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# Trade, Infrastructure and Development

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## Abstract

We survey the literature on trade and development with a particular emphasis on the role of complementarities associated with trade infrastructure. The empirical literature shows that on average trade causes growth, but the relationship is far from being homogeneous across countries. Initial conditions matter. We focus on the role played by infrastructure. While the empirical literature shows that investment in soft and hard infrastructure have an unambiguously positive impact on trade flows, the theoretical literature argues that priority may be given to investments in domestic rather than international infrastructure in countries with relatively poor domestic infrastructure (Martin and Rogers, 1995). We found that the data supports this prediction.

**JEL classification numbers:** F10; O19; O47

**Keywords:** Trade, Infrastructure, Development

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## **1 Introduction**

Sustainable Development Goal (SDG) 9 focuses on the role of infrastructure to promote inclusive and sustainable development. In SDG 9.1 it recognizes the importance of developing regional and international infrastructure to achieve this objective. This paper takes an international trade perspective to examine how the development of national, regional or international infrastructure can affect economic development.

There is ample literature that focuses on the relationships between trade and development, infrastructure and development, and trade and infrastructure. A quick look at this literature will tend to suggest that international trade and investments in infrastructure tend to promote development, and that this relationship is reinforced by the positive impact that investments in both domestic and international infrastructure have on international trade.

Our focus in this survey is to better understand why these positive and reinforcing relationships are not always observed. In particular, we examine the role played by initial conditions and complementarities in explaining the heterogeneity of outcomes that are observed when countries engage in trade reform or investments in domestic and international infrastructure.

The objective is not to determine whether trade or infrastructure investment is good or bad for development. It is rather to inform policy makers about the timing of trade reforms or investments in infrastructure so that they can help rather than hurt development. What are the other reforms, policies, institutions or investments that need to be in place to ensure that trade and infrastructure will have a positive impact on development?

It is important to note at this stage that we focus on economic growth rather than (sustainable) development. The latter is multi-dimensional and trying to capture the

impact of trade and infrastructure on development would transform this chapter into a volume by itself. Note that other chapters in this volume will examine the impact of trade on other economic and social outcomes.<sup>1</sup>

We start the survey by examining the relationship between trade and economic growth both from a theoretical and empirical perspective to highlight the importance of initial conditions in explaining the heterogeneity of outcomes associated with trade reforms in different countries with different initial conditions. An important result from the review of the recent literature is that on average trade leads to higher growth, but that there is an important degree of heterogeneity in this relationship. For trade to help economic growth, other policies and institutions need to be put in place. In particular, policies and infrastructure need to be in place that allow for the efficient reallocation of resources from less to more competitive sectors as countries engage in trade reforms.

We then look at the literature on the role played by investments in infrastructure in promoting trade. We survey papers on both hard and soft infrastructure, as well as papers on domestic and international infrastructure. The literature generally shows that investments in both hard and soft infrastructure tend to promote trade (with some papers suggesting that investment in hard infrastructure may have a larger impact). Similarly, investments in both domestic and international infrastructure tend to have a positive impact on international trade. While these results are obtained using mainly the gravity equation for bilateral international trade, the more recent studies using firm level data tend also to confirm the positive causal impact of investments in infrastructure on international trade.

The last section of the paper asks the question on whether policy makers should invest their marginal infrastructure dollar on domestic or international infrastructure. Building

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<sup>1</sup> Martin (this volume) examines the impact of trade on hunger. Porto (this volume) examines the impact of trade on poverty, Shepherd and Stone (this volume) on gender inequality, Narjoko and Urata (this volume) on income inequality, and Andrew (this volume) the impact on the environment.

on a location model by Martin and Rogers (1995) and using a new dataset on trade costs by Arvis et al. (2015), we show that in countries where domestic infrastructure is relatively better than the international infrastructure the marginal dollar should be invested in international infrastructure. On the other hand, in countries where domestic infrastructure is poor relative to international infrastructure, the marginal dollar should be spent on domestic infrastructure. These results call for some caution in promoting investments in trade facilitation exclusively in countries with relatively poor domestic infrastructure.

## **2 Does trade promote growth?**

A well-known result of classical growth theory is that decreasing marginal returns to the accumulation of capital result in declining growth rates in a closed economy. The only source of long-run growth in such models is productivity growth.

Ventura (1997) shows that in the presence of capital accumulation and diminishing returns, international trade allows for long term growth. He provides a multi-sector open economy version of the classical growth model where international trade allows factor price equalization to beat diminishing returns to capital, which leads to positive long-run growth without any need for productivity growth.

The key in Ventura's model is that as capital accumulates the comparative advantage of the economy changes, which changes the composition of aggregate production per Rybczynski theorem. These changes in the structure of production allow the capital accumulating country to beat marginal returns changes in the economy, and lead to long-run growth. In other words, international trade transforms the classic growth model into an AK model

But the restructuring of the production bundle in the economy does not unequivocally lead to higher growth. An example of this is provided by Matsuyama (1992) who shows that if trade pushes the economy towards specialization in a sector with low "learning" or growth opportunities, this can lead to lower aggregate economic growth through a composition effect.

When theory provides ambiguous answers, researchers turn to empirical evidence. If the early empirical literature tended to unambiguously suggest that trade liberalization was associated with higher growth (see for example Sachs and Warner, 1995 or Edwards, 1998), Rodríguez and Rodrik (2000) have shown that most of the early literature was plagued with methodological issues that went from the definition of trade reforms, which often included not only trade-related reforms but also macroeconomic reforms (Sachs and Warner, 1995), to issues of endogeneity and measurement (Edwards, 1998 or Frankel and Romer, 1999) which led to biased results. Moreover, the use of cross-sectional data from very different countries at different levels of development with very different initial conditions implicitly assumes that the response to trade reforms was homogeneous. This is unlikely to be the case.

Wacziarg and Welch (2008) addressed most of the criticisms that Rodríguez and Rodrik (2000). Making use of the within country variation in openness to trade and economic growth with the help of a difference-in-difference estimator, they are able to control for initial conditions and they estimate that when economies open up to trade, GDP growth increases on average by 2 percentage points (see Figure 1). They also provide evidence showing that the mechanism through which GDP grows is due to a sharp increase in investment following trade reforms.

