sector rents to be particularly valuable so that b_i is high. Given all other variables, we also have institutional persistence such that current average institutional strength increases with past institutions x_i, as in much of the existing literature. Equation (6) will form the basis for the further empirical investigation in the next section.

4 Empirical Analysis

4.1 Data and model specification

Due to the potential endogeneity of country size, we use a restricted sample of 127 former colonies that we have identified among the 208 countries listed in Kaufmann et al (2005). These countries were colonized between 1462 and 1922 following the expansion of Western Europe. Borders in former colonies have rarely been changed since colonial days and might reasonably be regarded as an exogenous variable in economic development. Some of the countries in our sample are very small both in terms of population and territory (for instance Nauru with a population of roughly 12,000 individuals on 21 square kilometers) and some are still dependencies to their old colonial powers. Many cross-country studies exclude such tiny countries, but given the issue at hand, they are relevant observations in our study.[20] We further believe that this inclusion neutralizes the concerns of Knack and Azfar (2003) about a commonly observed sample selection bias towards including only those relatively developed small countries where international investors have economic interests. Our sample is further by

[19] We might equivalently think of the expression in (6) as showing the expected quality of institutions for a randomly chosen individual (since individuals are randomly distributed across space).

[20] In section 4.4, we show that our main results are robust when we control for dependencies and exclude the smallest countries as well as those with the most uncertain data.

far the largest sample of former colonies in the literature and arguably includes all countries that were ever colonized.

The basic equation that we test in this section with many variations is given in (7)

$$Z_i = \alpha_0 + \alpha_1 S_i + C_i' \alpha_2 + \epsilon_i \tag{7}$$

where Z_i is the measure of *Rule of law* in country i, S_i is our country size variable (mainly *LogArea*), and C_i' is a vector of control variables, ϵ_i is the normally distributed error term, and α_k are the estimated coefficients.

The main variable of interest here is of course S_i. As argued in the theoretical section above, the issue of identification should be resolved since it seems highly implausible that Z_i could have caused S_i. Our main hypothesis is obviously that $\alpha_1 < 0$. The vector of controls in C_i' will always include the purely exogenous variable *Latitude,* measuring the absolute distance from the equator in latitude degrees, and the regional dummies *Sub-Saharan Africa* and *Neo-Europe* as in Table 1. The motivation for including *Latitude* is partially that it can be regarded as a proxy for the marginal 'spatial cost' of broadcasting institutions a_i and possibly also as a correlate of colonial institutions x_i.[21] A *Neo-Europe*-dummy is included since these four countries are extreme outliers and do not fit well into our basic framework, as explained above. Including a Sub-Saharan Africa dummy in our baseline regression further ensures that our results are not driven by some special characteristic of the African countries.

In accordance with our theory, C_i' will sometimes also include proxies for the peripherality of the capital q_i and for colonial institutions x_i. Lastly, b_i will be considered as a deep parameter that we do not attempt to control for.

4.2 Country Size and Its Correlates

Column 1 in Table 3 shows the baseline regression of our study. *LogArea* is a very strong predictor of *Rule of law* even in this colony sample, and together with the three controls (with unreported but highly significant estimates as in Table 1), it explains nearly 57 percent of the variation in the dependent variable (see Figure 3 for a partial scatter plot). If we were to interpret these results, a 100 percent increase in total area for any country implies a reduction in the *Rule of Law*-index by 0.152, which translates into about 3.6 percent of the whole dispersion between the highest and the lowest possible score (4.23). This

[21] See Diamond (1997), Herbst (2000), and Olsson and Hibbs (2005) for general treatments and Sachs (2001) for a more detailed discussion of the economic and institutional difficulties that are faced by governments near the equator. Hall and Jones (1999) develop further the argument for how *Latitude* might be seen as a proxy for Western influence.

relatively small effect is explained by that countries differ drastically in size.[22] If we instead compare a country with a total area of 1,000 square kilometers (about the size of Hong Kong) with a country with an area of 1,000,000 square kilometers (like Mauretania or Bolivia), the model predicts that all else equal the larger country should have a score on *Rule of law* that is 1.05 points lower, which is clearly a large effect.

Country area is however not the only variable that captures important elements of country size. The main objective of this section is to analyze what country size variable S_i that should be included and how it is related to some other variables. In the tradition of Alesina and Spolaore (1997, 2003) most studies have used the level of the population as the indicator of country size. In a recent paper, Rose (2005) investigates whether the level of the population has an impact on a battery of economic and institutional variables and finds that it has no or, at best, a very weak effect. We argue that unlike country area, the level of the population is in general endogenous to economic and institutional environments, sometimes even in the short run.[23] Nonetheless, we include the level of the population as a regressor in Table 3 to check whether country area or population size can best explain variations in the rule of law.

Column 2 shows that when *LogArea* is replaced by *LogPop* (the natural logarithm of the level of the population), the effect from *LogPop* is also negative and significant.[24] When included together with *LogArea* in column 6, the effect from *LogPop* is insignificant and changes sign whereas *LogArea* has a very similar coefficient as before. Given the high correlation between *LogArea* and *LogPop*, one should of course not take the specific estimate seriously, but column 6 appears to indicate that even when holding population constant, *Rule of law* diminishes with country territory and retains its significance.

Table 3 also includes three other variables that are believed to be strongly associated with country size. The first one is a proxy for natural resource rents, *Fuels and Minerals*, measuring energy and mineral rents as a share of GNI in 1999. This is the empirical equivalent of r in the model above, which was assumed to be a positive function of country area. Hence, we have good theoretical reasons for believing that *LogArea* and *Fuels and Minerals* should be colinear. This presumably also explains why *Fuels and Minerals* is positively

[22] India, one of the largest countries in our sample, is about 130'000 times larger than Macau, which is one of the smallest countries in our sample.

[23] There are several recent examples of episodes when the population has changed drastically as a result of institutional failures. In 1994, 800,000 Tutsi were slaughtered in Rwanda as a result of a collapse of the rule of law. The older experiences of Nazi Germany and Stalin's Soviet Union are well-known examples of how bad institutions have a very large impact on the level of the population.

[24] This result stands in sharp contrast to the main tendency in Rose (2005) who finds no robust association between population size and a number of institutional and economic variables.

and significantly related to *Rule of law* in column 3 but insignificant when run together with *LogArea* in column 7.

The second variable that is highly related to country size is *LogOpen,* measured in the conventional way as the log of imports plus exports as a share of GDP. As argued by for instance Alesina et al (1998) and Frankel and Romer (1999), small countries are naturally more open than larger countries that have major internal markets. In accordance with what is usually hypothesized in the literature, Table 3 suggests that a high degree of openness appears to act as a disciplining device for countries to uphold strong property rights and judicial constraints against opportunistic behavior by governments and individuals. The estimate in column 4 is positive and highly significant and the coefficient is still significant when *LogArea* is included in column 8.

Lastly, in column 5, we take into consideration the fact that country size might have an impact on the country's choice of fundamental institutions of governance. In particular, intuition suggests that large countries are more likely to be federal states with bicameral legislatures, i.e. with more regionally decentralized power. If public goods like the rule of law are primarily provided by regional governments, the negative impact of country size should be smaller. In order to control for this, we include a measure of *Unitarism*, a proxy for the degree of power separation between national and regional polities developed by Gerring et al (2005). A country with a high score on *Unitarism* is characterized by a high power concentration with the national government (non-federalism) and a single 'house' of parliament (non-bicameralism), whereas the lowest score implies a federal, bicameral state. In column 5, *Unitarism* has a positive and weakly significant effect on *Rule of law* in accordance with the general hypothesis in Gerring et al (2005).[25] In column 8, however, the coefficient switches sign and is insignificant. The effect from *LogArea* remains negative and significant in that same column, indicating that a large country size is bad for institutional quality regardless of whether countries have centralized or decentralized modes of governance.

As we have already touched upon, the colinearity between *LogArea* and the variables in Table 3 makes inference about the coefficients problematic. In the theory section, we even argued that a large area should increase natural resource rents. We are therefore tempted to propose a tentative structural model of the direct and indirect effects of country size. Suppose that our basic empirical equation (7) applies with the modification that the vector of control variables is $C_i' = \left\{C_i^X, C_i^N(S_i)\right\}$ where $C_i^N(S_i)$ are variables structurally related to size

[25] Gerring et al (2005) develop and test a theory of the benefits of 'centripetalism'. The main hypothesis is that democratic institutions work best when they are designed so as to allow for centralized authority and broad inclusion at the same time.

S_i whereas C_i^X is a set of purely exogenous control variables with respective coefficients α_2 and α_3. Suppose further that we can model this indirect effect of country size as

$$C_i^N = \beta_0 + \beta_1 S_i + \upsilon_i. \tag{8}$$

Whether β_1 is positive or negative depends on the specific dependent variable. In Table 4, we estimate four types of such relationships, namely how *LogArea* is associated with *LogPop, Fuels and Minerals, LogOpen*, and *Unitarism* from Table 3. All estimates for β_1 have the expected signs and are strongly significant. A noteworthy feature is for instance that large countries are unlikely to have centralized governments (i.e. they have a low score on *Unitarism*), as one would expect.

If we substitute the equation in (8) for C_i^N in the baseline regression, routine calculations show that the reduced-form expression for *Rule of law* can be rewritten as

$$Z_i = \alpha_0 + \alpha_2\beta_0 + (\alpha_1 + \alpha_2\beta_1)\, S_i + \alpha_3 C_i^X + \alpha_2\upsilon_i + \epsilon_i. \tag{9}$$

The central feature of this expression is that it shows how the reduced form-estimate for S_i picks up both the direct effect α_1 and the indirect effect $\alpha_2\beta_1$ of country size. Column 1 in Table 3 shows that $\alpha_1+\alpha_2\beta_1 = -0.152$. If we consider for instance *Fuels and Minerals*, a variable that we are particularly interested in since it proxies for r in our theoretical model, we can see from Table 3 that $\alpha_2 < 0$ and from Table 4 that $\beta_1 > 0$. From this we can infer that the relationship between the reduced form-estimate for S_i and the estimate from a regression including *Fuels and Minerals* as an independent variable is $\alpha_1 + \alpha_2\beta_1 < \alpha_1$. In Table 3, we see that this appears to hold: $\alpha_1 + \alpha_2\beta_1 = -0.152 < \alpha_1 = -0.137$.

The reason for this digression is that we will henceforth drop *LogPop, Fuels and Minerals, LogOpen*, and *Unitarism* from the analysis due to their high correlation with *LogArea*. It should be kept in mind, however, that by excluding these variables the estimate for *LogArea* will be greater in absolute terms than it would be otherwise since it captures both direct and indirect effects of size.

4.3 The Centrality of the Capital

Apart from the size of country territory, the degree of peripherality of the capital q_i is an important ingredient in our theory and in our empirical model. The model predicts that rule of law should decrease with q_i, holding country size s_i constant. Using data from CEPII (2006) and CIA (2005), we have constructed a measure of the distance in kilometers from the approximate center of the country to the city hosting the seat of the government (which is usually also the capital).[26] The measure is available for 120 countries in our ex-colony sample. The countries with the greatest distances are not surprisingly the United States and Canada. The natural logarithm of this score makes up *LogDistance*, which is featured in Table 5. When run together with *LogArea*, *LogDistance* is negative and significant in column 1, and strongly significant in column 2 when featured alone. The distance measure is clearly correlated with country area (larger countries like Brazil and Indonesia will, ceteris paribus, have a greater absolute distance from center to capital), and the coefficient in column 2 where *LogArea* is excluded presumably picks up some of the effect of country size. Furthermore, *LogDistance* is clearly an imperfect proxy for q_i in the theory section which is a size-neutral index of the peripherality of the capital.

We have therefore created a measure that, we believe, more clearly reflects the degree of peripherality. We have done so by dividing our calculated distance from center to capital by an approximate measure of the distance from the center of the country to the border, where we approximate the shape of all countries to be congruent to a circle as is common in the trade literature (Head and Meyer, 2002). Since countries that are island groups are extremely badly captured by this measure, we have excluded all such countries which makes the sample shrink to 95 observations (see Data Appendix for the details). This size-adjusted measure *Periphery* shows countries like Namibia and Costa Rica as being among the very lowest scorers whereas the countries with the most peripheral capitals include Mozambique and Benin. Figure 4 illustrates the peripherality measure with respect to Namibia (with a score of 0.125) and Mozambique (1.77).[27]

The model predicts that the strength of rule of law should decrease with q_i holding s_i constant, and in column 3 we try to accomplish a similar scenario. As hypothesized, *Periphery* has a negative coefficient and is moderately significant (column 3). Figure 5 shows the partial correlation between *Rule of law* and *Periphery* based on the specification in column 3. The figure indicates that the result is sensitive to the inclusion of outlier Somalia to the far right. We can also infer that the marginal impact is not large. A one standard deviation increase in *Periphery* (0.44) results in a predicted fall in *Rule of law* by 0.105 units, which is about 2.5 percent of the whole variation. (A standard deviation increase in *LogArea* implies a fall in *Rule of law* by a level of almost 11 percent of the whole variation). If we compare Namibia and Mocambique, the *Periphery* coefficient implies that Namibia should have a *Rule of law* that is 0.39 units greater.

When a dummy for *Landlocked* countries and a variable showing the extent of more or less uninhabited desert and polar areas (*DesertPolarArea*) are

[26] The measure was produced by translating data on locations in latitude and longitude degrees to distances in kilometers by employing the Great Circle Formula. See the Data Appendix for the exact details.
[27] The correlation coefficient between *LogArea* and *Periphery* is only around 0.1.

included, *Periphery*'s standard error increases and makes the estimate insignificant. Elaborating further on this in column 5, we see that the effect from *Periphery* is moderately significant and negative and that an interaction term between *Periphery* and *Landlocked* suggest that the negative impact of peripherality might be a lot more pronounced in countries without access to the sea. Intuitively, it seems likely that countries that has an ocean coastline and a capital by the sea might compensate the inevitable peripherality of the capital by the benefit of having it located close to trade routes and international influences.[28] The coefficient for the interaction term is however insignificant.

In column 6, lastly, an interaction between *Periphery* and a measure of ethnic fractionalization from Fearon (2003) seems somewhat surprisingly to indicate that *Periphery* is more harmful for institutional quality in countries that are ethnically homogeneous (i.e. have a low score on *Ethnicity1*). Still the overall impact of *Periphery* is negative even in totally fractionalized societies (i.e. with a score on *Ethnicity1* close to zero).

In summary, we believe that Table 5 provides some supporting evidence of the notion that the geographical peripherality of the capital negatively affects the average intensity of *Rule of law*, although the result is fragile. More work on the impact of capital location should be able to shed further light on the true relationships. It should also be noted that the coefficient for *LogArea* remains negative and highly significant throughout all specifications.

4.4 Robustness tests

In Table 6, we extend our set of control variables in C_i' from just *Latitude*, *Neo-Europe, and Sub-Saharan Africa* to include several other variables that have been suggested in the literature. Ethnic, cultural, and or religious fractionalization is an often argued cause for differences in institutional quality and civil conflict (see for example Alesina et al (2003), Easterly and Levine (1997), and Hibbs (1973)). Recently, partly due to the revived interest in the effects of fractionalization, Alesina et al (2003) and Fearon (2003) have created new measures for different aspects of fractionalization. The measures Ethnic fractionalization from Fearon (2003) (*Ethnicity1,* used above) and Ethnic and Religious fractionalization (hereafter called *Ethnicity2* and *Religion*) both from Alesina et al (2003) are used as control variables in equation (7). As can be seen from Table 6, the coefficient for *LogArea* is still negative and statistically significant, while controlling for the fractionalization measures. The coefficients for *Ethnicity1* and *Ethnicity2* are both positive and insignificant, while the coefficient

[28] This aspect is particularly relevant for West Africa with many capitals located by the Atlantic.

for *Religion* is positive and significant.[29] Before we leave the fractionalization measures, it is interesting to note that the correlations between *LogArea* and the three fractionalization measures are surprisingly low[30]. A large country, therefore, does not automatically imply a more fractionalized country.

Since we have a sample of former colonies, variables related to colonial heritage are obviously highly relevant. An often used variable is Acemoglu et al's (2001, 2002) famous proxy for settler mortality, constructed by using data on the mortality of soldiers and bishops in tropical diseases during colonial days. The hypothesis proposed by Acemoglu et al (2001) was that a high settler mortality and a subsequent low intensity of European settlement should have contributed to extractive, harmful colonial institutions that have persisted to this day, and vice versa.[31] The basic data on settler mortality is only available for 69 former colonies. When controlling for *Log Settler Mortality* in column 4 the coefficient for *LogArea* is still negative and significant.

The other colonial variables are *Duration of colonial rule* (suggested by Grier, 1999, and Price, 2003), *Years of independence from colonial rule*, a dummy for the colonies that were *Colonized after 1850* (mainly Africa), and *Legal Origin* (as suggested by La Porta et al, 1999). Controlling for these measures of colonial heritage does not alter the main results; the coefficient for *LogArea* is still negative and significant in all regressions.

Some additional variables related to geography are included in Table 7. In column 1, we include an adjusted measure of country area, taking into account that large portions of countries might be more or less uninhabitable. Consider for instance the population distribution of Algeria in Figure 6. Although the country has the eighth largest territory area in our sample, the politically most relevant area where people live in the north is much smaller.[32] In order to test whether hinterland countries like Algeria in any way drive our results, we subtract all desert or polar areas (characterized by BW and E types of climate according to the Köppen-Geiger classification system) from country size to form *LogArea2*.[33] The sample then shrinks to 95 countries and the estimate decreases in absolute terms somewhat but is still highly significant.

