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TRADE, INFRASTRUCTURE, AND DEVELOPMENT

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Abstract

In this paper, the literature on trade and development is surveyed, especially that regarding the role of complementarities associated with trade infrastructure. The empirical literature shows that, on average, trade causes growth, but the relationship is far from homogeneous across countries since initial conditions matter. Although the empirical literature shows that investment in soft and hard infrastructure has an unambiguously positive impact on trade flows, the theoretical literature argues that priority should be given to investments in national rather than international infrastructure in countries with relatively poor national infrastructure. This paper finds that data support this prediction.

JEL Classification: F10, O19, O47

Contents

1. INTRODUCTION

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

There is ample literature focusing on the relationships between trade and development, infrastructure and development, and trade and infrastructure. Often, it suggests that international trade and investment in infrastructure promote development, and that this relationship is reinforced by the positive impact that investments in both national and international infrastructure have on international trade. This paper, however, aims to better understand why these positive, reinforcing relationships are not always observed. In particular, the role played by initial conditions and complementarities is analyzed to explain the heterogeneity of outcomes that are observed when countries engage in trade reform or investments in national and international infrastructure.

The objective is not to determine whether trade or infrastructure investment is good for development; instead, it is to inform policy makers on the timing of trade reforms or investments in infrastructure so that they can help—rather than hinder—development. This paper also aims to identify other reforms, policies, institutions, and investments to ensure that trade and infrastructure have a positive impact on development.[1]

First, the relationship between trade and economic growth is examined, both from theoretical and empirical perspectives, to highlight the importance of initial conditions in explaining the heterogeneity of outcomes associated with trade reforms in different countries with various initial conditions. Second, the literature regarding the role played by investments in infrastructure in promoting trade is examined. The last section of the paper examines whether policy makers should invest their marginal infrastructure funds on national or international infrastructure.

2. DOES TRADE PROMOTE GROWTH?

Classical growth theory demonstrates that decreased marginal returns to accumulation of capital result in declining growth in a closed economy. The only source of long-term growth in such models is productivity. Ventura (1997) showed that in the presence of capital accumulation and diminishing returns, international trade allows for long-term growth. He provided 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-term 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 alters the composition of aggregate production per the Rybczynski theorem. These changes in the structure of production allow the capital-accumulating country to beat declining marginal returns of capital, and lead to long-run growth. In other words, international trade transforms the classical growth model into an AK model. However, restructuring the production bundle in an economy does not

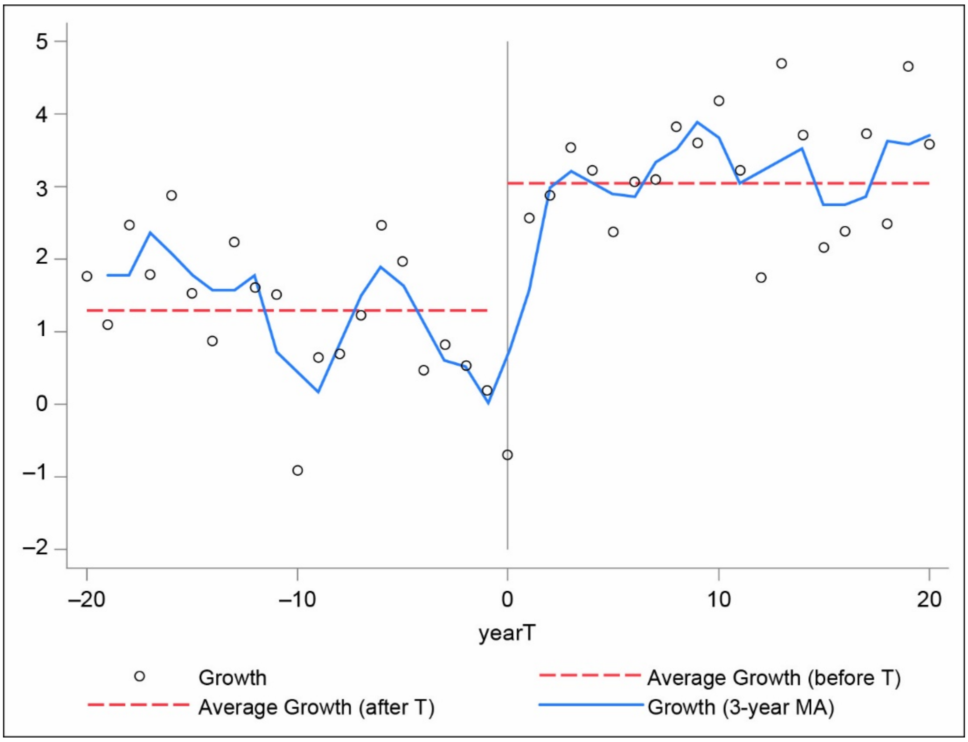
[1] It is important to note that this paper focuses on economic growth rather than sustainable development. The latter is multidimensional; trying to capture the impact of trade and infrastructure on development would transform this paper into a volume by itself.