Feyrer (2009a) using a methodology similar to Frankel and Romer (1999) estimate an elasticity of income per capita with respect to trade of 0.5. He circumvents the problem in Frankel and Romer (1999) who used time-invariant geography determinants of to

instrument for trade when explaining variations in income per capita across countries, by using a measure of the time-varying impact of geographic distance on trade. The idea is simple. With technological progress in the international transport sector, the same geographic distance does not have the same impact across time. He therefore instruments international trade flows using a measure of the time-varying distance. This allows Feyrer (2009a) to use bilateral fixed effects to control for time-invariant institutional determinants of income per capita (and trade) which as argued by Rodríguez and Rodrik (2000) were important omitted variables in Frankel and Romer (2009).<sup>2</sup>

There is also a fast growing literature on firm productivity and trade liberalization, which has tended to show that within firm productivity increases with trade reforms through two main channels (see Pavcnik, 2002, Amiti and Konings, 2007 or Topalova and Khandelwal, 2011). The first is an increase in within-firm productivity thanks to a larger variety of cheaper intermediate inputs and stronger competition. The second is a composition effect due to the exit of less productive domestic firms. The growth in aggregate productivity through these two channels can then partly explain the positive impact of trade reforms on GDP growth. Similarly, the literature on exporting firms and productivity has tended to show that exporting firms are more productive, but that this is mainly explained by a selection effect: more productive firms become exporters (Bernard and Jansen, 1999). However, most of the existing evidence is for developed countries. Recent empirical work using developing country data tends to show some evidence of "learning-by-exporting" whereas firms become more productive as they start exporting (see Van Biesebroeck, 2005).

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<sup>2</sup> Feyrer (2009b) also exploits the idea that the impact of geographic distance can be time-varying by using the changes in maritime shipping distance resulting from the closing of the Suez Canal in 1967 and its reopening in 1975. He argues that the shock provoked by the opening and closing of the Suez canal is exogenous and shows that the induced changes in trade had a positive and statistically significant impact on trade flows.

An issue not addressed by the recent empirical literature on trade and growth surveyed above is the potential heterogeneity in the impact of trade reforms on growth.<sup>3</sup> It is only on average that opening up to trade leads to 2 percentage higher growth in Wacziarg and Welch (2008) or in Feyrer (2009a). Perhaps, the more interesting question is why some countries grow faster and others slow down when they open up to trade.<sup>4</sup>

Freund and Bolaky (2008) are among the first to search for systematic differences. Their focus is on whether the sign and size of the impact depends on how flexible are business regulations in each country. The logic is quite simple. In order to take advantage of the new opportunities offered by trade openness, factors of production need to be reallocated from sectors with relatively low productivity to sectors with relatively high productivity. For this to occur, business regulations need to ensure that firms can exit and enter sectors without facing large costs. Figure 2 illustrates the importance of entry barriers in determining the gains from trade in a two sector model with an import-competing and an exported good. Panel A illustrates the classic gains from trade when there are no entry costs. Panel B shows the additional losses associated with trade when entry costs do not allow resources to be redeployed from low to high productivity sectors and, as a result, are unemployed.

Freund and Bolaky (2008) empirically examine the role played by business regulations in determining the impact of trade on income per capita. They split the countries in their

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<sup>4</sup> Important inputs into this process were the early CUTS case studies of episodes of trade reforms in a selected number of developing countries (CUTS, 2008), which highlighted and explain the heterogeneity of experiences across countries.



sample into countries with above median business regulations (left panel) and below median business regulations (right panel) in terms of the flexibility granted for the entry and exit of firms. There is a positive relationship between trade and income per capita, but only in countries with above median business regulations (left panel). The relationship is negative (although not statistically significant) for countries with below median business regulations (right panel). These results are robust to the introduction of control variables such as rule of law, distance to the equator, a dummy indicating whether the country is landlocked, and population size.

Chang, Kaltani and Loayza (2009) build on Freund and Bolaky (2008) and explore how other types of complementarities affect the relationship between trade and growth in a dynamic panel containing 22 developed countries and 60 developing countries with on average 11 observations per country. Using interaction terms they examine how the impact of trade reforms on economic growth varies depending on the level of education enrollment, financial depth, inflation, telecommunication infrastructure, governance, labor market flexibility and firm entry and exit flexibility.

They found that higher education enrollment, financial depth, better governance and telecommunication infrastructure, as well as more labor market and firm entry and exit flexibility turn from negative to positive the impact on GDP growth of a one standard deviation increase in the log of trade to GDP ratio. Thus, initial conditions do matter and can change the sign of the impact of trade reforms on economic growth from positive to statistically insignificant or even negative.

### **3 The role of infrastructure**

As shown by Chang, Kaltani and Loayza (2009) the quality of infrastructure (proxied by the number of main telephone lines per capita in their paper) is an important determinant of the impact of trade reforms on economic growth. At the bottom of the

sample in terms of quality of infrastructure, increases in trade openness lead to negative growth, whereas at the top of the distribution in terms of quality of infrastructure increases in trade openness leads to positive GDP growth.<sup>5</sup>

But the number of telephone lines is only a very partial indicator of infrastructure. And an important literature has been looking at how many other dimensions of hard infrastructure (physical infrastructure such as telephone lines, and other ICT infrastructure, ports, and roads) and soft infrastructure (border and transport efficiency, and the business and regulatory environment) affect international trade flows. Most of this literature uses the empirical workhorse of studies in international trade: the gravity equation.

Nordås and Piermartini (2004) are an early example. Their results are not very robust to the introduction of infrastructure variables in the gravity framework. One problem with their approach is that the gravity framework is built to explain the variation in bilateral trade flows, and infrastructure variables are measured at the aggregate level, i.e., the quality of the importer's port is the same no matter from which trading partner we are importing from. So a trick they use is to build a bilateral index of infrastructure that combines the level of infrastructure in the importing and exporting country. This implicitly assumes that the importing and exporting country infrastructure are perfect substitutes which may be too strong an assumption when looking at the impact in the importing country for example.