Controlling for *Island* status or whether the country is *Landlocked* or a *De-*

[29] A similar result was obtained by Alesina et al (2003).

[30] The Pearson correlation coefficients between *LogArea* and *Ethnicity1*, *Ethnicity2*, and *Religion*, are respectively; 0.1735, 0.4441, and -0.0920.

[31] See Rodrik et al (2004) and Glaeser et al (2004) for further discussions of this work.

[32] We do not argue, however, that deserts or uninhabited land is irrelevant for a country's level of institutional quality. In line with Herbst (2000) and others we argue that hinterlands like the Sahara constitutes an enormous challenge to governments since such areas easily become the home of rebel groups and other destabilizing forces.

[33] This means for instance that Algeria's area is reduced by about 87 percent and Canada's by about 22 percent. See the Data Appendix for the details about this adjustment of country size.

pendency (a country that is not sovereign) does not alter the significance of the coefficient for *LogArea.* The results remain unchanged when including a *Latin America* dummy in column 5. In columns 6-8, we then try three interaction terms. Interestingly, the estimate for the interaction term in column 6 indicates that the relationship between *LogArea* and *Rule of Law* is different in Sub-Saharan Africa compared to the rest of the world (the negative slope is flatter). Also, *LogArea* appears to have a smaller marginal impact among countries that are more ethnically divided (column 7). However, none of the interaction terms take away the significant estimate of *LogArea*.

Lastly, in Table 8, we have attempted to control for sample selection bias and measurement error. In row 1, we exclude Sub-Saharan Africa from the sample, in row 2 we exclude the smallest countries in the sample, and in row 3 we exclude countries with the largest potential measurement error. In the latter case, we exclude observations with a standard error in the measurement of the dependent variable that is larger than 0.2, which reduces the sample by 37 countries.[34] This does not alter the significance of *LogArea*'s negative estimate. In rows 4-5, we use two related measures from Kaufmann et al (2005) as dependent variables instead of *Rule of* law: *Government Effectiveness* and *Regulatory Quality.* The level of the estimate changes somewhat but the relationship is still robustly negative. Finally, in row 6, we use an outlier robust estimator instead of OLS for the whole colony sample. The coefficient for *LogArea* remains negative and strongly significant.

5 Conclusions

In the spirit of Montesquieu, this paper demonstrates that there is a clear, robust and significant negative relationship between the size of nations and the strength of rule of law for a large cross-section of countries. For former colonies, up to 60 percent of the variation in rule of law is explained by the variables *LogArea*, *Latitude,* and *Sub-Saharan Africa*, and *NeoEurope.* This strong negative relationship is robust to the inclusion of a variety of control variables such as trade openness, ethnic and religious fractionalization, settler mortality, colonial heritage, and legal origin. The negative relation between *LogArea* and *Rule of Law* is even robust to including the level of the population, suggesting that country area is a stronger predictor of institutional quality than population levels.

[34] Our *Rule of Law* measure from Kaufmann et al (2005) is a composite index based on several different independent sources. Therefore, attached to each country's score is also the estimate's standard error and how many sources that has been used for that particular estimate. For the Rule of Law 2004 estimate, the great majority of countries have a standard error of between 0.1 and 0.2. The cut-off point that we employ is therefore to exclude countries with a standard error larger than 0.2. This turns out to be almost the same as excluding those countries with less than six independent sources.

We believe that these results strongly suggest that large countries are seriously disadvantaged in the formation and maintenance of institutions for economic development.

In our model, we further propose that the centrality of the capital should play an important role in the broadcasting of high quality institutions. We therefore construct a measure for the peripherality of the capital by relating the distance in kilometers from the capital to the center of the country, to the approximate distance from the center of the country to the border. As predicted by our model, the peripherality of the capital appears to be negatively associated with *Rule of Law,* although the result is not very robust. We believe that the relationship between the location of the capital and the country-wide provision of public goods is a potential area for future research.

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Table 1: OLS regressions for measures of institutional quality in 2004.

	Dependent variables											
Independent variables	(1) Rule of Law	(2) Rule of Law	(3) Political Stability	(4) Political Stability	(5) Voice & Account	(6) Voice & Account	(7) Gov't Effective	(8) Gov't Effective	(9) Reg Quality	(10) Reg Quality	(11) Corrup-tion	(12) Corrup-tion
LogArea	-0.126*** (0.018)	-0.153*** (0.016)	-0.166*** (0.017)	-0.192*** (0.016)	-0.116*** (0.018)	-0.141*** (0.018)	-0.068*** (0.022)	-0.097*** (0.017)	-0.115*** (0.021)	-0.146*** (0.018)	-0.092*** (0.023)	-0.132*** (0.018)
Latitude		0.023*** (0.004)		0.019*** (0.004)		0.018*** (0.004)		0.026*** (0.004)		0.022*** (0.004)		0.025*** (0.005)
Neo-Europe		1.993*** (0.199)		1.517*** (0.172)		1.641*** (0.187)		1.879*** (0.192)		1.742*** (0.197)		2.162*** (0.197)
Sub-Saharan Africa		-0.352*** (0.121)		-0.155 (0.134)		-0.210 (0.151)		-0.352*** (0.130)		-0.282** (0.140)		-0.220* (0.117)
R^2	0.145	0.460	0.251	0.432	0.123	0.310	0.043	0.393	0.108	0.373	0.069	0.403
n	208	208	207	207	207	207	209	209	204	204	204	204

Notes: The superscript *** denotes significant at the 1% level, ** significant at the 5% level, * significant at the 10% level. In parenthesis are robust standard errors. Intercept included but not reported.

Table 2: IV-regresssions with GDP per capita in 2004 as dependent variable and Rule of Law in 2004 as endogenous variable.

	(1) World sample	(2) World Sample	(3) Former colonies	(4) Former colonies	(5) Former colonies	(6) Former colonies
Panel A: Second Stage						
Rule of law	0.836***	0.772***	0.882***	0.785***	1.398***	1.308***
	(0.211)	(0.160)	(0.273)	(0.202)	(0.178)	(0.452)
Latitude		0.008		0.007		-0.007
		(0.005)		(0.009)		(0.012)
Neo-Europe		-0.026		-0.031		-1.083
		(0.258)		(0.336)		(0.965)
Sub-Saharan Africa		-0.721***		-0.69***		-0.68***
		(0.150)		(0.172)		(0.236)
LogArea					0.060	0.103
					(0.042)	(0.089)
Panel B: First Stage for Rule of law						
LogArea	-0.103***	-0.145***	-0.091***	-0.140***	-0.091***	-0.165***
	(0.033)	(0.026)	(0.032)	(0.023)	(0.037)	(0.030)
Log Settler Mortality					-0.462***	-0.213***
					(0.064)	(0.070)
R^2	0.060	0.477	0.081	0.581	0.540	0.723
n	157	157	97	97	66	66

Notes: The superscript *** denotes significant at the 1% level, ** significant at the 5% level, * significant at the 10% level. In parenthesis are robust standard errors. Intercept included but not reported. First-stage estimates for exogenous variables Latitude, Neo-Europe, and Sub-Saharan Africa are omitted in columns (2), (4), and (6) due to space constraints. In columns (1)-(4), we use LogArea as the excluded instrument whereas Log Settler Mortality is the excluded instrument in columns (5)-(6) with LogArea as an exogenous conditioning variable.

Table 3: OLS regressions for Rule of law in 2004 on correlates of country size among former colonies.

	Dependent variable: Rule of law in 2004								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
LogArea	-0.152*** (0.016)					-0.132*** (0.043)	-0.137*** (0.020)	-0.106*** (0.025)	-0.140*** (0.019)
LogPop		-0.173*** (0.021)				-0.030 (0.055)			
Fuels and Minerals			-1.810** (0.795)				-0.457 (0.519)		
LogOpen				0.569*** (0.116)				0.273* (0.140)	
Unitarism					0.204* (0.110)				-0.016 (0.123)
Controls for Latitude, Neo-Europe, and Sub-Saharan Africa	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.571	0.520	0.398	0.510	0.377	0.573	0.571	0.596	0.568
N	127	127	112	97	88	127	112	97	88

Notes: The superscript *** denotes significant at the 1% level, ** significant at the 5% level, * significant at the 10% level. In parenthesis are robust standard errors. Intercepts included but not reported.

Table 4: Bivariate regressions estimating the impact of LogArea on correlated variables.

	Independent variable: LogArea			
Dependent variables	Constant	LogArea coefficient	R^2	*n*
(1) LogPop (OLS)	8.110*** (0.417)	0.635*** (0.037)	0.724	127
(2) Fuels and Minerals (OLS)	-0.033* (0.018)	0.059*** (0.002)	0.052	112
(3) LogOpen (OLS)	0.911*** (0.150)	-0.108*** (0.012)	0.317	97
(4) Unitarism (logit)	-	-1.810*** (0.628)	0.527[a]	88

Notes: The superscript *** denotes significant at the 1% level, ** denotes significant at the 5% level, and * denotes significant at the 10% level. In parenthesis are robust standard errors. OLS estimator in rows (1)-(3) and ordered logit in row (4).

[a] Pseudo R^2.

Table 5: Testing for the centrality of the capital among former colonies.

	Dependent variable: Rule of law in 2004					
Independent variables	(1)	(2)	(3)[a]	(4)[a]	(5)[a]	(6)[a]
LogArea	-0.096*** (0.024)		-0.172*** (0.025)	-0.107** (0.045)	-0.171*** (0.025)	-0.147*** (0.054)
LogDistance	-0.137** (0.054)	-0.276*** (0.039)				
Periphery			-0.236* (0.141)	-0.262 (0.169)	-0.246* (0.143)	-0.500** (0.234)
Landlocked				-0.163 (0.171)		
DesertPolarArea				0.127 (0.205)		
Periphery*Landlocked (interaction)					-0.240 (0.251)	
Periphery*Ethnicity1 (interaction)						0.408 (0.330)
Controls for Latitude, Neo-Europe, and Sub-Saharan Africa	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.564	0.523	0.545	0.471	0.551	0.479
n	120	120	95	85	95	82

Notes: The superscript *** denotes significant at the 1% level, ** denotes significant at the 5% level, and * denotes significant at the 10% level. In parenthesis are robust standard errors. All estimations use OLS. Intercept included but not reported. See data appendix for information on measurement and sample.
a: Excluding countries which are defined as an "island group". See data appendix for further information.

Table 6: Controlling for fractionalization and colonial heritage

	Dependent variable: Rule of Law in 2004							
Independent variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
LogArea	-0.1581*** (0.0420)	-0.1678*** (0.0202)	-0.1450*** (0.0160)	-0.1828*** (0.0347)	-0.1493*** (0.0161)	-0.1366*** (0.0210)	-0.1525*** (0.0157)	-0.1353*** (0.0183)
Ethnicity1	0.7623** (0.304)							
Ethnicity2		0.4274 (0.2625)						
Religion			0.5457** (0.2391)					
Log Settler Mortality				-0.2367** (0.0957)				
Duration of colonial rule					0.0007* (0.0004)			
Years of independence from colonial rule						-0.0016 (0.0013)		
Colonized after 1850 (dummy)							-0.1811 (0.1170)	
Legal Origin UK (dummy)								0.9783*** (0.2072)
Legal Origin France (dummy)								0.8216*** (0.1950)
Controls for Latitude, Neo-Europe, and Sub-Saharan Africa	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.5274	0.5676	0.5924	0.6516	0.5788	0.5777	0.5791	0.6226
n	92	117	125	69	127	127	127	125

Notes: The superscript *** denotes significant at the 1% level, ** denotes significant at the 5% level, and * denotes significant at the 10% level. In parenthesis are robust standard errors. All estimations use OLS. Intercept included but not reported. See data appendix for information on measurement and sample.

Table 7: Controlling for geography and interaction terms

	Dependent variable: Rule of Law in 2004							
Independent variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
LogArea		-0.1445*** (0.0234)	-0.1502*** (0.0162)	-0.1370*** (0.0170)	-0.1524*** (0.0156)	-0.1660*** (0.0181)	-0.1878*** (0.0465)	-0.1504*** (0.0163)
LogArea2	-0.099*** (0.0265)							
Island (dummy)		0.0670 (0.1690)						
Landlocked (dummy)			-0.1202 (0.1655)					
Dependency (dummy)				0.5839*** (0.1510)				
Latin America (dummy)					0.1720 (0.1441)			
Sub-Saharan Africa * Logarea (interaction)						0.0716* (0.0428)		
Ethnicity1 * Logarea (interaction)							0.0581** (0.0246)	
Landlocked * Logarea (interaction)								-0.0070 (0.0135)
Controls for Latitude, Neo-Europe, and Sub-Saharan Africa	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.5061	0.5716	0.5729	0.5906	0.5767	0.5797	0.5242	0.5720
N	95	127	127	127	127	127	92	127

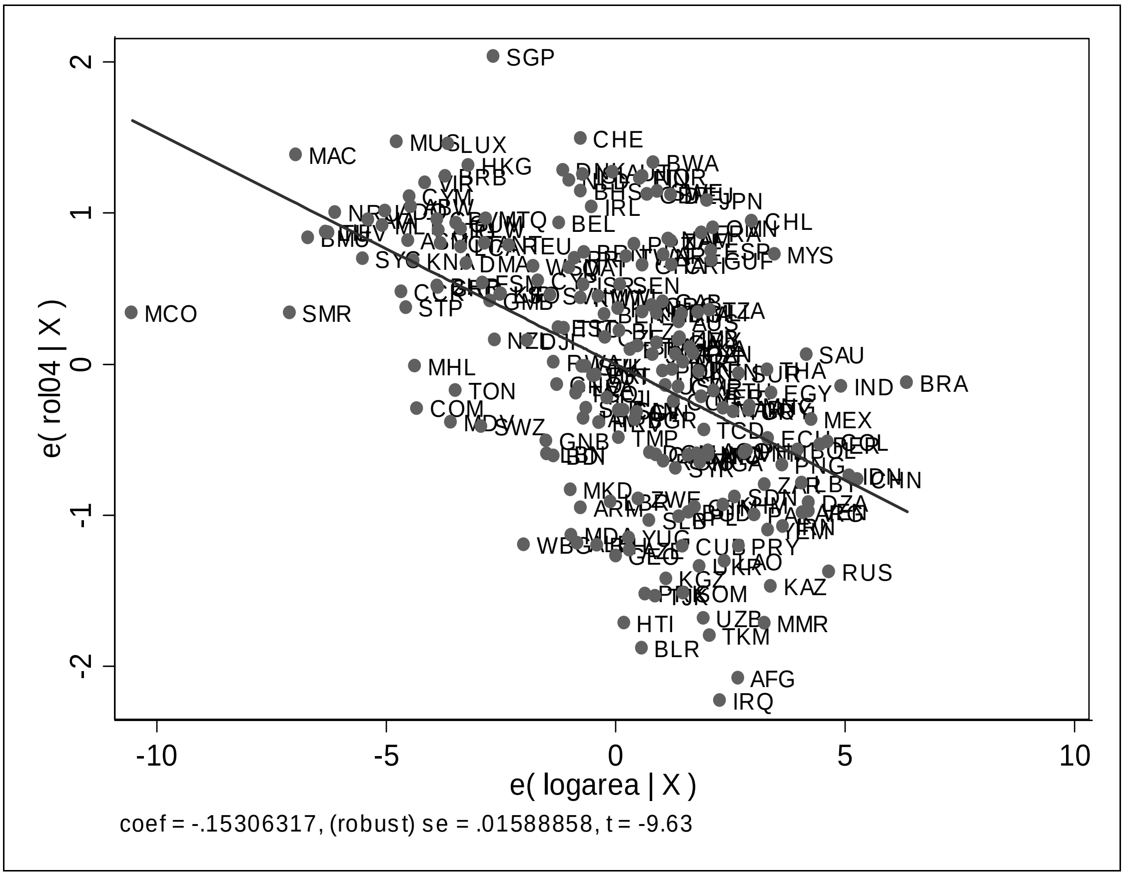
Notes: The superscript *** denotes significant at the 1% level, ** denotes significant at the 5% level, and * denotes significant at the 10% level. In parenthesis are robust standard errors. All estimations use OLS. Intercept included but not reported. See data appendix for information on measurement and sample.

Table 8: Controlling for sample selection bias and measurement error.

	Dependent variable: Rule of law in 2004			
	Controls for Latitude, Neo-Europe, and Sub-Saharan Africa	LogArea coefficient	R^2	*n*
(1) Excluding Sub-Saharan Africa (OLS)	Only Latitude and Neo-Europe	-0.1622*** (0.0176)	0.5476	81
(2) Excluding countries with a population < 500,000 (OLS)	Yes	-0.1451*** (0.0387)	0.5057	97
(3) Excluding countries with imprecise estimates (OLS)	Yes	-0.1614*** (0.0387)	0.5208	90
(4) Using Government Effectiveness as dependent variable (OLS)	Yes	-0.0810*** (0.0223)	0.4199	127
(5) Using Regulatory Quality as dependent variable (OLS)	Yes	-0.1151*** (0.0212)	0.3893	126
(6) Robust regression (rreg)	Yes	-0.1528*** (0.0198)	-	127

Notes: The superscript *** denotes significant at the 1% level, ** denotes significant at the 5% level, and * denotes significant at the 10% level. In parenthesis are robust standard errors expect in row (6). OLS estimator in rows (1)-(5) and robust regression (*rreg* in *Stata*) in row (6).