unequivocally lead to higher growth. An example of this is provided by Matsuyama (1992), who showed that if trade pushes an economy toward specialization in a sector with low "learning" or growth opportunities, this can lead to lower aggregate economic growth through a composition effect.

When a theory provides ambiguous answers, researchers turn to empirical evidence. Although early empirical literature tended to suggest that trade liberalization is associated with higher growth, Rodríguez and Rodrik (2000) showed that most of this literature was plagued with methodological issues, including the definition of trade reforms, which often used not only trade-related reforms but also macroeconomic reforms (e.g., Sachs and Warner 1995), and issues of endogeneity and measurement (e.g., Edwards 1998, Frankel and Romer 1999) leading to biased results. Moreover, the use of cross-sectional data from different countries at various levels of development with diverse initial conditions implicitly assumed that the response to trade reforms is homogeneous, but this is unlikely.

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

Figure 1: Gross Domestic Product Growth before and after Trade Liberalization



y-axis = percentage points.

Source: Wacziarg and Welch (2008).

Feyrer (2009a), using a methodology similar to Frankel and Romer (1999), estimated an elasticity of income per capita with respect to trade of 0.5. This circumvented the problem in Frankel and Romer (1999), who used time-invariant geography determinants of bilateral trade to instrument for aggregate trade when explaining variations in income per capita across countries, by using a measure of the time-varying impact of geographic distance on trade (i.e., with technological progress in the international transport sector, the same geographic distance does not have the same impact across time). Feyrer, therefore, instrumented international trade flows using a measure of time-varying distance; this enabled using bilateral fixed effects to control for time-invariant institutional determinants of income per capita (and trade), which, as argued by Rodríguez and Rodrik (2000), are important omitted variables in Frankel and Romer.[2]

The literature is growing on firm productivity and trade liberalization, which has tended to show that within-firm productivity increases with trade reforms through two main channels: (i) a larger variety of cheaper intermediate inputs and stronger competition, and (ii) a composition effect due to the exit of less-productive domestic firms (Pavcnik 2002, Amiti and Konings 2007, Khandelwal and Topalova 2011). The growth in aggregate productivity through these two channels then partly explains 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 due to a selection effect that more productive firms become exporters (Bernard and Jensen 1999). Although most of the existing evidence is for developed countries, recent empirical work using developing country data shows some evidence of "learning-by-exporting," in which firms become more productive as they start exporting (Van Biesebroeck 2005).