Helble, Shepherd and Wilson (2009) focus on how the degree of transparency in setting trade policy affects bilateral trade flows among Asian-Pacific countries. They do suffer from the same problem as Nordås and Piermartini (2004) as transparency in trade policy only varies at the importer or exporter level, but they circumvent this problem by

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<sup>5</sup> One reason why increases in trade openness may lead to negative GDP growth in the presence of poor infrastructure is as in Freund and Bolaky (2008) that it is difficult to reallocate resources to more productive uses in the presence of poor infrastructure.

accepting potential bias due to the absence of multilateral resistance terms in their gravity specification. Their measure of transparency in trade policy partly captures measures of soft infrastructure such as the degree of trade-related corruption, the efficiency of customs and border agencies, logistics indicators, as well as the degree of uncertainty in trade policy. They also cleverly address the problem of endogeneity using the fact that ex-British colonies tend to have more transparent trade regimes. While the degree to which being an ex-British colony satisfies the exclusion restriction cannot be tested (as there is only one instrument), this is one of the rare studies in this literature that takes seriously the problem of endogeneity. Their results reproduced in Table 1 show that transparency in trade policy setting in the importing country positively affects bilateral trade flows. Exporter transparency in trade policy setting seems to have a more ambiguous impact on trade flows.

Francois and Manchin (2013) examine the impact of infrastructure and institutional quality on bilateral trade flows using a gravity setup that controls for zero trade, as well as multilateral resistance using the method proposed by Baier and Bergstrand (2009). To control for endogeneity of infrastructure and institutional quality they used their lagged values, as many others in the literature, but one may wonder whether these are adequate instruments given the important time persistence of variables such as infrastructure and institutions. Nevertheless, consistent with other results in the literature, they found that both infrastructure and institutional quality are important determinants of bilateral trade.

Portugal-Perez and Wilson (2012) also use a gravity framework to examine the impact on bilateral trade flows of hard and soft infrastructure. They found that physical infrastructure was the most robust determinant of bilateral exports, whereas the impact of other variables often changed sign depending on specifications or the estimators they used.

Djankov, Freund and Pham (2010) use a difference gravity equation to solve the problem that most of infrastructure variables do not have a bilateral dimension which is the variation in the data used to estimate gravity equations.<sup>6</sup> They find that soft infrastructure does matter for international trade. An extra day on the number of days necessary to clear customs in the exporting country leads to a 1 percent reduction in exports. They also cleverly control for potential reverse causality. Indeed countries that rely more heavily on export markets may invest more on export infrastructure. To address this they use a sample of landlocked countries and instrument the time to export with the time to export in neighboring countries. Note that it is not clear that this solves the potential omitted variable bias, as the time to export in neighboring countries may be a direct determinant of exports in landlocked countries.

Helble (2014) focuses on international transport infrastructure and is one of the rare papers on infrastructure that does not suffer from the difficult problem of having to explain the impact of an aggregate variable (infrastructure) using a model that explains bilateral trade patterns. Indeed, he examines how shipping and air-cargo connections and frequency among Pacific countries affect their bilateral trade flows. Thus, his variables of interest (direct connectivity and frequency) have a bilateral dimension. In his setup he fully addresses the problem of zeroes and multilateral resistance as well as endogeneity that he instruments using measures of direct connectivity and frequency for passenger flights rather than shipping and cargo flights. The instrumental variable results suggest that having a direct connection and a high connection frequency has a large and statistically significant impact on bilateral trade flows.

There is also a recent and interesting literature on the importance of soft and hard infrastructure on exports at the firm level. The advantage of this empirical literature at the firm level is that the identification of the causal effect is generally much neater. It

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<sup>6</sup> The problem with the difference gravity equation is that results are sensitive to the choice of reference countries.

also allows focusing not only on international infrastructure, but also domestic infrastructure.

An example of the importance of hard infrastructure on exports using firm level data is Volpe and Blyde (2013). They use the damage caused to roads by the Chilean earthquake (a natural experiment) to identify the impact of deterioration in road infrastructure on firms' exports depending on their location. They use a difference-in-difference estimator where the change in exports of firms that were not affected by the earthquake serves as a counterfactual for those firms that were close to damaged roads. They find a large negative and statistically significant effect of the earthquake on firms' exports.

Volpe et al. (2014) use a similar empirical approach to look at the impact of shipping costs on exports. Using another "natural experiment" associated with the closing of the main bridge between Argentina and Uruguay due to an environmental dispute, they estimate how the closing of the bridge lead to higher shipping costs and how this affected exports between the two countries. They found again a very large impact. A 1 percent increase in shipping costs causes a 7 percent decline in exports.

There is also a large and growing literature focusing on the impact on firm exports of soft infrastructure projects related to customs efficiency. Volpe, Carballo and Graziano (2015) how the functioning of customs, and in particular the time it takes to clear customs, affects firms' export value. In other words, they address a similar question to the one in Djankov, Freund and Pham (2010) but use firm level data to identify the causal impact.<sup>7</sup> Endogeneity and reverse causality in particular is a problem here as larger and more frequent exporters may face shorter (or longer) customs delays. Using Uruguayan customs data at the transaction level, they solve this problem by using the random allocation of shipments to more or less expedient customs channels, which they

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<sup>7</sup> They also have information of the actual time spent by each shipment at customs rather than the time reported by a few customs operators as in the Doing Business database.

use as an instrument for the time spent at customs. They found that customs delays have a negative, large and statistically significant impact on the value of export shipments.

An interesting point made by Carballo, Graziano, Schaur and Volpe (2016a) is that the time spent at customs is endogenous, as firms will chose different channels or whether to export or not, depending on the length and frequency of customs delays. Thus any ranking of customs efficiency based on actual time spent at customs will be biased by a composition effect. More importantly, they show that the impact of customs delays is heterogeneous across firms. In particular new firms are more elastic to customs delays. This may be explained by the fact that unexpected delays may hurt the reputation of new firms more than those of more established firms.

Another interesting question is to examine whether export programs aiming at facilitating trade for small firms are effective. An example of such a program is Peru's *Exporta Fácil*, which allow for the export of small shipments (below USD 2000 and a maximum of 30kg) through Peru's postal system using simplified export procedures. Carballo, Schaur and Volpe (2016a) examine its impact on exports and find that the program boost exports mainly through the extensive margin allowing smaller firms to enter new markets with new products. The survival rate of new exporting firms seems also to be much larger for those firms using the postal program. Trade facilitation programs can therefore have larger impact on smaller firms.