Figure 1: Partial Scatter Plot, Rule of Law vs. Log Area (World Sample)



Notes: The partial scatter plot from specification in Table 1, column 2.

Figure 2

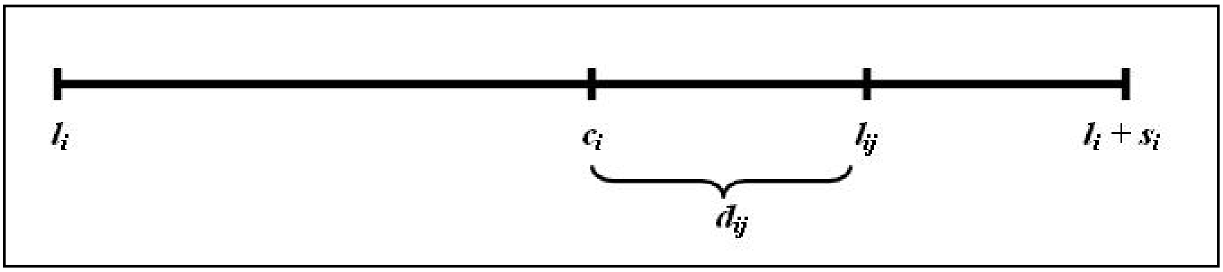
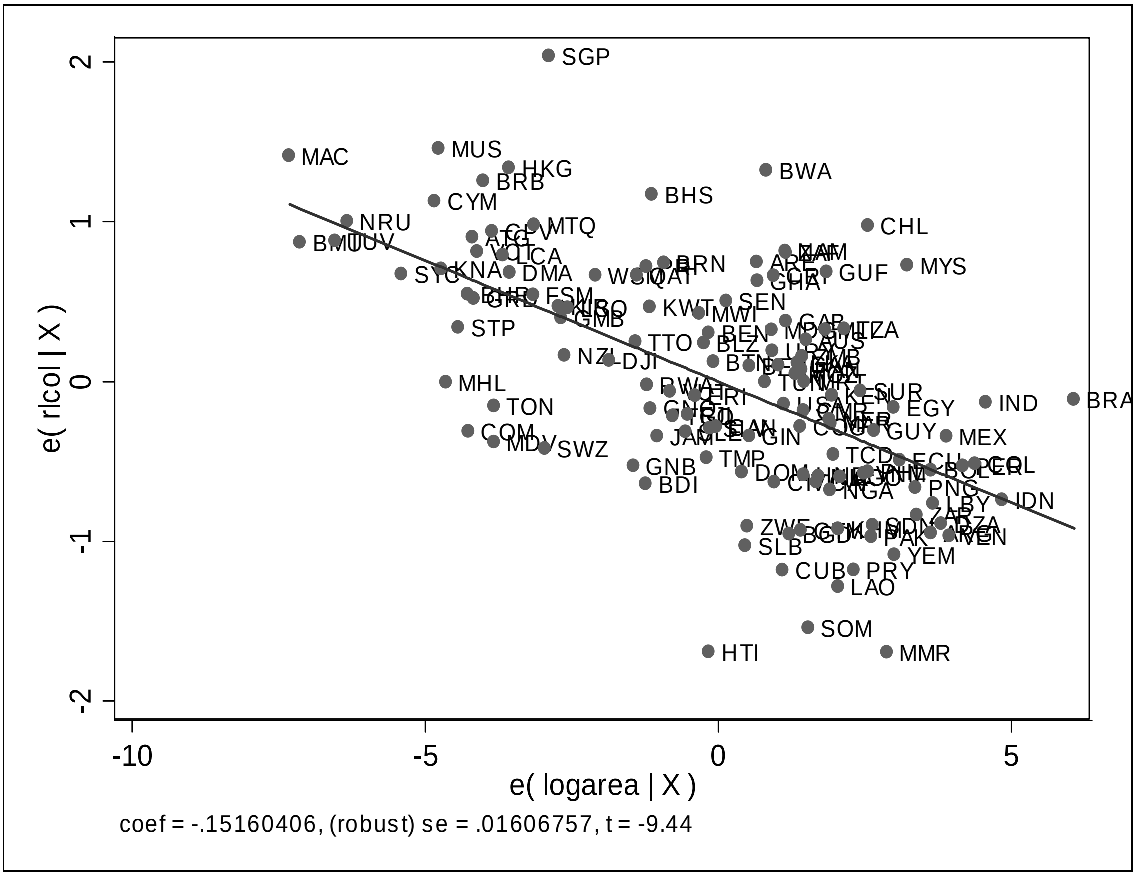


Figure 3: Partial Scatter Plot, Rule of Law vs. Log Area (Former Colony Sample)

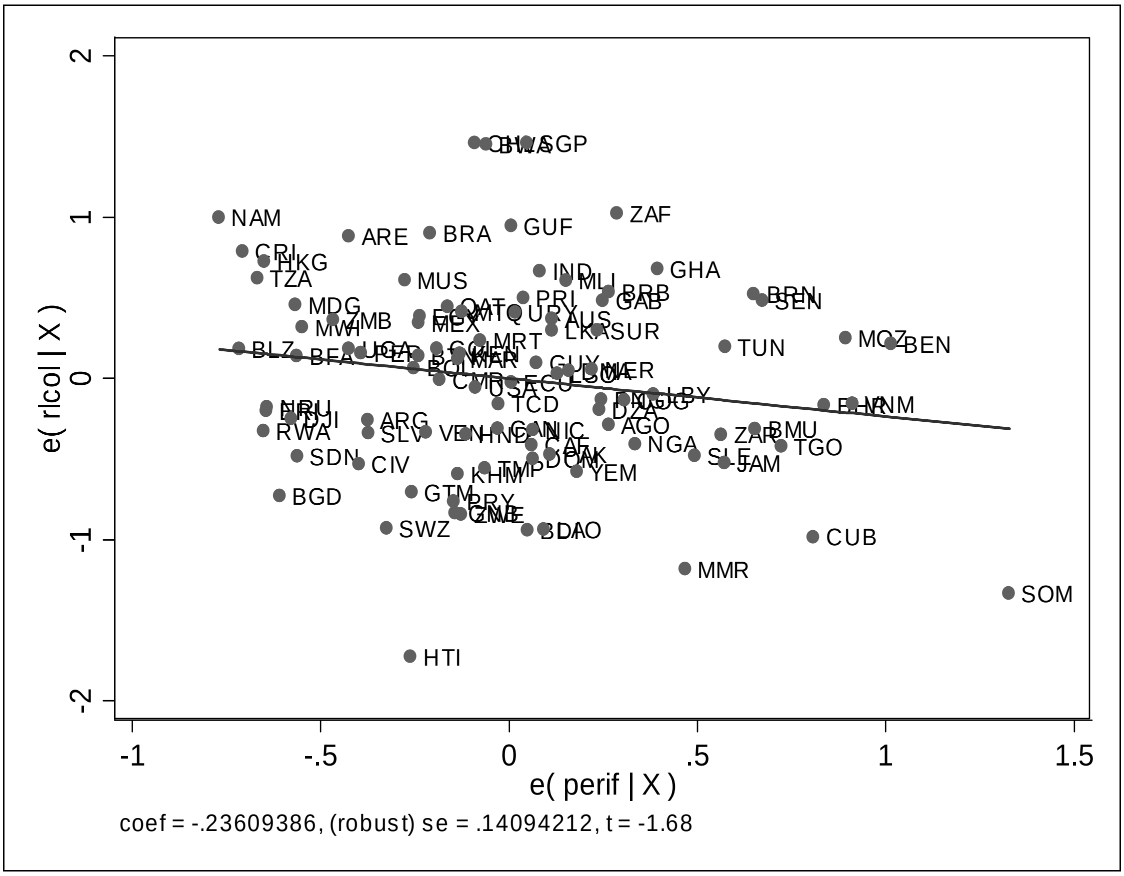


Notes: The partial scatter plot from specification in Table 3, column 1.

Figure 4: Illustration of Periphery Measure, Namibia and Mozambique

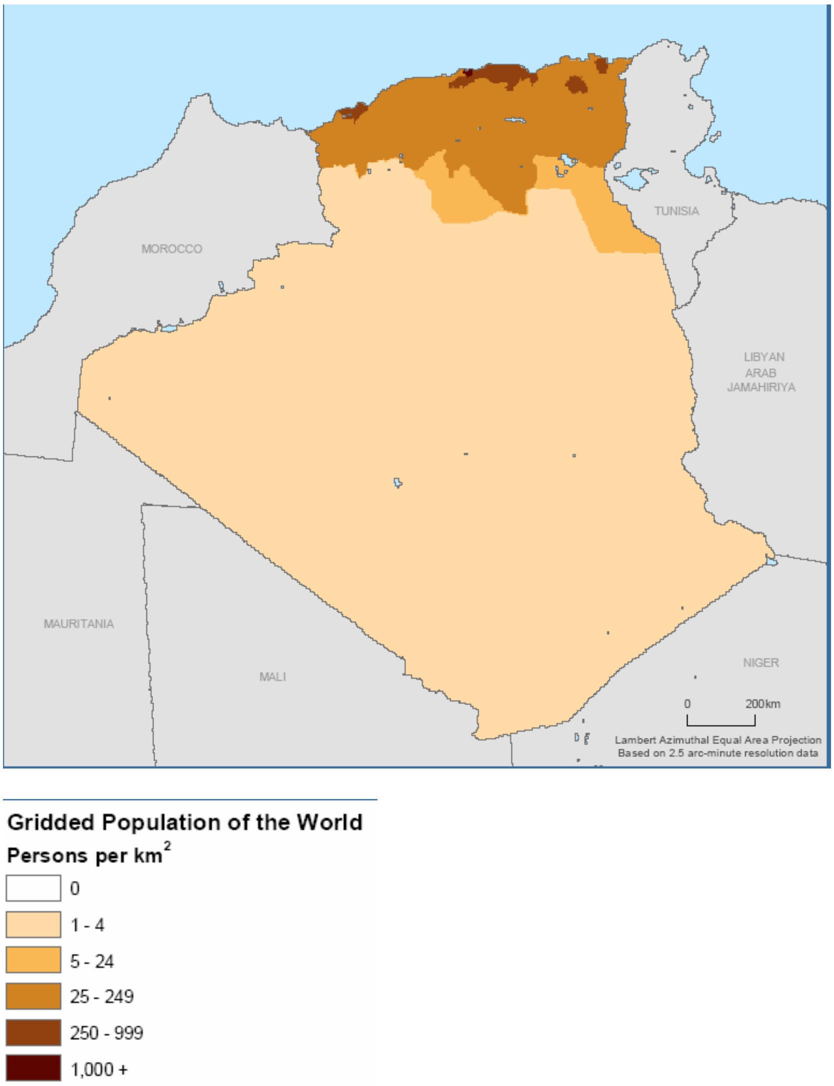
Source: CIA (2005)

Figure 5: Partial Scatter Plot, Rule of Law vs. Periphery (Former Colony Sample)



Notes: The partial scatter plot from specification in Table 5, column 3.

Figure 6: Population Distribution of Algeria.



Source: CIESIN (2006).

Summary Statistics

All the World Sample

Variable	Obs	Mean	Std. Dev.	Min	Max
Control of Corruption	204	0.0000	1.0000	-1.6488	2.5301
Gov't Effectiveness	209	0.0000	1.0000	-2.3204	2.2523
Political Stability	207	0.0000	1.0000	-2.8718	1.7696
Rule of Law	208	0.0000	1.0000	-2.3068	2.0124
Regulatory Quality	204	0.0000	1.0000	-2.6269	2.0159
Voice & Accountability	207	0.0000	1.0000	-2.1875	1.5851
GDP per capita	157	10452.2400	11280.6500	561.0012	69961.2900
LogArea	209	10.8734	3.0395	0.6678	16.6546
Latitude	209	24.6153	16.5380	0.0000	65.0000
Sub-Saharan Africa	209	0.2297	0.4216	0.0000	1.0000
Neo-Europe	209	0.0191	0.1373	0.0000	1.0000

Former Colony Sample

Variable	Obs	Mean	Std. Dev.	Min	Max
Colonized after 1850	127	0.5197	0.5016	0.0000	1.0000
Dependency	127	0.0551	0.2291	0.0000	1.0000
DesertPolarArea	95	0.1734	0.3173	0.0000	1.0000
Duration of Colonial Rule	127	173.1890	126.5852	38.0000	513.0000
Ethnicity1	92	0.5522	0.2536	0.0395	1.0000
Ethnicity2	117	0.4932	0.2601	0.0000	0.9302
Unitarism	88	1.5455	0.6371	0.0000	2.0000
Island	127	0.2992	0.4597	0.0000	1.0000
Landlocked	127	0.1417	0.3502	0.0000	1.0000
Latin America	127	0.2756	0.4486	0.0000	1.0000
Legal Origin France	125	0.4960	0.5020	0.0000	1.0000
Legal Origin UK	125	0.4640	0.5007	0.0000	1.0000
LogArea	127	10.9877	3.0812	3.0445	16.1166
Area	127	680882.0000	1634000.0000	21.0000	9984670.0000
LogArea2	95	11.9860	2.1077	4.7295	16.0103
LogDistance	120	4.9640	1.4520	0.9285	7.6325
LogOpen	97	-0.3360	0.5369	-1.4426	1.0761
LogPop	127	15.0881	2.3000	9.2398	20.7762
Log Settler Mortality	69	4.6852	1.2171	2.1459	7.9862
Fuels and Minerals	112	0.0331	0.0751	0.0000	0.3622
Periphery	95	0.8269	0.4434	0.0000	2.1631
Religion	125	0.4621	0.2427	0.0023	0.8603
Rule of Law	127	-0.2194	0.8876	-2.3068	1.9258
Rule of Law n	127	9.2047	4.4496	1.0000	17.0000
Rule of Law se	127	0.1786	0.0749	0.1135	0.7105
Years of Independence	127	62.7638	57.3785	0.0000	228.0000

Variable Description

Control of Corruption	Control of Corruption, Source Kaufmann et al (2005)
Colonized after 1850	Dummy variable. =1 if colonized after the year 1850. Own assessment.
Dependency	Dummy variable. =1 if country is not independent, not its own sovereignty. From CIA World Factbook 2005
DesertPolarArea	Share of country area with desert and/or polar climate. Data from Gallup et al (1999), Desert climate *kg_a_bw* (BW-type according to the Köppen-Geiger classification) and polar climate *kg_a_e* (E-type). DesertPolarArea= *kg_a_bw* + *kg_a_e*
Duration of Colonial Rule	Duration of colonial rule. Year of independence (max 2004) minus year of colonialization. Own assessment.
Ethnicity1	Ethnic Fractionalization. From Fearon (2003)
Ethnicity2	Ethnic Fractionalization. Covers the period 1979-2001. From Alesina et al (2003)
Fuels and Minerals	Energy (crude oil, natural gas, and coal) and Mineral (bauxite, copper, gold, iron, lead, nickel, phosphate, silver, tin, and zinc) depletion as a share of GNI 1999. From World Bank data on Adjusted Net Savings.
GDP per capita	PPP GDP per capita 2004. Data from World Development Indicators 2005
Gov't Effectiveness	Government Effectiveness. Source Kaufmann et al (2005)
Island	Dummy variable. =1 if Island. An Island is defined as a country with no land boundary. Based on "land boundary" from CIA World Factbook 2005.
Landlocked	Dummy variable. =1 if country is landlocked. From CIA World Factbook 2005
Latin America	Dummy variable. =1 if country is part of Latin America
Latitude	Absolute latitude degree. Source CIA World Factbook 2005,
Legal Origin France	Legal Origin French From La Porta et al (1999)
Legal Origin UK	Legal Origin British, From La Porta et al (1999)
Log Settler Mortality	Natural logarithm of Settler Mortality, from Acemoglu et al (2000)
LogArea	Natural logarithm of total area (including lakes and rivers) in sq km. Source CIA World Factbook 2005
LogArea2	To adjust for uninhabitable areas, we have used data from Gallup et al (1999) measuring the share of country area with desert climate *kg_a_bw* (BW-type according to the Köppen-Geiger classification) and the share with a polar climate *kg_a_e* (E-type). We have then used the formula: *LogArea2*=ln(Area(1-(*kg_a_bw* + *kg_a_e*)/1.01)). This conversion allows countries that are coded as having all their area in a desert climate (for instance Egypt) to have at least 0.99 percent of their territory counted.
LogDistance	Natural logarithm of the distance in kilometers from the Seat of the Government (data from CEPII, 2006) to the approximate center of the country (CIA, 2005). Calculated by Great Circle Distance Formula (see http://mathworld.wolfram.com/GreatCircle.html, and; http://www.meridianworlddata.com/Distance-Calculation-asp) Step 1: Retrieve the coordinates for the two locations, expressed in decimal degrees. Step 2: Convert all latitude and longitude degrees into radians by taking the decimal degree/(180/ Π) where Π=3.14159. Define the first coordinate as "lat1" and "lon1" and the second coordinate as "lat2" and "lon2". Step 3:calculate according to Great Circle Formula: *Distance*=r*arccos*[sin(lat1)*sin(lat2)+cos(lat1)*cos(lat2)*cos(lon2-lon1)) where r=6378.7, the radius of the earth in kilometers. Macau, Guinea, Kuwait, The Gambia, Saint Lucia where excluded due to erroneous data in either capital or approximate center coordinate. Nauru and Micronesia both have a distance of zero.