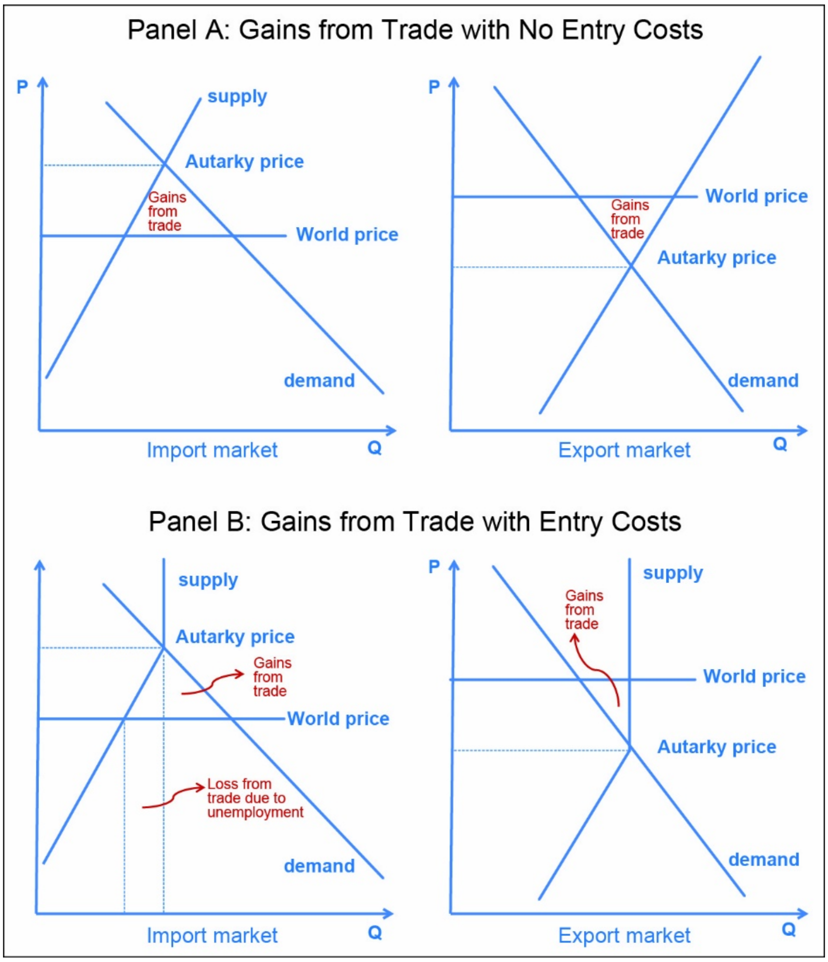
An issue not addressed by recent empirical literature on trade and growth is the potential heterogeneity in the impact of trade reforms on growth. It is only on average that opening up to trade leads to the 2-percentage-point-higher growth in Wacziarg and Welch (2008) and Feyrer (2009a). Perhaps the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

Freund and Bolaky (2008) were among the first to search for systematic differences. Their focus was on whether the sign and size of the impact depend on the flexibility of business regulations in each country. To take advantage of 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 must 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 exported good. Panel A illustrates the classic gains from trade when there are no entry costs, while 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.

[2] Feyrer (2009b) also exploited 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 argued that the shock provoked by the opening and closing of the canal was exogenous and showed that the induced changes in trade had a positive and statistically significant impact on trade flows.

[3] Important inputs into this process are early case studies of episodes of trade reforms in a selected number of developing countries (CUTS International 2008), which explained the heterogeneity of experiences across countries.

Figure 2: Gains from Trade with and without Entry Costs



Source: Freund and Bolaky (2008).

Freund and Bolaky (2008) empirically examined the role played by business regulations in determining the impact of trade on income per capita. They split countries in their sample into those with above-median business regulations and those with below-median business regulations in terms of the flexibility granted for the entry and exit of firms. They showed that a positive relationship exists between trade and income per capita, but only in countries with above-median business regulations. The relationship is negative although not statistically significant for countries with below-median business regulations. 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) built on Freund and Bolaky (2008) in exploring 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 examined how the impact of trade reforms on economic growth varies depending on education enrollment, financial depth, inflation, telecommunications infrastructure, governance, labor market flexibility, and firm entry and exit flexibility. They found that higher education enrollment, financial depth, better governance, and telecommunications infrastructure, as well as more labor market and firm entry and exit flexibility, shift, from negative to positive, the impact on GDP growth of a one standard deviation increase in the log of trade-GDP ratio. Thus, they showed that initial conditions do matter and can change the impact of trade reforms on economic growth from positive to statistically insignificant or even negative.