The development of online platforms such as eBay, Alibaba and Amazon that allow small firms to access customers in very distant countries combined with trade facilitation programs such as *Exporta Fácil* has a strong potential for making trade more inclusive by allowing smaller and less productive firms in far away countries to reach international customers everywhere. Lendle, Olarreaga, Schropp and Vézina (2016) show that geographic distance matter much less on online platforms than offline, and that through

feedback mechanisms they allow for the creation of reputation at relatively low costs. This explains why relatively small firms can access a large number of distant export markets and have higher survival rates than offline firms (Lendle, Olarreaga, Schropp and Vézina, 2013). This literature suggests that the combination of postal trade facilitation programs with programs providing access to online platforms to small firms in remote areas can be an effective way for spreading the benefits of globalization where they are most needed.

More generally the simplification of customs procedures through the introduction of electronic customs single windows in (Carballo, Graziano, Schaur and Volpe, 2016b) or through the implement of Authorized Economic Operator programs (Carballo, Schaur and Volpe, 2016b) that simplify procedures for trustworthy firms generate increases in firms' exports along both the intensive and extensive margins.

#### **4 Domestic versus international infrastructure**

As shown by the papers reviewed in the previous section domestic and international infrastructures tend to have a positive impact on exports. There is however an important question that remains unanswered: should public investment in infrastructure be targeted towards domestic or international infrastructure? Where are the largest returns?

Recent evidence by Atkin and Donaldson (2015) suggests that the answer to this question may be country specific. Indeed, they show that in Ethiopia and Nigeria domestic trade costs may be 4 to 5 times larger than in the United States. Does this imply that more priority should be given to investment in domestic infrastructure in Ethiopia and Nigeria than in the United States?

Martin and Rogers (1995) put forward a theoretical model of firm location that addresses this question. Domestic infrastructure is defined as the infrastructure that helps domestic trade, whereas international infrastructure is defined as the infrastructure helping international trade. The focus of their model is not on the impact on exports (on which most of the empirical literature surveyed above focused), but on GDP per capita.

In their location model, trade integration implies that in the presence of economies of scale firms tend to locate in countries with better domestic infrastructure as they offer lower costs to serve all markets. Better international infrastructure magnifies the industrial relocation of firms towards the country with better domestic infrastructure. This has implications for developing countries which tend to have poor infrastructure. Investment in domestic infrastructure will help the relocation of firms towards developing countries, which become more attractive. On the other hand, investment in international infrastructure will make it more attractive to serve the developing country market from countries with better domestic infrastructure. Thus, if investment in domestic and international infrastructure unambiguously makes rich infrastructure countries more attractive, this is not the case for poor-infrastructure countries. Only investment in domestic infrastructure will make countries with poor infrastructure more attractive to investors.

The prediction of Martin and Rogers (1995) has not been empirically tested so far. There are probably two reasons for this. First, there is a measurement problem. It is difficult to distinguish between domestic and international infrastructure: is the road from the firm to the port part of domestic or international infrastructure? Second, there is an endogeneity problem in trying to assess the impact of infrastructure on income. The fact that a region is more attractive and richer makes it easier to invest in infrastructure.



We try to circumvent these two problems as follows. The measurement problem is partly solved by the new databases with measurement of bilateral trade costs between countries made available by Novy (2013) and Arvis et al. (2015). These papers used the gravity framework and bilateral trade and production data to back out bilateral trade costs between countries. It is important to note that trade costs do not only imply bad infrastructure, but they will be affected by bad infrastructure. Moreover, the logic of Martin and Rogers (1995) paper will carry to other determinants of domestic and international trade costs.

One problem with the existing bilateral trade cost dataset is that the methodology developed by Novy (2013) and implemented by Arvis et al. (2015) only captures bilateral trade costs relative to the geometric average of domestic trade costs in the exporting and importing country. What we need in order to test Martin and Rogers (1995) is a measure of international trade costs relative to domestic trade costs in each country, and not relative to the average domestic costs of the importing and exporting country.

To circumvent this problem we will work at the region rather than country level and focus on intra-regional (as a proxy for domestic) to extra-regional (international) infrastructure. We use the 22 UN geographical regions (4 in the Americas, 5 in Asia, 5 in Africa, 4 in Europe, and 4 in the Indian Ocean) and then measure for each region the ratio of intra-regional to extra-regional trade costs as explained below.

Note that this does not totally solve the problem. The intra-regional trade costs now capture the average intra-regional trade costs relative to the geometric mean of domestic costs within the region, which is the type of measure we are after. However, to only use this measure would potentially suffer from an omitted variable bias as we will be excluding extra-regional trade costs from the analysis. But using the ratio of intra-regional to extra-regional trade costs suffers from the problem that the extra-regional trade costs is actually given by the ratio of extra-regional trade costs relative to

the geometric mean of domestic costs in the region and in rest-of-the-world trading partners. The assumption we then need to make is that at the regional level the ratio of domestic regional trade costs to extra-regional domestic trade costs is relatively constant across time and can be captured by a region dummy.<sup>8</sup>

The endogeneity problem of domestic and international infrastructure is usually addressed by using an instrumental variable estimator, but as discussed above it is difficult to identify a variable that will be correlated with infrastructure (or trade costs), but otherwise uncorrelated with international trade or income. The solution to this is not to focus on the impact of domestic or international infrastructure, but on the ratio of domestic to international infrastructure (i.e., the ratio of international to domestic trade costs). The idea is that if domestic and international infrastructures (i.e., trade costs) are likely to be endogenous to economic activity, their ratio is less likely to be affected by economic activity. In other words, the identifying assumption is that anything that may be simultaneously affecting infrastructure and income is affecting domestic and international infrastructure in a similar way so that it does not create an endogeneity problem.