LogOpen	Natural logarithm of Open, where Open=(exports + imports)/GDP, all from 2002 in current prices local currency units. Source World Development Indicators 2004
LogPop	Log of total population (2002). Source UNSTATS
Neo-Europe	Dummy variable, =1 if Australia, Canada, New Zealand, or the USA
Periphery	Measure of uncentrality of the capital: $Periphery = Distance / (\text{Area}/\Pi)^{1/2}$ For *Distance* see description of LogDistance The shape of all countries is here assumed to be described as a circle, and where $(\text{Area}/\Pi)^{1/2}$ is the radius of that circle, hence the approximate distance from the center to the border. Countries which we defined as "island group" have been excluded. Island groups are the countries which shape least can be approximated as a circle. Countries classified as Island group: Antigua and Barbuda; The Bahamas; Comoros; Cape Verde; Cayman Islands; Fiji; Micronesia; Grenada; Kiribati; Saint Kitts and Nevis; Maldives; Marshall Islands; New Zealand; Philippines; Solomon Islands; Sao Tome and Principe; Seychelles; Tonga; Trinidad and Tobago; Tuvalu; Saint Vincent and the Grenadines; Vanuatu; Samoa. Countries similar to island group (also excluded): Equatorial Guinea; Indonesia; Malaysia; Panama.
Political Stability	Political Instability and Violence, Source Kaufmann et al (2005)
Regulatory Quality	Regulatory Quality, Source Kaufmann et al (2005)
Religion	Religious Fractionalization, for 2001. From Alesina et al (2003)
Rule of Law	Rule of Law, Source Kaufmann et al (2005)
Rule of Law n	Standard Error of Rule of Law measure, Source Kaufmann et al (2005)
Rule of Law se	Number of sources per estimate, Source Kaufmann et al (2005)
Sub-Saharan Africa	Dummy variable. =1 if country is part of Sub-Saharan Africa
Unitarism	Unitarism year 2000. Average of Nonfederalism and Nonbicameralism. Nonfederalism is coded as 0 = federal (elective regional legislatures plus conditional recognifition of subnational authority), 1= semifederal (where there are elective legislatures at the regional level but in which constitutional sovereignty is reserved to the national government), or 2=nonfederal. Nonbicameralism is coded as 0=strong bicameral (upper house has some effective veto power, though not necessarily a formal veto; the two houses are congruent), or 2=unicameral (no upper house or weak upper house). Source: Teorell, Jan, Sören Holmberg & Bo Rothstein. 2006. The Quality of Government Dataset, version 1Jul06. Göteborg University: The Quality of Government Institute, http://www.qog.pol.gu.se.
Voice & Accountability	Voice and Accountability, Source Kaufmann et al (2005)
Years of Independence	Years of independence since colonialization. 2004 minus year of independence. Own assessment.

Where Did All the Investments Go? New Evidence on Equipment Investment and Economic Growth

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Abstract

Equipment investment is one of the very few variables claimed to be robustly related to economic growth. This paper examines new empirical evidence on the robustness of this relation. Firstly, the main result from DeLong and Summers (1991) is extended and tested. Secondly, the investment growth nexus is examined in a panel data setting. Thirdly, the paper relates the investment-growth relationship to recent findings on investment prices and economic development. The results repeatedly refute that there is a strong robust correlation between investment and income growth.

JEL classification: E31; O11; O16; O40.
Keywords: Economic Growth; Equipment; Investment; Prices.

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1. Introduction

Understanding the process of economic growth is one of the most important objectives in economics. However, to empirically determine the robust correlates to income growth has proven surprisingly hard. In a series of papers, DeLong and Summers (1991, 1992, 1993) described a strong and robust relationship between equipment investment and income growth. Equipment investment was also one of the very few variables found to be robustly related to growth by Levine and Renelt (1992), Sala-i-Martin (1997a, b), and Hoover and Perez (2004). The importance of equipment investment has therefore almost come to be accepted as a stylized fact (Abel, 1992) and is an often advocated remedy for poor growth (World Bank, 2005; Easterly, 2001).

The strength of the investment growth nexus is questioned by Auerbach et al. (1994), Blomström et al. (1996), Easterly and Levine (2001) and Easterly (2001) among others. The critique is of both theoretical and empirical nature. Theoretically, the discussion ranges from the Solow (1956) growth model, where investment is not the key to long run growth due to diminishing returns to capital, to the *AK* model where "learning by doing" due to capital accumulation leads to sustained income growth. Empirically, the relation between equipment investment and growth described in DeLong and Summers (1991) is challenged foremost by Auerbach et al. (1994), who show that the results are sensitive to small sample modifications and are based on poor data. Because of these data limitations, DeLong and Summers (1994, p.807) reply that they "hope and expect to se others either confirm or disconfirm our results by using different procedures to estimate the components of investment, by analyzing different samples and time periods…"

Despite the uncertainty about the relationship, the belief that investment is important for growth remains strong and is largely influenced by DeLong and Summers (1991) and Sala-i-Martin (1997a, b). Interestingly, the data constructed in DeLong and Summers (1991, 1993) has survived to this day and is the same data used in Sala-i-Martin (1997a,b) and Hoover and Perez (2004). The fact that both arguments and data from DeLong and Summers (1991, 1993) still play an influential role in the debate today motivates the following question: If we reconstruct and extend the analysis using more recent data, do the main results from DeLong and Summers (1991) still hold? The analysis is implemented in three steps.

Firstly, the main regressions from DeLong and Summers (1991) are reconstructed and extended. Most importantly, the average equipment investment share is reconstructed and extended using updates of detailed Purchasing Power Parity (PPP) adjusted data from the U.N. International Comparison Programme. As it turns out, the estimated effects from equipment investment are much lower and most often statistically different from the effects found in DeLong and Summers (1991). Moreover, in the largest sample, the effect from equipment investment is statistically insignificant. The relationship between equipment investment and income growth is therefore no longer a strong and robust finding in a DeLong and Summers regression set-up.

Secondly, although the relationship between equipment investment and growth is proven to be weak using more recent data, one might still not be satisfied with the data construction and regression specification suggested by DeLong and Summers (1991). Most importantly, this concerns the measurement of the average equipment share and the possibility of reverse causality, as pointed out by Sala-i-Martin (1997a,b), Hoover and Perez (2004), and Blomström et al. (1996) among others. This paper therefore suggests an alternative yet straightforward approach which includes all the variables proposed by DeLong and Summers, but at the same time uses better and more direct measures of the investment shares as well as initial investment shares in a panel data setting in order to reduce the problems of reverse causality. Using measures of the equipment share, the producer durables share, and the total investment share, the results show that investments, however defined, do not correlate strongly and robustly to income growth.

As a last exposition, this paper relates DeLong and Summers (1991) to recent findings on the relationship between investment prices and economic development. Closely connected to the claim that investment is important for income growth is the claim that countries that invest too little have a high price on investment goods. Rich countries are here associated with high quantities of investment and low prices of investment. It is therefore often suggested that policy should aim at reducing trade restrictions and taxes on capital goods.[1] As clarified by Hsieh and Klenow (2006), the

[1] See the reference cited in Hsieh and Klenow (2006).

price level of investment goods is not systematically higher in poor countries compared to rich. The relative price level is negatively related to income, simply due to consumption goods in general being much cheaper in poor countries. Furthermore, this relates to the derivation of the PPP adjusted prices used to transform expenditures valued at domestic prices (called nominal expenditures) to expenditures valued at common international prices (called real expenditures). As it turns out, the real investment share is positively related to income, while the nominal investment share is not. These findings create interesting questions relating to our analysis of investment and growth. Firstly, since the findings above highlight the importance of the nominal equipment share, is there any justification for using the nominal equipment share in a growth regression, and what would the results then be? This paper argues that the use of nominal shares could be justifiable, but the nominal investment shares still do not seem to be robustly related to income growth. Secondly, how does the above relation between prices and income relate to the DeLong and Summers argument that low prices of investment are associated with high quantities of investment, which in turn are associated with high income growth rates? As it turns out, although there is no systematic relation between the investment price and income, countries with lower investment prices tend to invest more, however, higher investment quantities do not seem to promote growth.

The three main contributions of this paper are that it reconstructs and extends the influential analysis of DeLong and Summers (1991), it examines the relation between initial investment shares to subsequent growth in a panel data setting (while the use of initial investment shares is not new, the use of the detailed ICP data in a DeLong and Summers regression set-up to my knowledge is), and that it relates recent findings about investment prices and income levels to the analysis of investment prices and income growth. Additionally, the use of nominal investment shares in a cross country growth regression is, as far as I know, a novelty in the literature.

The paper is organized as follows: Section 2 reconstructs, extends, and discusses the main regression in DeLong and Summers (1991). Section 3 transforms the cross section regressions into a panel data set using initial investment shares. Section 4 discusses the nature of investment prices and its implications for the investment share, and Section 5 concludes the paper.

2. Equipment Investment and Economic Development

2.1 Why Should Investment Cause Growth?

The difference between capital fundamentalists and their critics can be explained as the difference between the *AK* model and the Solow (1956) growth model. In the Solow model, the investment share (equal to the saving rate) is important since it determines the income level, even though investment is not the key to long run growth due to diminishing returns to capital. As capital accumulation takes place, each additional unit of capital will produce less and less additional output up to the point where a steady state is reached where growth is only determined by technological progress. In the *AK* model, the diminishing returns to capital effect is absent, often modeled to be due to the notion of "learning by doing" introduced by Arrow (1962). The intuition is that the capital accumulation in itself teaches us something about the production process, and this learning by doing contributes to productivity.[2]

The assumption made in DeLong and Summers (1991, 1992, 1993) is that the strong correlation between equipment investment and income growth is due to these additional benefits of capital accumulation, or more specifically as DeLong and Summers (1992, p.193) write: "…the large coefficient on equipment investment arises because equipment investment is a trigger of learning-by-doing and thus of substantial total factor productivity growth."

The idea that there is a "learning by doing" effect is neither farfetched nor implausible. The question should maybe instead be concerned with the size of this effect. Either the "learning by doing" effect is large and we should see a strong positive relationship between investment and growth, or it is very small or non-existent and investment has a very small or no effect on long run growth.

2.2 Extending DeLong and Summers (1991)

Investment, or more formally Gross Capital Formation, is divided into: Construction (residential, nonresidential, and land improvements), Producer Durables (transport equipment, electrical and non-electrical machinery and equipment); and Increases in Stocks (inventories and valuables). In DeLong and Summers (1991)

[2] See for example Barro and Sala-i-Martin (1995).

(henceforth DS), investment is divided into equipment investment and non-equipment investment in order to demonstrate the importance of equipment investment specifically, as the important driver of income growth. The main regression specification used in DS to test and describe the impact of equipment investment and growth is formulated as

$$growth_i = \beta_0 + \beta_1(equip.\ share_i) + \beta_2\ (struct.\ \ share_i) + \beta_3\ (n_i) + \beta_4(gap_i) + \varepsilon_i\ , \qquad (1)$$

where "*growth*" is the annual growth rate of GDP per worker from 1960 to 1985. The "*equipment share*" is the average equipment investment share of GDP from 1960 to 1985, and the "*structures share*" is the average share of GDP devoted to non-equipment investment for the same period. "*n*" is the growth rate of the labor force also for the same period, and "*gap*" is the proportionate initial gap in real GDP per worker relative to the US in 1960.[3] The control variables "*gap*" and labor force growth "*n*" are included to capture other factors that could influence the growth rate of GDP per worker. More specifically, the "*gap*" variable is included to control for any "systematic causal relationship running from the level of GDP per worker to the level of equipment investment" (DeLong and Summers, 1991, p.453).

As a first exercise, this paper will try to extend and reconstruct equation 1 by using more recent data. That is, using more recent data, does the main result from DeLong and Summers (1991) still hold? To do this, let us first get a clear understanding of the data and how the investment share is constructed.

2.3 Data and Sample

Cross country comparisons of national accounts are usually made by using data valued at common international prices. Detailed headings such as the equipment investment share are not readily available at international prices. DS therefore constructed their average equipment investment share based on data from the United Nations International Comparison Programme (ICP) and the Penn World Tables (Summers and Heston, 1990).

The ICP collects prices of hundreds of identically specified goods and services around the world in order to construct PPP estimates. The data collection is made

[3] Gap= $1-(Y/L)_i/(Y/L)_{us}$, where Y is GDP, L is labor force, and the subscripts i and us stand for country i and the US, respectively.

about every fifth year for a limited number of countries, and forms a so-called "benchmark." The PPPs for the countries and years not part of the ICP benchmark are then estimated based on the benchmark data. The PPPs that finally emerge are used to convert expenditures in *domestic* prices into expenditures at *common* prices called "real expenditures," enabling international comparisons. Well-known datasets such as the Penn World Tables and the World Development Indicators base their PPP adjusted data on these benchmark studies from the ICP.[4]

DS wanted to calculate the average real equipment share for the 1960-1985 period, but the ICP data was only available for the years 1970, 1975, and 1980. DS therefore combined the ratio of equipment investment to total investment and multiplied it by the total investment share of GDP from the Penn World Tables in the following manner: If the equipment-to-total-investment-ratio was available for 1970, 1975, and 1980 (which were the benchmarks available at the time), then the average equipment share was constructed by multiplying the 1970 ratio by the average total investment share of GDP from 1960-72, multiplying the 1975 ratio by the average total investment share of GDP from 1973-1977, and the 1980 ratio by the average equipment shares from 1978-1985. These three values were then averaged. If only the 1975 and 1980 ratios were available, then they were first multiplied by the average investment share of GDP from 1960-1977 and 1978-1985, respectively, and then averaged. Finally, if only the 1980 equipment share of investment was available, then it was simply multiplied by the average investment share of GDP from 1960-1985.

Since the DS study, more ICP benchmark data has become available, and data for the benchmark years 1970, 1975, 1980, 1985, and 1996 is freely available from the Penn World Tables website.[5] It is therefore possible to reconstruct and extend the average equipment share as formulated in DS, and this paper presents three ways in which this is done.

Firstly, the data is reconstructed for the 1960-1985 period, which is the same period as in DS, using the same method as DS but with more up-to-date data (Penn

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[4] For more information on the ICP procedure and PWT methodology, see for example: Handbook of the International Comparison Programme (1992), Summers and Heston (1991), Data Appendix for Space-Time System of National Accounts: Penn World Table 6.1 (PWT 6.1), and PWT6 Technical Documentation.

[5] http://pwt.econ.upenn.edu/Downloads/benchmark/benchmark.html The years and number of countries for the different ICP benchmark studies are: 1970 (16 countries), 1975 (34 countries), 1980 (61 countries), 1985 (64 countries), 1990 (24 countries), and 1996 (115 countries). The 1990 benchmark is not available at the Penn World Tables website.

World Tables 5.6). The reconstructed equipment share has a correlation of 0.9 to the original DS equipment share, and is therefore an almost perfect image of the original data.

Secondly, by using the ICP benchmark data for 1985 and Penn World Tables 5.6, the average equipment share is extended to cover the 1960-1990 period. The matching between the equipment-to-total-investment-ratio and the total investment share is done in the same spirit as in DS, details of which are presented in the Data Appendix.

Thirdly, the ICP benchmark 1996 is added and the period covered is now 1960-2000, using Penn World Tables 6.1. The 1996 benchmark is special since the investment data is now only disaggregated into producer durables (equipment investment and transport equipment), construction, and change in stocks. This should be of little concern. DS focused primarily on equipment investment and not producer durables since they found that transportation provided "little information" (DS p.449). In DeLong and Summers (1992, 1993), the focus is instead on producer durables. The difference between producer durables and equipment investment should therefore play a minor role. The matching between the producers-durables-to-total-investment-ratio and the total investment share is done in the same DS spirit, details of which are described in the Data Appendix.

The use of ICP benchmark data restricts the sample to only include benchmark countries. DS divided this sample into a "large" sample containing all countries available (n=61), and a "high productivity" sample (n=25) (both after excluding major oil exporting countries). A high productivity sample is created since DS are skeptical of what can be learnt by combining very poor countries, which have very low productivity levels, with very rich countries, which have high productivity levels. The high productivity sample is constructed to consist of industrialized countries most like the US, by including countries with GDP per worker levels greater than 25 percent of the US level in 1960 $\left((Y/L)_i / (Y/L)_{us} > 0.25\right)$.

In a critical comment by Auerbach et al. (1994), an OECD sample is preferred to represent the countries most like the US. They demonstrate that for the OECD sample, the relationship between equipment investment and growth falls apart. DeLong and Summers (1994) reply that the OECD is foremost a political and not an economic grouping. Since the goal of DS was to create a high productivity sample with industrialized countries most like the US, it is argued that the high productivity sample should be based on economic rather than political grounds. In DeLong and Summers (1993), the importance of a high productivity sample is weakened, and it is shown using a new dataset that the equipment and growth nexus is the strongest amongst developing countries. Since this paper primarily follows in the footsteps of DS, both a large and a high productivity sample will be used. Regardless of the sample, the empirical examination will put special attention into finding influential outliers. As it turns out, the choice of sample plays a crucial role, and we will return to this issue repeatedly throughout the paper.