3. THE ROLE OF INFRASTRUCTURE

As further 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, while at the top of the distribution, trade openness leads to positive GDP growth.[4]

Yet the number of telephone lines is only a partial indicator of infrastructure. Other literature has been examining how many other dimensions of hard infrastructure (e.g., telephone lines and other information and communications technology infrastructure, ports, and roads) and soft infrastructure (e.g., border and transport efficiency, and the business and regulatory environment) affect international trade flows. Most of this literature has used the empirical workhorse of studies in international trade—the gravity equation.

Nordås and Piermartini (2004) were an early example, although their results were 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 whom one is importing). They built a bilateral index of infrastructure that combines the levels in the importing and exporting country, which implicitly assumed that they are perfect substitutes for each other.

Helble, Shepherd, and Wilson (2009) focused on how the degree of transparency in setting trade policy affects bilateral trade flows among Asia-Pacific countries. However, they had the same issue as Nordås and Piermartini (2004), as transparency in trade policy varies at the importer or exporter level, but they circumvented this problem by accepting potential bias due to the absence of multilateral resistance terms in their gravity specification. Their measure of transparency in trade policy partly captured measures of soft infrastructure (e.g., the degree of trade-related corruption, efficiency of customs and border agencies, logistics indicators, as well as the degree of uncertainty in trade policy), and they addressed the problem of endogeneity using the fact that ex-British colonies tend to have more transparent trade regimes. While the degree to which this supposition—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 that recognized the problem of endogeneity. Their results showed that transparency in trade policy setting in an importing country positively affects bilateral trade flows, while exporter transparency in trade policy settings seems to have a more ambiguous impact on trade flows (Table 1).

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[4] Increases in trade openness may lead to negative GDP growth in the presence of poor infrastructure, because, as in Freund and Bolaky (2008), it is difficult to reallocate resources to more productive uses in the presence of poor infrastructure.

Table 1: Impact of Importer and Exporter Transparency on Trade Flows

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

NTB = Non-tariff barriers to trade; HS = Harmonized system code; RG Weighted = Reference group weighted.

Notes: Robust standard errors in brackets; * significant at 15%; ** significant at 10%; significant at 5%. Estimation method in Poisson QML. Importer and exporter transparency are instrumented by British colonization of the importer and exporter. First-stage *F*-statistics are 374.68*** and 306.88*** respectively. Reference group weighting is included to circumvent endogeneity problems.

Source: Helble, Shepherd, and Wilson (2009).

Francois and Manchin (2013) examined the impact of infrastructure and institutional quality on bilateral trade flows using a gravity setup that controlled for zero trade as well as multilateral resistance using a method proposed by Baier and Bergstrand (2009). To control for endogeneity of infrastructure and institutional quality, they used their lagged values, like many others in the literature, but these may be inadequate 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 used the gravity framework to examine the impact of hard and soft infrastructure on bilateral trade flows. They found that physical infrastructure is the most robust determinant of bilateral exports, whereas the impact of other variables often changes sign depending on specifications or the estimators used.

Djankov, Freund, and Pham (2010) used a difference gravity equation to solve the problem that most infrastructure variables do not have a bilateral dimension, which is the variation in data used to estimate gravity equations.[5] They found that soft infrastructure does matter for international trade; for example, an extra day in the number of days necessary to clear customs in an exporting country leads to a 1% reduction in exports. They also controlled for potential reverse causality, as countries that rely more on export markets may invest more on export infrastructure. To address this, they used a sample of landlocked countries and instrumented the time to export with the time to export in neighboring countries. Note that it is unclear that this solved the potential omitted variable bias, as the time to export in neighboring countries may be a direct determinant of exports in landlocked countries.

5 The problem with the difference gravity equation is that results are sensitive to the choice of reference countries.

Helble (2014) focused on international transport infrastructure, examining how shipping and air cargo connections and frequency among Pacific countries affect their bilateral trade flows. The variables of interest (i.e., direct connectivity and frequency) had a bilateral dimension, and the setup addressed the problem of zeroes and multilateral resistance as well as endogeneity using measures of direct connectivity and frequency for passenger flights rather than shipping and cargo flights. The instrumental variable results suggested that having a direct connection and high connection frequency have a large and statistically significant impact on bilateral trade flows.