We also address any omitted variable bias that is country or time specific by using a set of country and time specific fixed effects. The test of the Martin and Rogers (1995) prediction is then given by:

$$\ln y_{r,t} = \alpha_r + \alpha_t + \beta \ln r_{r,t} + \delta D_{r,t} + \gamma D_{r,t} \ln r_{r,t} + \epsilon_{r,t} \quad (12)$$

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<sup>8</sup> Note that there is a tension with the argument here. As we aggregate to the region level we average out the country specific shocks within the region, but because the rest of the world becomes smaller (as our unit of observation becomes the region) the averaging out of specific shocks in the rest of the world becomes less effective. As an alternative we will run the same econometric specifications described below at the country level and then assume that the country fixed effects will capture the ratio of domestic trade costs to rest of the world domestic trade costs.

where  $y_{r,t}$  is a measure of economic activity (GDP per capita) in country  $r$  at time  $t$ ;  $r_{r,t}$  is the ratio of intra-regional (domestic) to extra-regional (international) trade costs; this ratio is positively correlated with the ratio of international to domestic infrastructure;  $D_{r,t}$  is a dummy taking the value 1 when region  $r$  at time  $t$  has a level of intra-region to extra-region trade costs that are above the median (trade costs above the median imply that infrastructure is below the median everything else equal);  $\epsilon_{r,t}$  is an identical and independently distributed error term;  $\alpha_s$  are fixed effects that control for anything that is region or time invariant, and  $\beta$ ,  $\gamma$  and  $\delta$  are parameters to be estimated.

Our parameter of interest is  $\gamma$  which according to Martin and Rogers (1995) we expect to be negative. Indeed, in countries with poor infrastructure, an increase in the ratio of regional to international trade costs (i.e., a reduction in the ratio of domestic to international infrastructure) should lead to a reduction in economic activity in the region.

#### 4.1 Testing Martin and Rogers (1995) prediction

The results of the estimation of equation (12) are reported in Table 2. The first column simply reports a regression of the ratio of GDP per capita on intra to extra-regional trade costs, as well as region and year fixed effects. It suggests that there is not much of a correlation between the two. However, as the second column illustrates, once we allow for the non-linearities in Martin and Rogers (1995) and introduce an interaction of the ratio of intra to extra-regional trade costs with a dummy that signals that the ratio is above the median of the distribution, we obtain a negative, large and statistically significant coefficient in the interaction of the relative cost of intra to extra regional trade costs with a dummy variable indicating that the region has above median intra to extra-regional trade costs. This is Martin and Rogers' (2005) prediction. In countries where the intra-regional infrastructure is relatively bad, a deterioration of the ratio of intra to extra-regional infrastructure hurts growth. Note that deterioration in the ratio of intra to extra-regional infrastructure can be achieved by improving the extra-regional infrastructure while leaving the intra-regional infrastructure unchanged. Thus, in

countries with a relatively bad domestic infrastructure relative to their international infrastructure, the priority should be given to investments in domestic infrastructure, not international infrastructure.

In the third column we use the distribution of intra-regional trade costs instead of the distribution of intra to extra-regional trade costs to split the sample at the median, and we obtain results very similar to the ones in the second column. The reason for this robustness test is that the intra-regional trade costs at the regional level are not contaminated by the domestic trade costs in the rest-of-the-world.

In the fourth column our level of observation is the country, and not the region. As discussed above, here we suffer from the problem that the measures of international trade costs in Arvis et al. (2015) are actually the ratio of international trade costs to the geometric mean of domestic trade costs between the importer and the exporter. As long as all countries are small the rest-of-the-world domestic trade costs may be captured by the year dummies. Because their measure is the ratio of international to domestic cost we took the inverse to make them comparable with our intra (as a proxy for domestic) to extra (as a proxy for international) regional trade costs. Results in the fourth column confirm that the coefficient on the interaction is negative and statistically significant.

In the fifth and sixth column we tested how sensitive were the results to our splitting of the sample at the median. In the fifth column we split the same at the 25 percentile and in the sixth column at the 75 percentile. Even though the coefficient on the interaction is always negative, it is not statistically significant, which suggests that results are not very robust to the choice of threshold. This may have been expected from Martin and Rogers (1995) model which does not specify the level of threshold at which the change in regime occurs. Nevertheless, these results call for some further robustness or confirmation that a split at the median is reasonable.

To examine whether the split of the sample at the median is a reasonable assumption we will let the data speak as theory is not very informative. We follow a Hansen (2000) threshold model estimation and rewrite equation (12) as a two regime model:

$$\ln y_{r,t} = \alpha_r + \alpha_t + \gamma D_{r,t} \ln r_{r,t} + \rho(1 - D_{r,t}) \ln r_{r,t} + \epsilon_{r,t} \quad (13)$$

where  $\gamma$  captures how the ratio of intra to extra-regional trade costs affects GDP per capita when we are in a regime with relatively high intra to extra-regional trade costs (i.e., relative bad intra-regional infrastructure), and  $\rho$  captures the impact on GDP per capita of intra to extra-regional trade costs when we are in a regime with relatively low intra to extra-regional trade costs (i.e., a relatively good intra-regional infrastructure). The threshold at which we shift from one regime to another is estimated as follows. We estimate equation (13) for all the percentiles of the distribution of intra to extra-regional trade costs by constructing a new dummy  $D_{r,t}$  for each percentile. The estimated threshold is the one that minimizes the sum of squared residuals.<sup>9</sup>

The results are reported in Table 3. The first column estimates equation (13) using an exogenous threshold at the median. It is the equivalent of the second column in Table 2 and it confirms that for countries with intra to extra-regional trade costs above the median, an increase in the ratio of intra to extra-regional trade costs leads to a decline in GDP per capita, whereas for countries with a ratio of intra to extra-regional trade costs below the median an increase in the ratio leads to an increase in GDP per capita. The second column provides the estimation of a Hansen (2000) threshold model. Figure

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<sup>9</sup> Following Hansen (2000) we can test for the statistical significance of the threshold as follows. The threshold is statistically different from zero at the  $\alpha$  percent confidence level if the likelihood ratio statistics described by expression  $n(S(0) - S^*)/S^*$  (where  $S^*$  is the minimum sum of squared residuals at the estimated threshold,  $S(0)$  is the sum of squared residuals if we set the threshold at 0, and  $n$  is the number of observations) is greater than  $-2\ln(1 - \sqrt{1 - \alpha})$ .

4 shows the sum of squared residuals of regressions for different percentiles. The minimum is achieved at 54 percent, so slightly above the median. The threshold is statistically different from zero and results are very similar to the ones reported for the median in the first column.