2.4 Results

Table 1 presents the regression results using the reconstructed and extended data. Columns 1-6 present the regression results for the 1960-1985 period. Columns 1 and 2 contain the regression results for the high productivity sample (labeled hp) and for all countries (labeled large), using the original DS data as it appears in the journal article.[6] Not surprisingly, the parameter estimates for the real equipment shares are positive and statistically significant in both the hp and the large sample. If the parameter estimate for the equipment share in the hp sample were to be interpreted, then a three percentage point increase (one standard deviation) in the equipment share would lead to a 1.02 percentage point increase in the annual GDP per worker growth, which is a large effect.

Columns 3 and 4 present the regression results for the same sample of countries using the same benchmark years as in the previous columns, but using the reconstructed data based on Penn World Tables 5.6. As mentioned earlier, the reconstructed equipment share has a correlation of 0.9 to the original DS data, and the coefficients are therefore also very similar to the original DS results.

The regression results in Columns 5 and 6 are based on the same data sources as in Columns 3 and 4. However, the high productivity sample is here selected by the more recent data source (Penn World Table 5.6), and the large sample also includes Syria, Romania, and Yugoslavia.[7] The regression results concerning the equipment

[6] I am aware that DeLong and Summers have made a slight modification in this dataset due to an error. Nonetheless, the error is supposed to play only a minor role, and the replications in Columns (1) and (2) still serve their purpose.

[7] These countries are in the 1970, 1975, or 1980 ICP benchmarks, but were for some reason not included in DS.

share in Columns 5 and 6 are still in line with the original DS results. Reconstructing the data for the 1960-1985 period does therefore not present any surprises concerning the relationship between the equipment share and income growth.

In the next two columns, 7 and 8, the benchmark year 1985 has been added and the period studied is 1960-1990. The coefficients for the equipment share are still positive and significant, although the coefficient for the equipment share in Column 7 is statistically different from the DS result in Column 1.[8] The coefficient in Column 7 can be interpreted as if the equipment share increases by three percentage points, then the annual growth rate increases by 0.64 percent. This is almost half of the effect compared to the DS high productivity sample.

Finally, in the last two columns of Table 1 (Columns 9 and 10), the ICP benchmark year 1996 is added and the period studied is 1960-2000. As described above, the equipment investment share now includes transportation equipment. The 1960-2000 sample makes use of most ICP benchmark studies and a more recent version of the Penn World Tables (Mark 6.1). The investment shares that emerge are not necessarily of any higher quality than before, but the sample of countries is the largest and therefore perhaps the most important of the samples in Table 1. As it turns out, the coefficient for the equipment share in Columns 9 and 10 are both statistically insignificant and statistically different from the coefficients in Columns 1 and 2. If the effect from the hp sample was to be interpreted despite its insignificance, then a three percent increase in the equipment share would increase the annual growth rate by 0.3 percentage points. This effect is rather poor, and is less than a third of the effect that DS found.

Figure 1 illustrates the partial scatter plot between the equipment share and income growth for the 1960-2000 hp sample (Column 9 in Table 1). More precisely, the figure illustrates the component of the equipment share that is orthogonal to the GDP per worker gap, labor force growth, and the non-equipment share, against the component of income growth that is orthogonal to the same three variables. The plot does not portray a convincing picture of a robust relation between investment and income growth.

The insignificance of the equipment share in the high productivity sample is robust both to an exclusion of large fuel exporting countries, and to an extension of

[8] The parameter estimate for equipment investment in Column 7 is not included in the 95% confidence interval for the corresponding parameter estimate in Column 1.

the sample to include countries missing up to 10 years of GDP per worker or labor force observations. If the 1960-2000 sample is reduced to only include those countries of the *large* DS sample (as in Column 2 and 4 with the exception of Tunisia, West Germany, and Botswana due to data limitations), then the coefficient for the equipment investment is still insignificant. If instead the 1960-2000 sample is reduced to the DS *hp* sample (as in Column 1 and 3 except West Germany), then the coefficient for the equipment share is instead positive and significant. The insignificant effect from equipment investments in Column 9 is therefore not due to strange data, but instead to what sample is being used.[9]

Turning the attention to the non-equipment share, it is important to note that its coefficient in Column 1 is statistically insignificant. DS argued that this suggests that equipment investments drive growth and not the other way around. If it were the case that income growth causes investments, then the coefficients for both the equipment *and* non-equipment investments would logically be significant. For the reconstructed and extended data in Table 1, the coefficient for the non-equipment share is significant for the hp sample for the 1960-1985 period (Column 5) and the 1960-1990 period (Column 7) and in all large samples (Columns 2, 4, 6, 8, and 10). By using the DS argumentation, this indicates that growth might actually cause investment and not the other way around.

To summarize, there are three main conclusions to be made from Table 1. Firstly, the coefficients for the equipment share are positive in all specifications, but statistically insignificant for the 1960-2000 samples. The relationship between investment and growth is therefore no longer a robust finding in a DeLong and Summers regression set-up. Secondly, the effects from equipment investment are with the extended and reconstructed data much lower and most often statistically different from the effects using the original DS data. Thirdly, the effects from equipment investment and non-equipment investment both being statistically significant indicate that income growth might cause investment and not the other way around.

[9] The difference between the DS high productivity sample and the 1960-2000 high productivity sample is the exclusion of West Germany and Hong Kong, and the inclusion of Australia, Barbados, Colombia, El Salvador, Greece, Iceland, Jordan, New Zealand, Portugal, Sweden, Switzerland, and Trinidad and Tobago.

2.5 Problems and Weaknesses

Although the causal relationship between equipment and growth seems less strong when the DS analysis is updated, one might still be dissatisfied with how the analysis is implemented. As with most research, the DS analysis has its weaknesses. The weaknesses discussed in this paper are: The measurement of the investment share, the likely possibility of reverse causality, sample selection, and data availability forcing us to put the most emphasis on regressions with only 23 to 35 observations.

As described above, the average equipment share is constructed by multiplying the equipment-to-total-investment-share-ratio for a specific year by the average total investment share. As DeLong and Summers (1992, 1993) themselves explain, this construction relies heavily on the ratio of equipment investment to total investment in the benchmark years as being a good proxy for the average ratio of equipment to total investment. In order to sharpen these estimates, DeLong and Summers (1992) impute values based on equipment imports from the OECD, and DeLong and Summers (1993) impute values based on the relationship between the equipment share in their 1991 paper and reported equipment imports from the OECD, the relative price of capital, the total investment share, and the average ratio of the national product per worker to the US one. Still, these equipment shares can only be rough approximations of the true equipment shares, and in light of what will be clarified in Section 4 about the relation between the relative price of equipment and income, the above procedure raises doubts.

A more important question is if the use of an *average* equipment share is desirable at all. Using the DeLong and Summers (1993) data on equipment shares, Sala-i-Martin (1997a,b) and Hoover and Perez (2004) found equipment investment to be one of the very few variables to be robustly related to income growth.[10] The average equipment share for 1960-1985 was related to the income growth rate for 1960-1992. Sala-i-Martin (1997a, p.8) therefore makes clear that the inclusion of "such a variable may be 'more endogenous' then exogenous," and that a variable measured at the beginning of a period would be preferable. Hoover and Perez (2004, p.788n) also remark that it is "ambiguous" to interpret the coefficient for equipment investment in their final specification due to endogeneity concerns. That is, although

[10] Hoover and Perez (2004) use the dataset from Sala-i-Martin (1997a, b). The reference for equipment investment cited in Sala-i-Martin (1997a,b) is DeLong and Summers (1991), while the data is in fact from DeLong and Summers (1993).

both Sala-i-Martin (1997a, b) and Hoover and Perez (2004) found equipment investment to be one of the very few variables robustly related to growth, they also clearly acknowledge that their results could be due to reverse causality. The significant non-equipment effects in Table 1 also indicate that we might have reverse causality.

Time series studies on investments and growth put more light on this issue. Blomström et al. (1996) found that growth rates cause investments, but investment shares do not cause growth rates. Carroll and Weil (1994) found a similar result between savings and growth. Podrecca and Carmeci (2001) found that causality probably runs in both directions: investment shares Granger-cause growth rates, and growth rates Granger-cause investment shares. Additionally, the causality from investment shares to growth rates is in Podrecca and Carmeci (2001) found to be negative. A negative correlation between growth and lagged investment, controlling for lagged growth, is perfectly consistent with the Solow (1956) growth model, but inconsistent with endogenous growth theory such as for example the *AK* model.[11]

In DS the endogeneity concern is addressed to some degree by having the lagged investment shares for the 1960-1975 period determine the income growth rate for the 1975-1985 period (Table VII in DS). Using the original DS data as well as reconstructing the data using Penn World Tables 5.6, the "lagged" investment regressions are presented in Table 2. In the large sample, neither the DS data nor the replicated data can show a statistically significant coefficient for the lagged equipment share or the lagged non-equipment share. In the high productivity sample, the coefficient for the lagged equipment share is positive and significant while using the DS data, but insignificant using the replicated data. The replicated hp sample is based on Penn World Tables 5.6, where Hong Kong and Japan no longer meet the requirements for being part of the hp sample and are therefore not included. In fact, this small change makes a difference. If Hong Kong and Japan instead are included, then the parameter estimate for the lagged equipment share is positive and significant also when using the replicated data. This small exercise therefore demonstrates that the results are sensitive to small sample modifications, a problem that is exaggerated by the small sample size.

[11] See Vanhoudt (1998) for a formal demonstration.

However, the lagged equipment shares as constructed by DS and used in Table 2 are not really lagged equipment shares. The lagged equipment shares were constructed by taking the average of the equipment-to-total-investment-ratios for the benchmark years 1970, 1975, and 1980, and then multiplying them to the average total investment share of GDP for 1960-1975. As much as 10 out of the 25 countries in the hp sample are only part of the 1980 benchmark. Hong Kong and Israel are two countries that are only part of the 1980 benchmark and both have large lagged equipment shares and high income growth rates. If the equipment investment ratios were achieved through high income growth, then the "lagged" investment shares become biased. Consequently, the "lagged" investment share is not really a lagged investment share.

3. An Alternative Approach

3.1 Real Investments and Growth

The problems mentioned above call for an alternative approach to examine the relationship between equipment investment and income growth. This alternative approach should include the variables proposed by DS, but at the same time improve upon gaining better measurements of the investment share and be less likely to suffer from reverse causality.

As mentioned above, real PPP adjusted data for such a detailed heading as equipment share is hard to come by. The best possible data of real equipment shares is from the ICP benchmark data. Therefore, in order to use the best possible data available and at the same time try to reduce the risk of reverse causality, the equipment share from the 1970 ICP benchmark will be used to explain the income growth rate from 1970 to 1975. The other benchmark years will work the same way. This is a very straightforward approach, and as suggested by Sala-i-Martin (1997a), having the equipment share measured at the beginning of the period is preferable to using averages over the growth period. The identification strategy is therefore to have the average annual growth rate of GDP per worker for the period 1970-1975 regressed on the equipment share 1970, the non-equipment share 1970, the labor force growth rate 1970-1975, and the GDP per worker gap 1970. The ICP benchmarks used are 1970, 1975, 1980, 1985, and 1996, which are related to the growth rates for the time period 1970-75, 1975-80, 1980-85, 1985-90, and 1996-2000, respectively. The fact that we are now studying the growth rates over five year periods instead of over a 25 year period is an important difference. Analyses of shorter time periods might be more important in a political perspective.

To make things more interesting, the ICP benchmark data is used to derive both the equipment investment share (as in DeLong and Summers, 1991) and the producer durables share (as in DeLong and Summers, 1992, 1993). The use of the ICP benchmark data allows for the study of the detailed headings equipment and producer durables, but also restricts the sample to former benchmark countries. To widen the sample, the total investment share (gross capital formation) is also studied. Since the total investment share consists of both producer durables and non-equipment investment, it is no longer a study of the difference between these two types of investment. On the positive side, there is no longer a restriction of only benchmark countries and years, and the sample stretches from 1970 to 2000 using investment data for 1970, 1975, 1980, 1985, 1990, and 1995.

The different time series are formed into a panel that lets us control for both time and country fixed effects. The idea that each country has a fixed effect (like culture and moral) that is correlated with investment effort seems most plausible, and the Hausman test agrees.

To summarize, the variables and the division into a large and high productivity are the same as in the DS regression set-up. The differences are that now we are using a more direct measurement of the investment shares, another matching of years which gives less opportunity for reverse causality, and a panel data set that gives us the opportunity to control for both time and country fixed effects.

3.2 Panel Data Results

The main results from this exercise are presented in Table 3. As can be seen, neither the equipment shares nor the producer durables shares are significant in any sample. The total investment share is significant only in the large sample. The effect can be interpreted as if the total investment share increases by three percentage points (one standard deviation), then the annual growth rate in GDP per worker increases by 0.3 percentage points. As depicted by the partial scatter plot in Figure 2, this effect is sensitive to the inclusion of Romania (ROM) and Guinea Bissau (GNB). If these two countries are dropped, the effect from total investment is insignificant.

It is important to note that although the samples overlap, they are also different. The significance of the total investment share does not prove it is “better” than the equipment share or the producer durables share. In the case of the total investment share, the number of observations, countries, and time periods are superior to the other samples. If the sample is reduced as close as possible to the sample with the equipment share or the producer durables share, then the coefficient for the total investment share is insignificant.

4. The Behavior of Equipment Prices

4.1 Equipment Prices and Income

Closely connected to the claim that investment is important for income growth is the claim that countries that invest too little have a high price on equipment investment. In DS, low prices of investment are associated with high quantities of investment, which in turn are associated with high income growth rates. Similarly, rich countries are often associated with high quantities of investment and low prices of investment. As portrayed in Figure 3, the relative price of equipment investment is higher in relatively poor countries compared to rich ones. A common argument is therefore that poor countries have low investment shares simply because they tax capital or have other barriers to capital imports. Hence, policy should be aimed at reducing trade restrictions and taxes on equipment goods.[12] As is clarified by Hsieh and Klenow (2006), although this is not untrue, it does not tell the whole story. In order to make things clear, let us take a look at the relative price:

$$R_{ij} = \frac{p_{ij}^{dom} q_{ij}}{\sum_{i=1}^{m} p_{ij}^{dom} q_{ij}} \Bigg/ \frac{p_{i}^{ppp} q_{ij}}{\sum_{i=1}^{m} p_{i}^{ppp} q_{ij}} . \qquad (2)$$

The relative price (R_{ij}) is the amount of expenditure spent on good i in country j (price times quantity; $p_{ij}^{dom} q_{ij}$) in relation to total spending (the sum of expenditures for all m goods; $\sum_{i=1}^{m} p_{ij}^{dom} q_{ij}$), both at domestic prices, relative to the amount spent on good i in

[12] See the references cited in Hsieh and Klenow (2006).

relation to total spending at international prices ($p_i^{ppp} q_{ij} / \sum_{i=1}^{m} p_i^{ppp} q_{ij}$) (note that prices at international PPP prices are constant across countries). Equation 2 therefore tells us the relation of the price *structure* of good *i* in country *j*, compared to some world average price *structure* of good *i*. To use the language of Kravis, Heston, and Summers (1982), equation 2 is maybe better referred to as the relative “price structures” instead of the “relative price.” Alternatively, the price level as denoted in for example Penn World Tables 6.1 is:

$$P_{ij} = \frac{PPP_{ij}}{xrate_j} = \frac{p_{ij}^{usd}}{p_i^{ppp}},$$

where P_{ij}, the price level for good *i* in country *j,* is equal to the PPP of good *i* for country *j*, divided by the exchange rate of country *j* in relation to US dollars. The price level for good *i* in country *j* is therefore the price for good *i* in country *j* converted to US dollars, compared to the international (PPP) price of the same good (where the international price is expressed in US dollars). The price level (P_{ij}) compares the price of a specific good to some “average” price for the same good. The relative price structure (R_{ij}), on the other hand, compares the price *structure* at domestic currency (that is the expenditure on a specific good compared to all other goods) to the price *structure* at international prices.