There is also recent literature on the importance of soft and hard infrastructure on exports at the firm level, more neatly identifying the causal effect. It also has focused more on national rather than international infrastructure. One example is Volpe and Blyde (2013), who utilized the damage caused to roads by a Chilean earthquake (i.e., a natural experiment) to identify the impact of road deterioration on firms' exports, depending on their location. They used a difference-in-difference estimator where the change in exports of firms that were unaffected by the earthquake serves as a counterfactual for those firms that were close to damaged roads. They discovered a large negative and statistically significant effect of the earthquake on firms' exports.

Volpe et al. (2014) used a similar empirical approach to examine the impact of shipping costs on exports. Using another "natural experiment," that is, the closing of the main bridge between Argentina and Uruguay due to an environmental dispute, they investigated how the closing led to higher shipping costs and how it affected exports between the two countries. They found a very large impact; a 1% increase in shipping costs caused a 7% decline in exports.

Some literature also has focused on the impact of soft infrastructure projects related to customs efficiency on firm exports. Volpe, Carballo, and Graziano (2015) noted how the functioning of customs, and in particular the time it takes to clear them, affects firms' export values. In other words, they addressed a similar question as Djankov, Freund, and Pham (2010), but used firm-level data to identify the causal impact.[6] Endogeneity and reverse causality, in particular, are problematic, as larger and more frequent exporters may face shorter (or longer) customs delays. Utilizing Uruguayan customs data at the transaction level, they solved this problem by using the random allocation of shipments to expedient customs channels, which they used 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 et al. (2016a) is that the time spent at customs is endogenous, as firms will choose different channels or whether to export depending on the length and frequency of customs delays. Therefore, any ranking of customs efficiency based on actual time spent at customs will be biased by a composition effect. More importantly, they showed that the impact of customs delays is heterogeneous across firms; in particular, new firms are more elastic to customs delays. This may be because unexpected delays hurt the reputation of new firms more than that of established firms.

Another question is whether export programs aimed at facilitating trade for small firms are effective. An example of such a program is Peru's *Exporta Fácil*, which allows for the export of small shipments (i.e., below $2,000 and a maximum of 30 kilograms) through Peru's postal system using simplified export procedures. Carballo, Schaur, and Volpe (2016a) examined its impact on exports and found that the program boosts

[6] They also had information of the actual time spent by each shipment at customs rather than the time reported by a few customs operators as in the World Bank Doing Business database.

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 program. Trade facilitation programs can, therefore, have larger impacts on smaller firms.

Indeed, the development of online platforms such as eBay, Alibaba, and Amazon that allow small firms to access customers in distant countries, combined with trade facilitation programs such as *Exporta Fácil,* has the potential for making trade more inclusive by allowing smaller, less-productive firms in various countries reach international customers. Lendle et al. (2016) showed that geographic distance matters much less for online platforms than offline, and that through feedback mechanisms, they allow for the creation of a good reputation at a relatively low cost. This explains why small firms can access a large number of distant export markets and have higher survival rates than offline firms (Lendle et al. 2013). This literature also suggests that the combination of trade facilitation programs with programs providing access to online platforms to small firms in remote areas can be effective 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 (Carballo et al. 2016b) or implementation of authorized economic operator programs (Carballo, Schaur, Volpe 2016b) that simplify procedures for trustworthy firms generate increases in firms' exports along both the intensive and extensive margins.

4. NATIONAL VERSUS INTERNATIONAL INFRASTRUCTURE

As shown by the previously reviewed literature, national and international infrastructure tends to have a positive impact on exports. However, should public investment in infrastructure be targeted toward national or international infrastructure?

Recent evidence by Atkin and Donaldson (2015) suggested that the answer to this question may be country-specific. They showed that in Ethiopia and Nigeria, national trade costs may be 4–5 times larger than in the US, implying that more priority should be given to investment in national infrastructure in Ethiopia and Nigeria than in the US.

Martin and Rogers (1995) put forward a theoretical model of firm location that addresses this question. National infrastructure was defined as infrastructure that helps national trade, while international infrastructure was defined as the infrastructure helping international trade. The focus of their model was on GDP per capita. In their model, trade integration implied that in the presence of economies of scale, firms tend to locate in countries with better national infrastructure, as they offer lower costs to serve all markets. Better international infrastructure magnifies the industrial relocation of firms toward a country with better national infrastructure.