Thus, the threshold model confirms that there are two regimes. For countries with relatively low intra to extra-regional trade costs, the priority should be to reduce extra-regional trade costs by investing in extra-regional trade infrastructure so that the ratio increases and leads to increases in GDP per capita. On the other hand in countries with relatively high intra to extra-regional trade costs, the priority should be to reduce intra-regional trade costs by investing in intra-regional infrastructure so that the ratio declines and leads also to an increase in GDP per capita. These results confirm the theoretical predictions in Martin and Rogers (1995).

## **5 Concluding remarks**

Our survey of the literature on trade, infrastructure and development shows that trade openness has on average a positive impact on economic growth, but there is some important heterogeneity across countries in this relationship. In particular, how much countries benefit from further integration into global markets depends crucially on initial conditions in each country.

Among these initial conditions the quality of infrastructure matters. The micro and macro-econometric evidence has shown that better domestic and international infrastructure leads to higher levels of trade. And this is true for both soft and hard infrastructure associated with trade facilitation. Importantly, trade facilitation programs that aim at helping small exporters such as some of the Latin American postal export programs have a large impact along the product and market extensive margins of small firms. The combination of this type of programs with access to online platforms that

help small firms access far away customers and build reputation in international markets can help make trade more inclusive.

However, as theoretically shown in a location model by Martin and Rogers (1995) more trade does not necessarily mean higher economic activity in the country investing in international infrastructure. If countries with relatively poor domestic infrastructure and therefore higher domestic production costs invest in international infrastructure they will help the relocation of firms towards other countries with better domestic infrastructure and lower costs.

Using data on international trade costs estimated by Arvis et al. (2015) we show that this prediction is supported by the data. Increases in the ratio of domestic to international trade costs hurt GDP per capita in countries with relatively high domestic to international trade costs, but helps GDP per capita in countries with relatively low domestic to international trade costs.

This implies that in countries with relatively poor domestic infrastructure relative to international infrastructure, the priority should be given to improvements in domestic rather than international infrastructure. Similarly, in countries with relatively poor international infrastructure relative to domestic infrastructure the priority should be given to improvements in international rather than domestic infrastructure.

Another implication of the Martin and Rogers (1995) model is that investment in soft infrastructure (trade facilitation programs) that aim at helping exporters, such as Latin America's postal export programs are necessarily growth enhancing as long as they promote exports which is supported by the existing empirical evidence.

Finally, a few caveats. Let me first recall that throughout this paper we focused on the impact of trade and infrastructure on GDP per capita. Sustainable development by

definition is much broader than economic growth. Other chapters in this volume will address the relationship between trade and poverty, inequality, urbanization or hunger. However, it seems important to note that we leave as an open question the impact that investment in domestic versus international infrastructure may have on other dimensions of development. The relationship is unlikely to be linear and further work should explore this question.

Second, there are some unanswered questions regarding which type of infrastructure is desirable. The literature seems to suggest that investment in soft infrastructure that helps exporters is likely to be growth-enhancing. But there is no consensus on the broader question of whether priority should be given to investments in soft or hard infrastructure. This is important because 90 percent of aid-for-trade is granted to hard infrastructure. Investments in hard infrastructure are often more costly, but is it there were the higher returns will be obtained in terms of economic development?

Last, but not least, there are unanswered questions regarding different tradeoffs on investments in infrastructure: quality vs quantity, maintenance versus new infrastructure, financing with user fees vs subsidies, or universal services versus cost efficiency. The answers to these questions are likely to be country and investment specific and depend to a large extent on the development objectives of each country.



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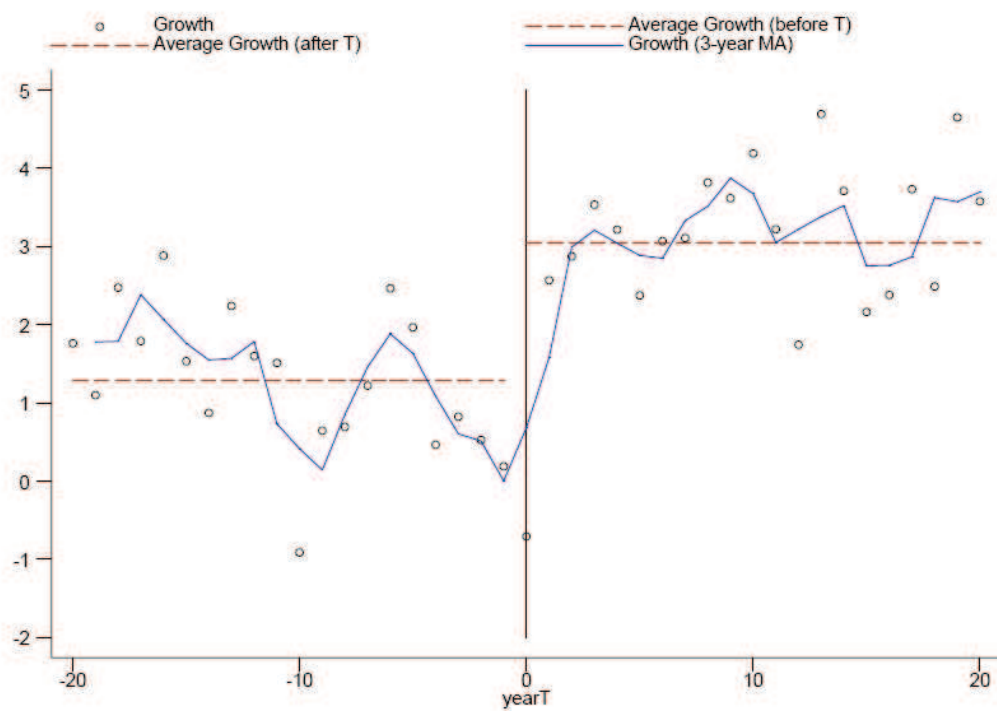
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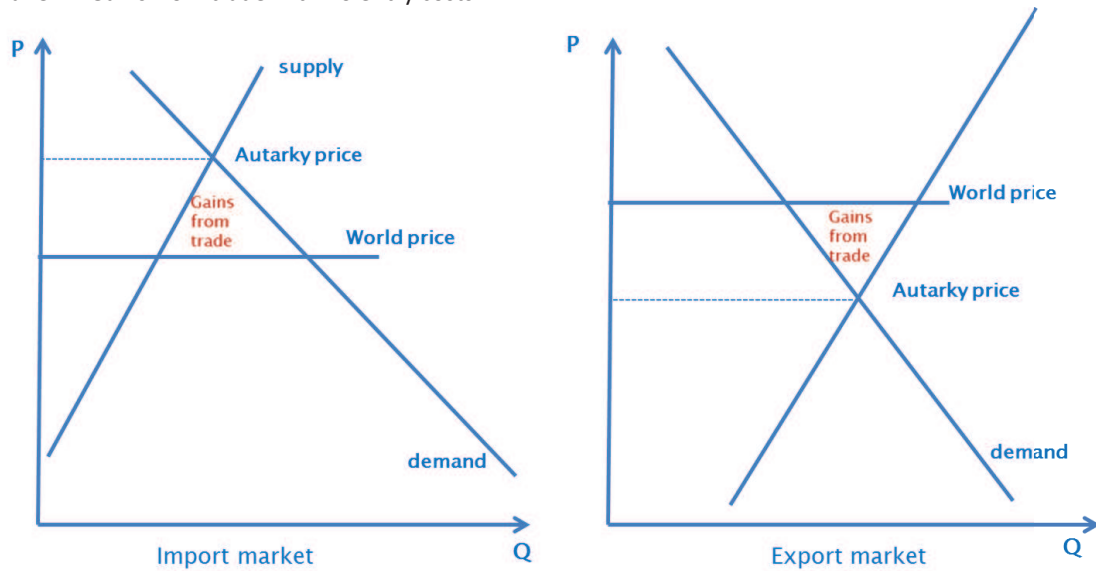
Figure 1: GDP growth before and after trade liberalization