Figure 4 illustrates the relationship between the log equipment price levels and log real GDP per worker. It is evident that investment prices are not systematically higher in relatively poor countries. On the contrary, equipment prices seem somewhat higher in relatively rich countries. The reason why the relative price is negatively related to income, while the price level is not, is easily explained. Let us consider equation 2 again, and simplify so that there are only two goods: investment goods and consumption goods. The relative price structure for investment goods can then be denoted as:

$$R_{Ij} = \frac{p_{Ij}^{dom} q_{Ij}}{p_{Ij}^{dom} q_{Ij} + p_{Cj}^{dom} q_{Cj}} \bigg/ \frac{p_I^{ppp} q_{Ij}}{p_I^{ppp} q_{Ij} + p_C^{ppp} q_{Cj}}.$$

The subscript *I* stands for investment goods and *C* stands for consumption goods. Let us rewrite this as:

$$R_{Ij} = \frac{q_{Ij}}{q_{Ij} + \left(\frac{p_{Cj}^{dom}}{p_{Ij}^{dom}}\right) q_{Cj}} \Bigg/ \frac{q_{Ij}}{q_{Ij} + \left(\frac{p_{C}^{ppp}}{p_{I}^{ppp}}\right) q_{Cj}} . \qquad (3)$$

Assume now that we have only two types of countries: rich and poor (*j=rich, poor*). As is shown in Figure 4 and Table 4, the price level for investment goods is roughly the same for poor and rich countries, whereas consumption prices (or as in Table 4 "the aggregate price level for all other goods then equipment goods"[13]) are lower in poor countries. The results in Table 4 are perfectly reasonable. To give an intuitive explanation, let us simplify by thinking of investment goods as highly internationally traded goods (for example computers), while consumption goods can be said to consist mainly of non-internationally traded goods (for example haircuts). Computers cost roughly the same in poor and rich countries, while the price of a haircut probably varies greatly. The fact that consumption goods in general are cheaper in relatively poor countries is a well-known fact and is referred to as the "Penn Effect" or "Balassa-Samuelson Effect."[14]

To continue with the relationship between the relative price and the price level, it is useful to know that the Gheary-Khamis aggregation method, used in for example Penn World Tables to generate PPP prices, uses weights according to aggregate quantities. This means that there will be more weight put on rich country prices relative to poor country prices. The derived international price will therefore tend to be closer to the prices in rich countries than in poor countries.[15] With this knowledge we can make the following simplifications: $p_I^{ppp} = p_{I,poor}^{dom} = p_{I,rich}^{dom}$ and $p_C^{ppp} = p_{C,rich}^{dom} > p_{C,poor}^{dom}$. The price ratio of consumption goods to investment goods for

[13] These are mostly consumption goods or modestly internationallt traded goods. Hsieh and Klenow (2006) focus on subsections of consumption goods valued at both official exchange rates and black market exchange rates.

[14] The Penn effect is the empirical finding that consumer price levels are systematically higher in rich countries compared to poor ones. The Balassa-Samuelson hypothesis, from Balassa (1964) and Samuelson (1964), is one of the theories that try to explain the Penn effect, hence it is also known as the Balassa-Samuelson effect. For another explanation of the Penn effect see, Bhagvati (1984).

[15] See for example the Handbook of the International Comparison Programme (1992, page 75), or Hsieh and Klenow (2006, p.10).

a poor country therefore seems smaller in domestic currency than in international currency:

$$\left(\frac{p_{C,Poor}^{dom}}{p_{I,Poor}^{dom}}\right) < \left(\frac{p_{C,Poor}^{ppp}}{p_{I,Poor}^{ppp}}\right). \tag{4}$$

From (3) and (4) we can then see that the relative price structure is smaller in a relatively poor country compared to a rich one ($R_{Ipoor} < R_{Irich}$). This is not due to differences in investment prices across countries; on the contrary, it is due to the fact that consumption prices differ.

To summarize, the equipment price is roughly the same for poor and rich countries, but the relative price is not. To use our example of computers and haircuts, a computer costs roughly the same in Tanzania as in the US, whereas the price of a computer compared to a haircut is probably higher in Tanzania than in the US.[16]

4.2 Implications for the Investment Share

Interestingly, the relation between consumption and investment prices helps explain the relation between the investment share of GDP and GDP per worker. As demonstrated in Table 5 and by Hsieh and Klenow (2006), Eaton and Kortum (2001), and Restuccia and Urrutia (2001): real investment shares measured at international prices are higher in relatively rich countries compared to poor ones, while the investment share measured at domestic prices is roughly the same for poor and rich countries. To understand why, let us again simplify GDP to consist of only two goods (investment and consumption) and two countries (rich and poor). The investment share at domestic prices for country *j* can then be denoted as:

$$i_j^{dom} = \frac{q_{Ij}}{q_{Ij} + \left(\frac{p_{Cj}^{dom}}{p_{Ij}^{dom}}\right) q_{Cj}}.$$

With the same reasoning as above, if $p_I^{ppp} = p_{I,poor}^{dom} = p_{I,rich}^{dom}$ and $p_C^{ppp} = p_{C,rich}^{dom} > p_{C,poor}^{dom}$ are approximately true, then the relation between relative prices in (4) are still

[16] For further discussion, see Hsieh and Klenow (2006).

valid. This implies that for a poor country the investment share is smaller at international prices than at nominal prices $\left(i_{poor}^{ppp} < i_{poor}^{dom}\right)$. This difference is not due to differences in quantities or investment prices, but simply to differences in consumption prices.

4.3 Further Implications

In the description above we have learnt that the price of equipment investment is not systematically related to income, and that nominal equipment shares are not systematically lower in poor countries. Now, what are the implications of these findings for the results in DS and our examination of the relation between the investment share and income growth? Let us pose two questions: Firstly, since the analysis above highlights the importance of the *nominal* equipment share, is there any justification for using the nominal equipment share in a growth regression, and what would the results then be? Secondly, how does the above relation between prices and *income levels* relate to our examination of investment shares and *income growth rates*? These questions are addressed below.

4.3.1 Real or Nominal?

DeLong and Summers (1991, 1992, 1993), and to my knowledge most other studies, use the *real* equipment share of GDP, measured at common international PPP adjusted prices. The reason is straightforward, as we saw above in Table 4: prices across countries vary, especially for non-traded consumption goods. Therefore, when comparing the GDPs of two countries, the comparison is made more transparent if the expenditures are valued at common international prices. A comparison between the two countries would then not be influenced by the relative price levels in the two countries, but rather be a comparison of quantity.

As described above, the real equipment share is higher in relatively rich countries compared to poor ones, while the nominal equipment shares are not. That is, looking at domestic prices, poor countries do not spend less on investment goods as a share of their income compared to rich countries. Does this mean that their investment effort is the same? Which of these equipment shares should we use: the real (at international prices) or the nominal (at domestic prices)? The answer depends on what we mean by "investment effort." A simplified interpretation to the real equipment share is that it is more a matter of looking at quantity. When comparing the equipment share for two countries valued at the same *real* prices, it is more a question of comparing how many investment goods compared to all other goods one country has in comparison to the other. The *nominal* equipment share is instead a pure expenditure measure. That is, based on a country's actual income valued at domestic prices, how much is spent on investment goods? Remember then that this investment share is determined at the prevailing actual domestic prices, which is what investors actually face and base their decision on.

If there is indeed a "learning by investing" effect, as is the implicit assumption for why investment should cause growth, then do we learn by having many machines (looking at real shares), or could it be the case that if the machine is relatively more expensive (nominal shares), more care will be put into the machine and therefore more will be learnt? This paper examines both alternatives. The use of nominal investment share in a cross country growth regression is, to my knowledge, a novelty in the literature.

Table 6 presents the regression results for the nominal investment shares. It displays the regression results for three types of investment shares in a panel data setting with time and country fixed effects, for both the high productivity and the large sample. Table 6 is therefore constructed similar to Table 3, with the single difference that the real investment shares are replaced by nominal shares. The results are also similar. The effects from equipment investment and producer durables investment are low and statistically insignificant. The effect from the total investment share is insignificant in the high productivity sample, but significant in the large sample. The data for the total investment share is retrieved from the World Development Indicators, which therefore deals with a slightly different sample than the real total investment share in Table 3 does. For the large sample, the effect can be interpreted as if the nominal total investment share increases by 3 percentage points, then the income growth rate increases by 0.1 percentage points.

Figure 5 depicts the partial scatter plot of this effect, and makes one wonder about robustness. If we exclude Papua New Guinea (PNG) and Guinea Bissau (GNB) (with or without Lesotho, LSO), then the effect from total investment is insignificant. The effect is also insignificant if we only include countries with Penn World Tables data quality rank A and B (the two highest ranks out of four), or if countries are weighted according to their data quality rank.[17]

4.3.2 Equipment Prices and Investment Shares

Above, we saw that equipment prices and nominal investment shares are not systematically related to *income levels*. Now how does this relate to our discussion about investment shares and *income growth rates*? DS argued that low prices of investment should be associated with high quantities of investment, which in turn should be associated with high income growth rates. This, a maybe more important issue, is not empirically examined by Hsieh and Klenow (2006). Therefore, by taking the Hsieh and Klenow (2006) findings one step further and relating it to DS, this paper uses an instrumental variables approach to test whether low investment prices are associated with high investment quantities, and whether theses are associated with high growth rates. The identification strategy is to regress income growth on labor force growth, the GDP per worker gap, the non-equipment share, and the equipment share, where the latter is instrumented by the equipment price level (P_{Ij}). This is similar to DS, who instrument equipment investment by the relative price of equipment (R_{Ij}).

In order to use the most accurate data available, the ICP benchmark data on equipment, non-equipment, and prices is used. The data is from 1975, 1980, 1985 and 1996, the years with broad cross sections of countries. The equipment share for e.g. 1975 is then used to explain the income growth rate from 1975 to 1980.

Table 7 reports the results from this short exercise. Interestingly, in the first stage regressions, the coefficients for the equipment price are negative and, most of the time, statistically significant. This means that although there are little differences between equipment prices in poor and rich countries, those countries with lower equipment prices indeed seem to have higher equipment shares. However, focusing on the second stage regressions, equipment shares do not seem to be related to income growth. The coefficients for the equipment share are statistically insignificant in all columns except for when the 1980 benchmark is used. Similar results are achieved if using producer durables investment in a cross section or in a panel data setting with time and country fixed effects.

[17] From the PWT 6.1 Data Appendix. The weights used were A=1, B=0.75, C=0.50, and D=0.25.

5. Conclusions

This paper presents new evidence on the relationship between investment and economic growth. Motivated by the influential analysis of DeLong and Summers (1991), it reconstructs and extends their analysis as closely as possible using more recent data, and relates to recent findings about the relation between investment prices and economic development.

Reconstructing and extending the analysis, there are three main conclusions: Firstly, the effects of equipment investment are much lower and most often statistically different from the effects in DeLong and Summers (1991). Secondly, the effects of equipment investment and non-equipment investment both being statistically significant indicate that growth might cause investment and not the other way around. Thirdly, for the largest sample, which covers the 1960-2000 period, the effect from equipment investment is statistically insignificant. The relationship between equipment investment and income growth is therefore no longer a strong and robust finding in a DeLong and Summers regression set-up.

The construction of an average investment share in DeLong and Summers (1991, 1992, 1993) is subject to critique, both because it is ill measured and because the regression is likely to suffer from reverse causality. This paper therefore suggests an alternative approach that includes all the variables proposed by DeLong and Summers, but at the same time uses better and more direct measures of the initial investment share in a panel data setting. Using measures of the equipment share, the producer durables share, and the total investment share, the results show that the investment share, however defined, is not strongly and robustly correlated with income growth.

As a last exposition, this paper relates to recent findings showing that the price of investment is not systematically higher in rich countries compared to poor ones. It shows that although the investment price is not systematically related to income, countries with investment prices tend to invest more, but these higher investments do not seem to promote growth.

This paper therefore repeatedly refutes the much acclaimed impression that there is a strong and robust correlation between investment and income growth, which is in line with the Solow (1956) growth model and is not controversial. The findings suggest that although investments are important, the benefits from investments are probably not as large as they often are portrayed to be. Policy that aims at promoting income growth should not overemphasize the importance of capital formation.

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Table 1
Replication and Extension of the Main Results in DeLong and Summers (1991)
Dependent Variable: Real GDP per worker growth

	1960-1985 sample, using the 1970-75-80 benchmarks						1960-1990 sample, 1970-75-80-85 benchmarks		1960-2000 sample, 1970-75-80-85-96 benchmarks	
	Original DeLong and Summers (1991) data		Replicated data, same sample		Replicated data, new sample[a]					
	hp	large	hp	large	hp	large	hp	large	hp	large
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Equipment share[b]	0.3373***	0.2653***	0.3261***	0.2474***	0.2663***	0.2379***	0.2135***	0.1439*	0.0905	0.0442
	(0.0538)	(0.0654)	(0.0755)	(0.0786)	(0.0666)	(0.0785)	[0.0624]	(0.0745)	(0.0594)	(0.0502)
Non-equipment share[c]	-0.0147	0.0623*	0.0516	0.1067***	0.0772*	0.1137***	0.0793*	0.1236***	0.0623	0.1533***
	(0.0328)	(0.0349)	(0.0547)	(0.0374)	(0.0431)	(0.0336)	[0.0403]	(0.0324)	(0.0413)	(0.0282)
Labor Force growth	-0.0004	-0.0296	-0.0427	-0.0681	-0.1839	-0.0736	-0.3120**	-0.2768	-0.5857***	-0.6122***
	(0.1463)	(0.1986)	(0.1741)	(0.1894)	(0.1408)	(0.1726)	[0.1391]	(0.1758)	(0.1350)	(0.1467)
GDP/wkr gap 1960	0.0305***	0.0202**	0.0373***	0.0389***	0.0252***	0.0404***	0.0236***	0.0315***	0.0239***	0.0210***
	(0.0088)	(0.0092)	(0.0086)	(0.0084)	(0.0080)	(0.0079)	[0.0067]	(0.0069)	(0.0062)	(0.0051)
n	25	61	25	61	23	64	27	71	35	78
R^2	0.718	0.338	0.701	0.405	0.720	0.439	0.717	0.421	0.672	0.522

Notes: The superscript *** denotes significant at the 1% level, ** significant at the 5% level, * significant at the 10% level. Standard errors in ( ), robust standard errors in [ ], robust standard errors if heteroscedasticity according to Whites test. Each regression includes a constant, which is not reported. hp denotes a high productivity sample where the ratio between the GDP/wkr in country *i* and the GDP/wkr 1960 in the US is larger than 0.25. For further information see text and Data Appendix. Rows (1) until (6) have the income growth rate for the 1960-1985 period, labor force growth rate, and average investment shares for the same period. The other samples are constructed in a similar manner with the difference of considering the 1960-1985 period and the 1960-2000 period.

a: The differences from the previous samples are that the hp sample is based on PWT 5.6, and that Romania, Syria, and Yugoslavia are added to the large sample.

b: Electrical and non-electrical machinery. For the 1960-2000 sample, producer durables (equipment + transport equipment) has been used due to data limitations.

c: Structures, transport equipment and change in stocks. For the 1960-2000 sample, only structures and change in stocks.

Table 2
Lagged Investment
Dependent Variable: Real GDP per worker growth rate 1975-1985

	Original Delong and Summer (1991) data		Replicated data, new samples	
Independent Var.	hp sample	larger sample	hp sample	larger sample
Equipment share 1960-75	0.3903*** (0.0965)	0.1304 (0.1016)	0.1535 (0.1080)	-0.0170 (0.1347)
Non-equipment share 1960-75	0.0272 (0.0515)	-0.0455 (0.0368)	0.0861 (0.0532)	-0.0127 (0.0618)
Labor force growth 1975-85	-0.0558 (0.2637)	-0.4297 (0.3403)	-0.5083** (0.2205)	-0.5171* (0.2998)
GDP/wkr gap 1975	0.0176 (0.0154)	0.0088 (0.0129)	0.0018 (0.0140)	0.0118 (0.0127)
n	25	61	23	66
R^2	0.541	0.074	0.615	0.054

Notes: Standard errors in ( ). *** significant at the 1% level, ** 5% level, * at the 10 % level. Intercept included but not reported. Hp sample in replicated data excludes Hong Kong and Japan. The lagged equipment share was constructed by taking the average of the ratio from equipment investment to total investment for the benchmark years 1970, 1975, and 1980, and then multiplying it by the total investment share of GDP for 1960-1975. The correlation between the original DS lagged equipment share and the reconstructed is 0.91 for the large sample and 0.97 for the hp sample. The difference between the large reconstructed sample and the large sample in Table 1, Column 6 is the inclusion of Hungary and Poland.

Table 3
Real Investment and Growth
Dependent Variable: Real GDP per worker growth

	hp (1)	hp (2)	hp (3)	large (4)	large (5)	large (6)
Equipment share	0.003			0.002		
	(0.137)			(0.150)		
Non-equipment share	-0.145**			-0.111*		
	(0.065)			(0.060)		
Producer durables share		-0.066			0.034	
		(0.081)			(0.079)	
Non-producer durables share		-0.146***			-0.116***	
		(0.052)			(0.042)	
Total investment share			-0.019			0.100***
			(0.032)			(0.022)
GDP/wkr gap	0.120*	0.035	0.076***	0.147**	0.047*	0.134***
	(0.069)	(0.021)	(0.018)	(0.070)	(0.027)	(0.021)
Labor force growth	-1.450***	-0.225	-0.639***	-1.410***	-1.147***	-0.783***
	(0.494)	(0.391)	(0.122)	(0.168)	(0.169)	(0.097)
Time and country fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Number of observations	85	140	308	147	244	635
Number of countries	35	54	56	68	103	115
R^2 (within)	0.570	0.452	0.255	0.563	0.359	0.213

Standard errors in ( ). * significant at 10%; ** significant at 5%; *** significant at 1%.

Table 4
Relative Equipment Prices vs. Equipment Prices
Independent variable: log PPP GDP per worker

Dependent var.	1975	1980	1985	1996[a]
Log Relative equipment price	-0.3933*** (0.0539) R^2=0.6244	-0.2152*** (0.0503) R^2=0.2367	-0.3806*** (0.0425) R^2=0.5645	-0.4055*** [0.0420] R^2=0.5288
Log Equipment price	-0.0319 (0.0344) R^2=0.0262	0.0125 (0.0379) R^2=0.0018	-0.0505 [0.0337] R^2=0.0213	0.0517 [0.0335] R^2=0.0209
Log Aggregate price level of all goods other than equipment	0.3858*** [0.0606] R^2=0.5587	0.2381*** [0.0435] R^2=0.3101	0.3449*** [0.0486] R^2=0.4787	0.4924*** [0.0581] R^2=0.5164
n	34	61	64	114

Notes: Standard errors in ( ), robust standard errors in [ ]. *** significant at the 1% level, ** 5% level, * at the 10 % level. See text for further information.
a: Price for producer durables. Aggregate price is then the aggregate price level of all goods other than producer durables.