This, of course, has implications for developing countries, which tend to have poor infrastructure. Investment in national infrastructure will help the relocation of firms to developing countries, which become more attractive. However, investment in international infrastructure will make it more attractive to serve the developing country market from countries with better national infrastructure. Thus, if investment in national and international infrastructure unambiguously makes infrastructure-rich countries more attractive, this is not the case for countries with poor infrastructure—only investment in national infrastructure will make countries with poor infrastructure more attractive to investors.

The prediction of Martin and Rogers (1995) has not been empirically tested due to a measurement problem (i.e., it is difficult to distinguish between national and international infrastructure, as it cannot be known if the road from the firm to the port part of national or international infrastructure) and an endogeneity problem in trying to assess the impact of infrastructure on income.

This paper tries to circumvent these two issues. The measurement problem is partly solved by new databases with the measurement of bilateral trade costs between countries made available by Novy (2013) and Arvis et al. (2015), who used these data and the gravity framework to back out bilateral trade costs between countries. It is important to note that trade costs do not only imply bad infrastructure, but they are affected by bad infrastructure. Moreover, the logic of Martin and Rogers (1995) carries over to other determinants of national and international trade costs.

One problem with the existing bilateral trade cost dataset is that the methodology only captures bilateral trade costs relative to the geometric average of national trade costs in an exporting and importing country. To test Martin and Rogers (1995), a measure of international trade costs relative to national trade costs in each country is needed—not one relative to the average domestic costs of an importing and exporting country. Thus, this paper must work at the region rather than country level to focus on intraregional (as a proxy for national) to extraregional (i.e., international) infrastructure. The 22 United Nations geographical regions are used (four in the Americas, five in Asia, five in Africa, four in Europe, and four in the Indian Ocean), and then the ratio of intraregional to extraregional trade costs for each region are measured.

Note that this does not completely solve the problem. The intraregional trade costs now capture the average intraregional trade costs relative to the geometric mean of national costs within the region, which is the type of measure necessary. However, to only use this measure would potentially suffer from an omitted variable bias, as extraregional trade costs are excluded from the analysis**.** However, using the ratio of intraregional to extraregional trade costs is problematic, as the extraregional trade costs are actually given by the ratio of extraregional trade costs relative to the geometric mean of national costs in the region and rest-of-the-world trading partners. The assumption necessary is at the regional level, the ratio of national regional trade costs to extraregional national trade costs is relatively constant across time and can be captured by a regional dummy.[7]

The endogeneity problem of national 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 be uncorrelated with international trade or income. The solution to this is not to focus on the impact of national or international infrastructure, but on the ratio of national to international infrastructure (i.e., the ratio of international to national trade costs). The idea is that if national and international infrastructure (i.e., trade costs) are likely to be endogenous to economic activity, the 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 national and international infrastructure in a similar way, so it does not create an endogeneity problem.

[7] Note that there is a tension with the argument here. As the region level is aggregated, country-specific shocks are averaged out, but because the rest of the world becomes smaller (as the unit of observation becomes the region) the averaging out of specific shocks in the rest of the world becomes less effective. As an alternative, the same econometric specifications are run at the country level, and then the country fixed effects will capture the ratio of national trade costs to rest-of-the-world national trade costs.

Further, any omitted variable bias that is country- or time-specific is addressed by using a set of country- and time-specific fixed effects. The test of the Martin and Rogers (1995) prediction is given by:

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

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 intraregional (national) to extraregional (international) trade costs; this ratio is positively correlated with the ratio of international to national infrastructure; $D_{r,t}$ is a dummy taking the value of 1 when region *r* at time *t* has a level of intraregional to extraregional 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; αs are fixed effects that control for anything that is region or time invariant, and β, γ, and δ are parameters to be estimated.

The parameter of interest is γ, which, according to Martin and Rogers (1995), is expected 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 national to international infrastructure) should lead to a reduction in economic activity in the region. The results of the estimation of equation 1 are reported in Table 2.