Source: Wacziarg and Welch (2008).

Figure 2: Gains from trade with and without entry costs

Panel A: Gains from trade with no entry costs



Panel B: Gains from trade with entry costs

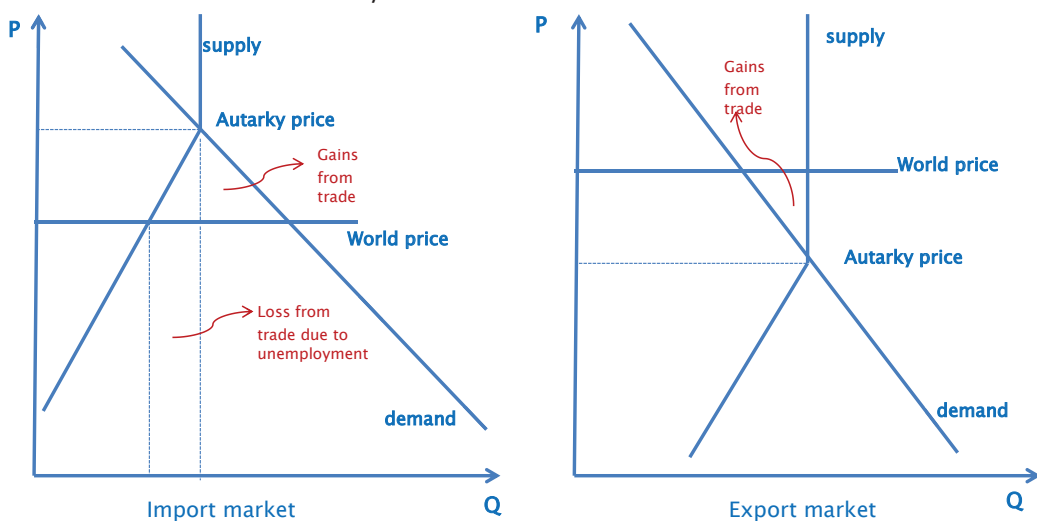
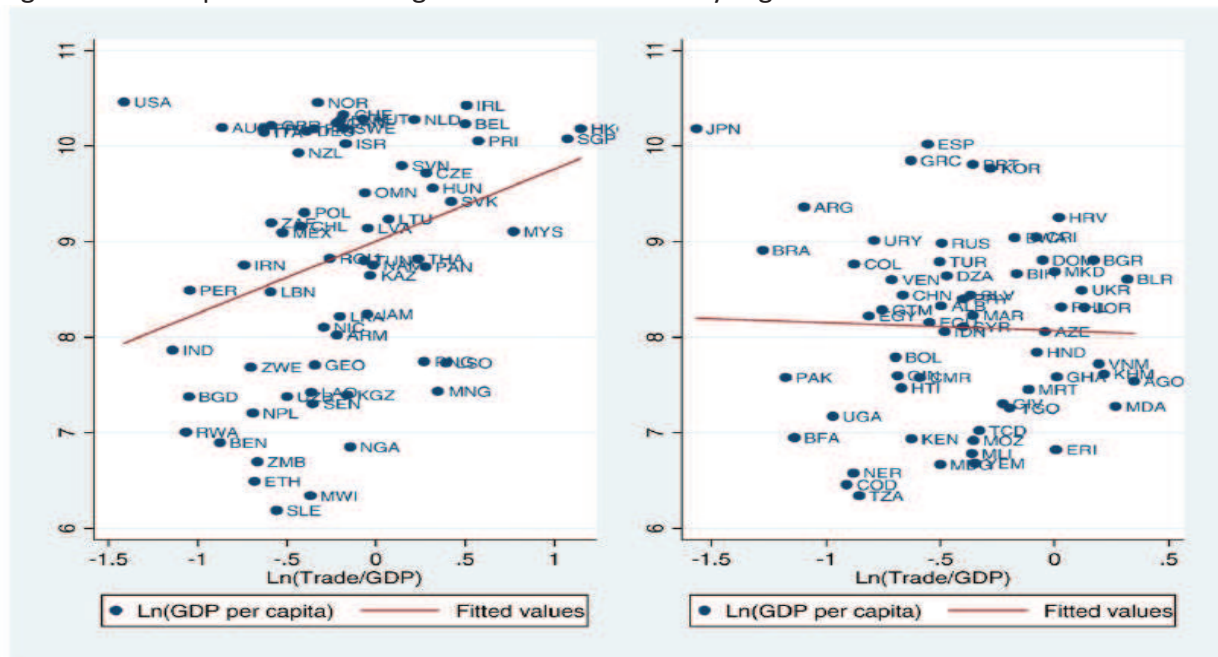
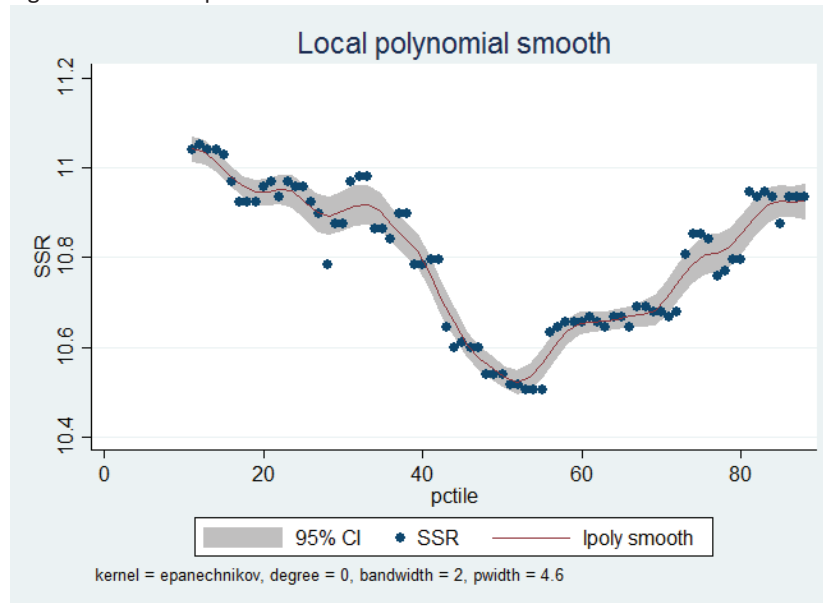