Table 5
Real vs. Nominal Investment shares
Independent variable: log PPP GDP per worker

Real Shares				
Dependent Var.	1975	1980	1985	1996
Real equipment share	0.0150*** (0.0051) R^2=0.2158	0.0129*** (0.0038) R^2=0.1603	0.0191*** (0.0024) R^2=0.5082	N.A.
Real producer durables share	0.0194*** [0.0047] R^2=0.2230	0.0173*** [0.0045] R^2=0.1979	0.0273*** (0.0029) R^2=0.5946	0.0253*** (0.0044) R^2=0.2265
Nominal Shares				
	1975	1980	1985	1996
Nominal equipment share	-0.0077* [0.0045] R^2=0.0780	0.0030 (0.0028) R^2=0.0192	0.0051* (0.0030) R^2=0.0431	N.A.
Nominal producer durables share	-0.0139* [0.0073] R^2=0.1322	0.0022 [0.0037] R^2=0.0068	0.0058 (0.0037) R^2=0.0375	-0.0041 (0.0060) R^2=0.0041
n	34	61	64	114

Notes: Standard errors in ( ), robust standard errors in [ ]. *** significant at the 1% level, ** 5% level, * at the 10 % level. Producer durables are equipment plus transport equipment.

Table 6
Nominal Investment and Growth
Dependent Variable: Real GDP per worker growth

	(1) hp	(2) hp	(3) hp	(4) large	(5) large	(6) large
Nominal equipment share	0.051 (0.179)			0.167 (0.158)		
Nominal non-equipment share	-0.192 (0.124)			-0.150* (0.080)		
Nominal producer durables share		-0.051 (0.089)			0.001 (0.071)	
Nominal non-producer durables share		-0.161** (0.066)			-0.122** (0.054)	
Nominal total investment share			0.002 (0.029)			0.047** (0.021)
GDP/wkr gap	0.129* (0 .069)	0.048** (0.021)	0.082*** (0.017)	0.171** (0.068)	0.057* (0.026)	0.120*** (0.020)
Labor force growth	-1.287** (0.507)	-0.265 (0.407)	-0.557*** (0.115)	-1.267*** (0.180)	-1.047*** (0.174)	-0.774*** (0.092)
Time and country fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Number of observations	85	140	287	147	244	587
Number of countries	35	54	55	68	103	114
R^2 (within)	0.5467	0.4167	0.2799	0.5622	0.3454	0.2283

Standard errors in ( ). * significant at 10%; ** significant at 5%; *** significant at 1%.

Table 7
IV-Regressions
Dependent Variable: Real GDP per worker growth

benchmarks	High Productivity Sample 1975	1980	1985	1996	Large Sample 1975	1980	1985	1996
	Second Stage				Second Stage			
Predicted equipment share	0.2194 (0.3471)	0.6406*** (0.2279)	-1.1928 (1.6785)	0.0965 (0.1343)	0.8464 (0.6672)	0.3918* (0.2157)	0.5219 (0.6255)	1.0283 (1.6730)
Non-equipment share	-0.3492** (0.1580)	0.0014 (0.0716)	0.0411 (0.2248)	-0.0511 (0.0588)	-0.4433* (0.2169)	-0.0278 (0.0657)	-0.0504 (0.1258)	0.0033 (0.0768)
Labor force growth	-0.9836* (0.5252)	-0.0110 (0.4802)	-2.7679 (1.6154)	-0.5801* (0.3170)	-0.5507 (0.6517)	-0.8253** (0.3706)	-1.2228*** (0.2171)	-2.0387 (1.9226)
GDP/wkr gap	0.0581* (0.0287)	-0.0065 (0.0178)	-0.0024 (0.0479)	-0.0026 (0.0140)	0.0641* (0.0338)	0.0220 (0.0154)	0.0433 (0.0308)	0.1089 (0.1789)
	First Stage				First Stage			
Log equipment price.	-0.1079*** (0.0278)	-0.0528*** (0.0122)	-0.0343 (0.0228)	-0.1282*** (0.0449)	-0.0484** (0.0205)	-0.0434*** (0.0090)	-0.0152*** (0.0056)	-0.0084 (0.0125)
R^2	0.596	0.492	0.312	0.356	0.545	0.471	0.726	0.344
n	22	38	28	44	34	61	55	104

Notes: The superscript *** denotes significant at the 1% level, ** significant at the 5% level, * significant at the 10% level. Standard errors in ( ). Estimated regression is: $I_{eq}/Y= \alpha_0 + \alpha_1(log\ equip.price) + \alpha_2(n) + \alpha_3(gap) + \alpha_4(I_{st}/Y) + e$, $growth= \beta_0 + \beta_1(pred.I_{eq}/Y) + \beta_2(I_{st}/Y) + \beta_3(n) + \beta_4(gap) + \upsilon$. For 1975, growth is the income growth rate 1975-1980, *n* is the labor force growth for the same period, *gap* is the GDP per worker gap 1975, I_{eq}/Y and I_{st}/Y is the equipment share 1975, and *log equip. price* is the log equipment price 1975. The other benchmark years have a similar set-up. Due to data limitations in real GDP per worker and labor force, some countries are excluded. For 1985 these are: The Bahamas, Barbados, Botswana, Ethiopia, Nepal, St. Lucia, Suriname, Swaziland, and Tanzania. For 1996: Antigua and Barbuda, The Bahamas, Bermuda, Dominica, Grenada, Israel, Qatar, St. Kitts and Nevis, St. Lucia, St. Vincent and the Grenadines.

Figure 1: Partial Scatter Plot (Table 1, Column 9)

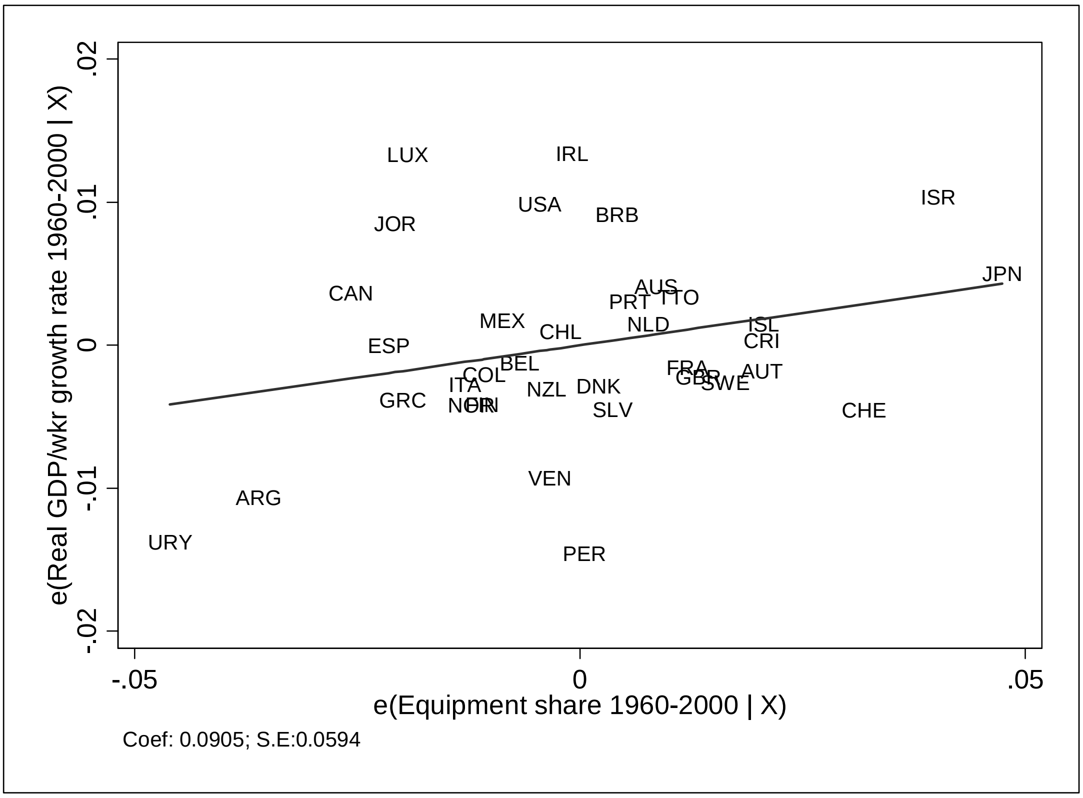
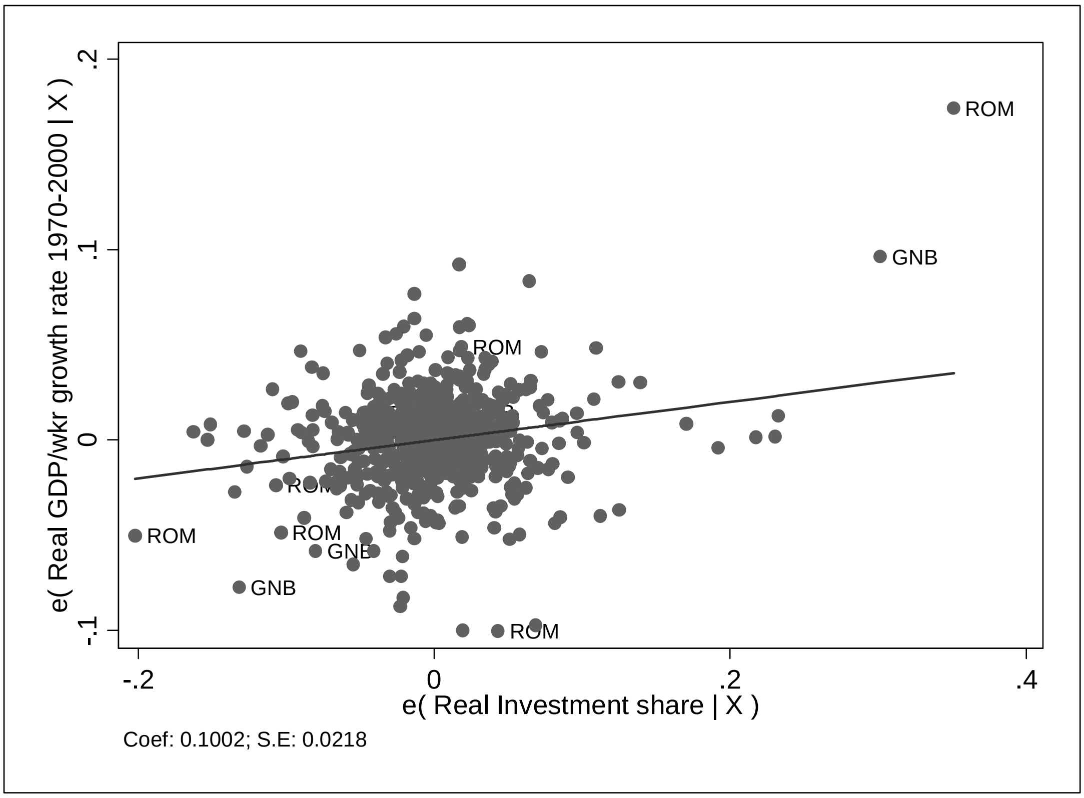


Figure 2: Partial Scatter Plot (Table 3, Column 6)



Note: Only a selection of country codes are included

Figure 3: Relative Price of Equipment vs. Income 1996

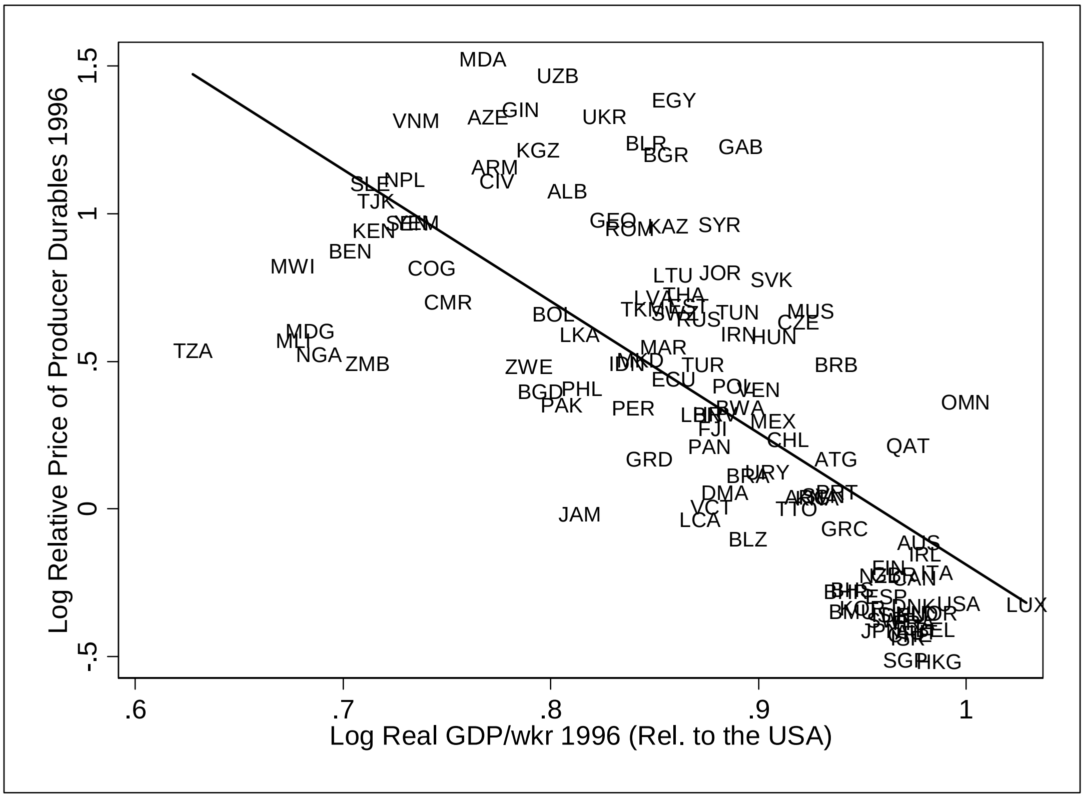


Figure 4: Price of Equipment vs. Income 1996

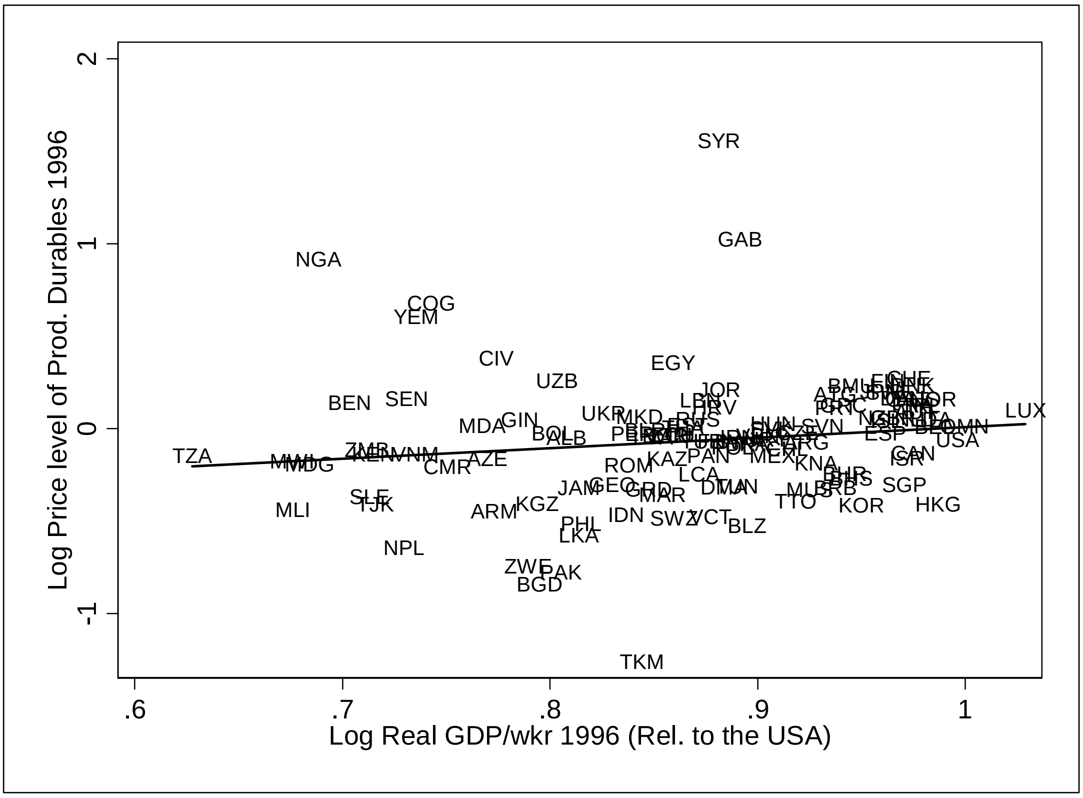
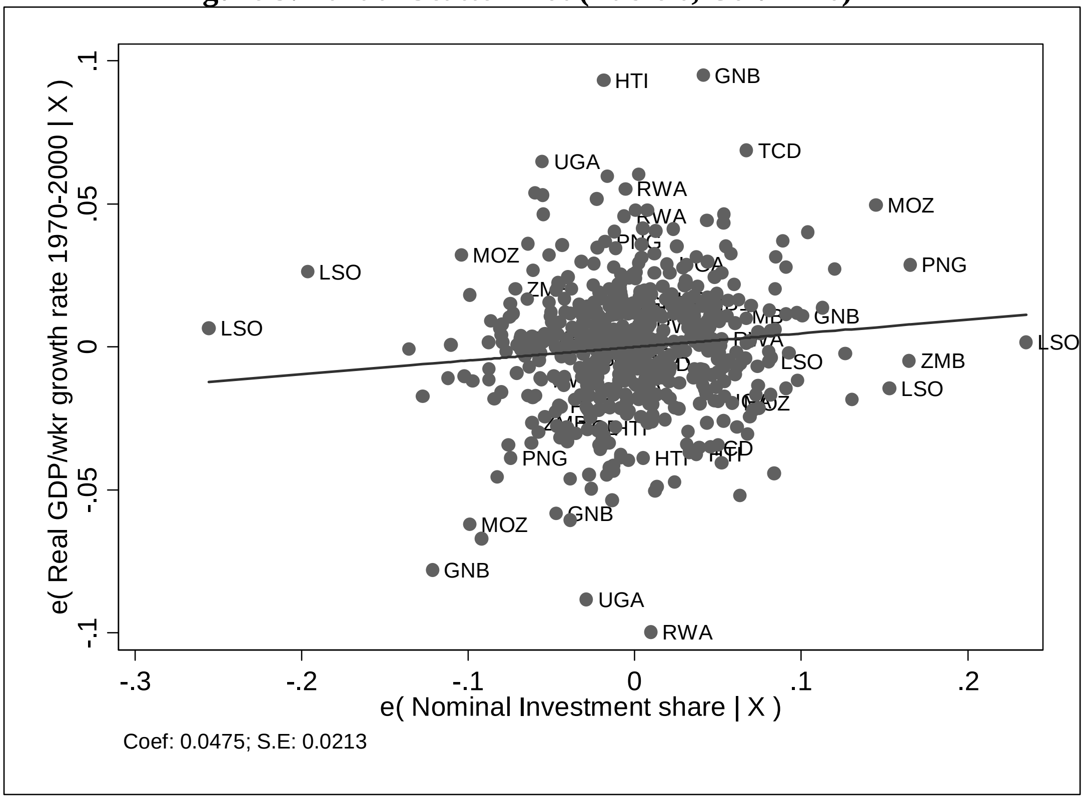