Figure 3: The impact of trade on growth: the role of entry regulations



Source: Freund and Bolaky (2008)

Figure 4: Sum of squared residuals of the estimation of the threshold model



Note: Each blue dot gives the sum of squared residuals of the regression for each percentile of the distribution of intra to extra-regional trade costs. The sum of squared residuals is minimized at the 54 percentile. The red line provides the estimation of a local polynomial and the gray area the 95 percent confidence interval.



Table 1: Impact of Importer and Exporter Transparency on trade flows

	<i>All Goods</i>	<i>HS &gt; 27</i>	<i>HS &gt; 83</i>	<i>Diff. Goods</i>	<i>Homog. Goods</i>
GDP Importer	0.605*** [0.023]	0.596*** [0.016]	0.599*** [0.018]	0.577*** [0.021]	0.641*** [0.028]
GDP Exporter	0.660*** [0.020]	0.745*** [0.017]	0.789*** [0.016]	0.770*** [0.770]	0.557*** [0.026]
Tariff (RG Weighted)	-0.701 [0.588]	-1.421 [0.988]	-2.121 [1.603]	0.138 [1.194]	-0.875 [0.702]
NTB (RG Weighted)	0.414 [0.469]	-0.951** [0.439]	-1.881** [0.805]	0.076 [0.023]	1.057*** [0.367]
Imp. Transparency	1.828*** [0.302]	1.864*** [0.373]	2.583*** [0.401]	3.889* [2.533]	1.987 [2.049]
Exp. Transparency	-0.406 [0.260]	-0.856*** [0.239]	-0.681*** [0.199]	3.071* [2.113]	1.939 [1.749]
Observations	29,376	21,114	4,284	76,500	50,694

Notes:

Robust standard errors in brackets; \* significant at 15%; \*\* significant at 10%; \*\*\* significant at 5%. Estimation method is Poisson QML. Importer and exporter transparency are instrumented by British colonisation of the importer and exporter. First-stage *F*-statistics are 374.68\*\*\* and 306.88\*\*\* respectively.

Source: Helble, Shepherd and Wilson (2009).

Table 2: Intra to extra-regional trade cost ratio and GDP per capita, 1995-2012

	No Dummy	Dummy at 50 percentile	Dummy at 50 percentile (intra)	Dummy at 50 percentile (country)	Dummy at 25 percentile	Dummy at 75 percentile
Log (Intra/Extra)	0.10 (0.09)	0.31** (0.10)	0.22 (0.09)	0.15 (0.21)	0.36** (0.16)	0.20* (0.09)
Dummy for High Intra/Extra		-0.46** (0.11)	-0.33** (0.11)	-4.28** (1.63)	-0.32 (0.21)	-0.21* (0.10)
Dummy High* Log(Intra/Extra)		-0.74** (0.18)	-0.62** (0.18)	-0.92** (0.33)	-0.29 (0.20)	-0.30 (0.24)
R <sup>2</sup>	0.53	0.55	0.55	0.21	0.53	0.53
Number of observation	354	354	354	2481	354	354

Note: All columns contain region and year fixed effects. Robust standard errors are in parenthesis. \*\* stands for statistical significance at the 1 percent level and \* for statistical significance at the 5 percent level. In the first column we do not introduce any dummy to split regions into high and low intra to extra-regional trade costs. In the second column we use each year's median to split regions into high and low intra to extra-regional trade costs. In the third column we use the 25 percentile and in the fourth column the 75 percentile of the distribution of intra to extra-regional trade costs every year. The fifth column uses the distribution of intra-regional trade costs to split the sample at the median. The sixth column uses country level data rather than region level data and the ratio is then the ratio of domestic to international trade costs (the inverse of the estimates in Arvis et al., 2015).

Table 3: Identifying the two regimes

	Dummy at 50 percentile	Estimated threshold
Dummy*Log (Intra/Extra)	-0.44** (0.16)	-0.41** (0.16)
(1-Dummy)*Log(Intra/Extra)	0.31** (0.10)	0.32** (0.10)
R <sup>2</sup>	0.55	0.55
Number of observation	354	354

Note: All columns contain region and year fixed effects. Robust standard errors are in parenthesis. \*\* stands for statistical significance at the 1 percent level and \* for statistical significance at the 5 percent level. In the first column we use each year's median to split regions into high and low intra to extra-regional trade costs. In the second column we use a Hansen (2000) threshold model. The optimum threshold is estimated at in the 54 percentile and is statistically different from zero (see also Figure 5).



*“Sur quoi la fondera-t-il l’économie du monde qu’il veut gouverner? Sera-ce sur le caprice de chaque particulier? Quelle confusion! Sera-ce sur la justice? Il l’ignore.”*

Pascal



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