Figure 5: Partial Scatter Plot (Table 6, Column 6)



Note: Only a selection of country codes are included

Data Appendix:

A1. Reconstructing DeLong and Summers

For the replicated data in Table 1, the average equipment shares of GDP were created by taking the ratio between equipment investment and total investment for a benchmark year and multiplying it by the average total investment share of GDP for a specific period. The equipment-total-investment ratio is calculated based on ICP benchmarks from the Penn World Tables.[18] The total investment share is the real investment share in constant prices retrieved from PWT 5.6 or PWT6.1, depending on coverage.

A1.1 The 1960-1985 sample (benchmarks 1970, 75, 80)

	Benchmark			Total Investment Share		
	70	75	80	70	75	80
	70	75	80	1960-72	1973-77	1978-85
		75	80		1960-77	1978-85
			80			1960-85
+	70	75		1960-72	1973-85	
+		75			1960-85	

For Thailand (part of the 1975 benchmark), Malaysia (1970, 1975) and Jamaica (1975), there is no information in DS on how to calculate. The table above indicates how these countries have been calculated. Other countries that are in at least one of the ICP benchmarks studies from 1970 to 1980 but not in the sample are: Poland (1975, 1980), Hungary (1970, 1975, 1980), and Iran (1970, 1975). Iran is excluded because it is a major oil exporter. Hungary and Poland are excluded because there is no data in PWT5.6 on GDP from 1960 to 1969. Including Hungary and Poland while calculating the income growth rate for 1970-1985 does not change the results.

Summary statistics 1960-1985 sample, reconstructed data (Table 1, Columns 3-4)

Variable	**Obs.**	**Mean**	**Std. Dev.**	**Min**	**Max**
Real GDP /wkr growth 1960-85	64	0.0247	0.0160	-0.0126	0.0685
Equipment share (reconstructed)	64	0.0499	0.0281	0.0038	0.1221
Non-equipment share (reconstructed)	64	0.1372	0.0547	0.0095	0.2499
Labor force growth 1960-85	64	0.0198	0.0094	0.0017	0.0376
GDP/wkr gap 1960	64	0.7289	0.2316	0.0000	0.9780

Note: Data from PWT 5.6.

Correlations

Corr(Equip. share (reconstructed); Equip. share (DS original))	0.9151
Corr(Nonequip. share (reconstructed); Non-equip. share (DS original))	0.8592
Corr(Equip. share (reconstructed); Non-equip. share (reconstructed))	0.6094

[18] http://pwt.econ.upenn.edu/Downloads/benchmark/benchmark.html

A1.2 The 1960-1990 Sample (benchmarks 1970, 75, 80, 85)

Equipment investment and total investment ratios (from ICP benchmarks) have been matched to the average total investment share (from PWT 5.6) as follows.

Benchmark				Total Investment Share			
70	75	80	85	70	75	80	85
70	75	80	85	1960-72	1973-77	1978-82	1983-90
70	75	80		1960-72	1973-77	1978-90	
	75	80	85		1960-77	1978-82	1983-90
70	75		85	1960-72	1973-79		1980-90
	75		85		1960-79		1980-90
70	75			1960-72	1973-90		
	75	80			1960-77	1978-90	
		80	85			1960-82	1983-90
		80				1960-90	
			85				1960-90
	75				1960-90		

Summary statistics

Variable	**Obs.**	**Mean**	**Std. Dev.**	**Min**	**Max**
Real GDP /wkr growth 1960-90	71	0.0201	0.0144	-0.0135	0.0593
Equipment share	71	0.0477	0.0270	0.0081	0.1200
Non-equipment share	71	0.1284	0.0558	-0.0257	0.2354
Labor force growth 1960-90	71	0.0208	0.0093	0.0027	0.0391
GDP/wkr gap 1960	71	0.7027	0.2475	0.0000	0.9687

The difference in sample from DS is the addition of Australia, Benin, Bangladesh, Republic of Congo, Egypt, Iran, Mauritius, New Zealand, Rwanda, Sweden, Syria, Trinidad & Tobago, Turkey, and Yugoslavia, and the exclusion (due to data limitations) of Botswana, Ethiopia, and Tanzania. Extending the sample to include countries that miss up tp ten years of data on GDP or investment adds another nine countries (including Botswana and Tanzania), but does not change the main results. Another difference from DS is that Hong Kong and Japan are not part of the high productivity sample.

A1.3 The 1960-2000 sample (benchmarks 1970, 75, 80, 85, 96)

Matching of equipment-to-total-investment-ratio to total-investment-to-GDP.

Benchmark					Total Investment Share				
70	75	80	85	96	70	75	80	85	96
70	75	80	85	96	1960-1972	1973-1977	1978-1982	1983-1990	1991-2000
70	75	80	85		1960-1972	1973-1977	1978-1982	1983-2000	
	75	80	85	96		1960-1977	1978-1982	1983-1990	1991-2000
70	75	80			1960-1972	1973-1977	1978-2000		
	75	80		96		1960-1977	1978-1986		1987-2000
	75		85	96		1960-1979		1980-1990	1991-2000
		80	85	96			1960-1982	1983-1990	1991-2000
70	75				1960-1972	1973-2000			
	75			96		1960-1984			1985-2000
		80	85				1960-1982	1983-2000	
		80		96			1960-1986		1987-2000
			85	96				1960-1990	1991-2000
			85					1960-2000	
				96					1960-2000
		80					1960-2000		

Summary statistics 1960-2000 sample

Variable	**Obs.**	**Mean**	**Std. Dev.**	**Min**	**Max**
Real GDP /wkr growth 1960-2000	78	0.0186	0.0140	-0.0121	0.0552
Equipment share	78	0.0654	0.0335	0.0084	0.1509
Non-equipment share	78	0.1016	0.0477	-0.0331	0.2217
Labor force growth 1960-2000	78	0.0205	0.0093	0.0021	0.0421
GDP/wkr gap 1960	78	0.6659	0.2833	-0.0584	0.9771

In the PWT benchmark downloads, from which the data has been retrieved, there is no data available for the 1990 benchmark. In the 1996 benchmark the data is only subdivided into producer durables (equipment and transport). The data above is therefore for the producer durables share of GDP, which is still in line with DeLong and Summers (1992, 1993).

The difference between the DS high productivity sample in Column (1) and the 1960-2000 hp sample in Column (9) is that West Germany and Hong Kong have been excluded, and the following countries have been added: Australia (AUS), Barbados (BRB), Colombia (COL), El Salvador (SLV), Greece (GRC), Iceland (ISL), Jordan (JOR), New Zealand (NZL), Portugal (PRT), Sweden (SWE), Switzerland (CHE), and Trinidad &Tobago (TTO) (the country codes in parentheses can be seen in Figure 1). West Germany is excluded because of data limitations. Hong Kong is excluded since it does not meet the requirements of the high productivity sample.

The differences between the DS large sample and the large sample (Column 10) are, in addition to the changes already mentioned above, the inclusion of: Benin, Bangladesh, Republic of Congo, Egypt, Gabon, Guinea, Mauritius, Nepal, Romania, Rwanda, Syria, and Turkey. Botswana and Tunisia are excluded based on data limitations.

There are 127 countries covered by at least one of the ICP benchmark studies 1970, 1975, 1980, 1985, or 1996. Due to data limitations in especially GDP per worker for 1960 and 2000, the sample is reduced to 78 countries. A great majority of the excluded countries are so called transition countries, which were not their own entities until 1990.

Iran is excluded since it is an oil country. The country was excluded by DS as well. The rationale for excluding major oil countries is that their income is based on natural resources and not industrial development. Except for Iran there is little guidance in DS on how to select and exclude high income oil exporters. The DS sample includes for example Ecuador, Indonesia, Nigeria, and Venezuela, all members of OPEC during the studied period, and with exports consisting to a large extent of oil.

A2. Description of variables and sample restrictions

Regressions with equipment investments

Equipment share of GDP: Electrical and non-electrical equipment and machinery investment as a share of GDP. Constructed based on ICP benchmarks from the PWT website.[19] Real shares in panel data are deflated by multiplying the equipment share by the ratio of the investment share at constant prices to the investment share at current prices (investment shares retrieved from PWT 5.6), nominal equipment shares are in current prices.

Non-equipment share of GDP: Consists of the non-equipment part of investments (structures, transport investment, and change in inventory). Source: ICP benchmarks. Real shares in panel data are deflated, nominal shares are in current prices.

Regressions with producer durables

Producer durables share of GDP: Equipment and transport investments as a share of GDP. Original source: ICP benchmarks from PWT website. Real shares in panel data are deflated by multiplying the producer durables share by the ratio of the investment share at constant prices by the investment share at current prices (investment shares retrieved from PWT 6.1), nominal shares are in current prices.

Non-producer durables share of GDP: Consists of the non producer durables part of investments (structures investment and change in inventory). Source: ICP benchmarks. Real shares in panel data are deflated, nominal shares are in current prices.

Regressions with total investments

Real total investment share (ki) from PWT 6.1.

Nominal investment share = Gross capital formation/GDP in current local currency units from World Development Indicators.

Common variables

GDP per worker growth rate: annual growth rate of real GDP per worker. For the 1960-1990 period, GDP per worker (rgdpw) is from PWT 5.6. For the 1960-2000 period, GDP per worker (rgdpwok) is from PWT6.1 (due to data limitations).

[19] http://pwt.econ.upenn.edu/Downloads/benchmark/benchmark.html

Labor force growth (n): annual growth rate of the labor force. For the 1960-1990 period, labor force is derived from GDP per capita (rgdpch), GDP per worker (rgdpw), and population (pop), all from PWT 5.6, as suggested by Summers and Heston (1991). For the 1960-2000 period labor force is derived from GDP per capita (rgdpch), GDP per worker (rgdpwok), and population (pop) from PWT 6.1.

GDP per worker gap (gap): Gap = 1-(GDP/wkr_i)/(GDP/wkr_{USA}).
GDP per worker is for the first year (i.e. for the 1970-1975 period, the gap is for 1970). For the 1960-1990 period, the source is PWT 5.6. For the 1960-2000 period, the source is PWT 6.1.

High productivity sample (hp)

If the GDP per worker gap (GDP/wkr_i/GDP/wkr_{USA}) is greater than 0.25, then part of the high productivity sample otherwise not. For cross sections in Table 1, the GDP per worker gap is based on 1960. For the panel data, it is the average GDP per worker gap during the studied period (due to data limitations). For the 1960-1990 period, GDP per worker is from PWT5.6. For 1960-2000, GDP per worker is from PWT6.1.

Major fuel exporter

In Tables 3 and 6, a country is labeled "major fuel exporter" and excluded from the sample if the average fuel exports of merchandise exports is greater than or equal to 50 percent over the period studied, and where the fuels consists of oil, gas, coal, and electric current (SITC Section 3, mineral fuels, source World Development Indicators).

A3. Summary statistics

Summary statistics for reconstructed lagged data in Table 2

Variable	Obs.	Mean	Std. Dev.	Min	Max
Real GDP /wkr growth 1975-85	66	0.0121	0.0216	-0.0416	0.0683
Equipment share 1960-75	66	0.0522	0.0316	0.0039	0.1209
Non-equipment share 1960-75	66	0.1270	0.0588	0.0090	0.2698
Labor force growth 1975-85	66	0.0202	0.0103	-0.0032	0.0389
GDP/wkr gap 1975	66	0.6448	0.2726	0.0000	0.9780

Summary statistics for Tables 3 and 6

Variable	Obs.	Mean	Std. Dev.	Min	Max
Equipment investments					
GDP/wkr growth	147	0.0109	0.0311	-0.0882	0.0872
Real equipment share	147	0.0556	0.0295	0.0042	0.1480
Real structures share	147	0.1498	0.0631	-0.0110	0.3231
Nominal equipment share	147	0.0681	0.0201	0.0147	0.1313
Nominal structures share	147	0.1673	0.0483	0.0364	0.3429
Labor force growth	147	0.0191	0.0162	-0.0054	0.1108
GDP/wkr gap	147	0.5973	0.2959	0.0000	0.9699
Producer durables					
GDP/wkr growth	244	0.0153	0.0275	-0.1097	0.0951
Real producer durables share	244	0.0708	0.0393	0.0052	0.2075
Real non-producer durables share	244	0.1141	0.0591	-0.0116	0.4359
Nominal producer durables share	244	0.0950	0.0339	0.0181	0.2373
Nominal non-producer durables share	244	0.1325	0.0490	0.0031	0.3280
Labor force growth	244	0.0172	0.0149	-0.0164	0.1108

GDP/wkr gap	244	0.6007	0.3083	-0.4290	0.9826
Total investments					
GDP/wkr growth	635	0.0135	0.0331	-0.1180	0.1995
Real investment share	635	0.1638	0.0958	0.0076	0.6835
Labor force growth	635	0.0202	0.0150	-0.0433	0.1161
GDP/wkr gap	635	0.6804	0.2869	-0.4274	0.9835
Nominal investment share	587	0.2239	0.0791	0.0340	0.6065

Summary statistics for Tables 4 & 5

Variable	Obs.	Mean	Std. Dev.	Min	Max
Log Relative price of equip. 1975	34	0.2637	0.4511	-0.5250	1.1407
Log Relative price of equip. 1980	61	0.2888	0.4230	-0.3595	1.7850
Log Relative price of equip. 1985	64	0.4363	0.5306	-0.2878	1.4561
Log Relative price of prod. dur. 1996	114	0.3902	0.5492	-0.5164	1.5225
Log price of equipment 1975	34	0.0691	0.1788	-0.3779	0.4817
Log price of equipment 1980	61	0.1465	0.2782	-0.4657	0.8156
Log price of equipment 1985	64	0.0183	0.3625	-0.8672	0.8157
Log price of prod. Durables 1996	114	-0.0670	0.3525	-1.2611	1.5590
Log price “all other” 1975	34	-0.2081	0.4678	-1.0878	0.5190
Log price “all other” 1980	61	-0.1545	0.4088	-1.4378	0.5396
Log price “all other” 1985	64	-0.4350	0.5220	-1.7166	0.3347
Log price “all other” 1996	114	-0.4862	0.6748	-1.9925	0.7537
Log GPP/wkr 1975	34	9.1564	0.9062	6.9930	10.3134
Log GPP/wkr 1980	61	9.0635	0.9561	6.5596	10.3640
Log GPP/wkr 1985	64	8.9911	1.0473	6.5582	10.4277
Log GPP/wkr 1996	114	9.5659	0.9849	6.9017	11.3123

Notes: For 1975, 1980, and 1985 the price level for ”all other” goods are the price level for all goods other than equipment investment. For 1996, it is the price level of all goods other than producer durables (due to data limitations). See text for further information. Log=natural logarithm (ln)