Table 2: Intraregional to Extraregional Trade Cost Ratio and Gross Domestic Product per Capita, 1995–2012

	No Dummy	Dummy at 50th Percentile	Dummy at 50th Percentile (intra)	Dummy at 50th Percentile (country)	Dummy at 25th Percentile	Dummy at 75th 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^2	0.53	0.55	0.55	0.21	0.53	0.53
Number of observations	354	354	354	2,481	354	354

Notes:

1. All columns contain region and year fixed effects.
2. Robust standard errors are in parenthesis.
3. ** stands for statistical significance at the 1% level, and * for statistical significance at the 5% level.
4. In the first column, no dummy is introduced to split regions into high and low intraregional to extraregional trade costs.
5. In the second column, each year's median is used to split regions into high and low intraregional to extraregional trade costs.
6. In the third column, the 25th percentile is used, and in the fourth column, the 75th percentile of the distribution of intraregional to extraregional trade costs every year.
7. The fifth column uses the distribution of intraregional trade costs to split the sample at the median.
8. The sixth column uses country-level data rather than region-level data, and the ratio is then of national to international trade costs (the inverse of the estimates in Arvis et al. 2015).

Source: Author's estimation.

The first column reports a regression of the ratio of GDP per capita on intraregional to extraregional trade costs, as well as region- and year-fixed effects, suggesting that a correlation does not really exist between the two. However, as the second column illustrates, once the nonlinearities in Martin and Rogers (1995) are allowed and an interaction of the ratio of intraregional to extraregional trade costs are introduced with a dummy that signals that the ratio is above the median of the distribution, a negative, large, and statistically significant coefficient is obtained in the interaction of the relative cost of intraregional to extraregional trade costs, with a dummy variable indicating that the region has above-median intraregional to extraregional trade costs—the prediction of Martin and Rogers (1995). In countries where the intraregional infrastructure is relatively bad, a deterioration of the ratio of intraregional to extraregional infrastructure hurts growth. Note that deterioration in the ratio of intraregional to extraregional infrastructure can be achieved by improving the extraregional infrastructure while leaving the intraregional infrastructure unchanged. Thus, in countries with relatively poor national infrastructure relative to international infrastructure, priority should be given to investments in national infrastructure, not international infrastructure.

In the third column, the distribution of intraregional trade costs is used instead of the distribution of intraregional to extraregional trade costs to split the sample at the median, and similar results are obtained to the ones in the second column. The reason for this robustness test is that the intraregional trade costs at the regional level are not contaminated by the national trade costs in the rest of the world.

In the fourth column, the level of observation is the country—not the region. As discussed above, the measures of international trade costs in Arvis et al. (2015) are actually the ratio of international trade costs to the geometric mean of national trade costs between the importer and exporter. As long as all countries are small, the rest-of-the-world national trade costs may be captured by the year dummies. Because their measure is the ratio of international to national cost, the inverse is taken to make them comparable with the intraregional (as a proxy for national) to extraregional (as a proxy for international) 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, how sensitive the results are to splitting of the sample at the median is tested. In the fifth column, the same is split at the 25th percentile, and in the sixth column, it is at the 75th percentile. Although 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 the Martin and Rogers (1995) model, which did 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, a Hansen (2000) threshold model estimation is followed, rewriting equation 1 as a two-regime model:

$$\ln y_{r,t} = \alpha_r + \alpha_t + \gamma D_{r,t} \ln r_{r,t} + \rho\left(1 - D_{r,t}\right) \ln r_{r,t} + \epsilon_{r,t} \tag{2}$$

where γ captures how the ratio of intraregional to extraregional trade costs affects GDP per capita in a regime with relatively high intraregional to extraregional trade costs (i.e., relative poor intraregional infrastructure), and ρ captures the impact on GDP per capita of intraregional to extraregional trade costs when in a regime with relatively low intraregional to extraregional trade costs (i.e., a relatively good intraregional infrastructure).

The threshold at which one shifts from one regime to another is estimated as follows. Equation 2 is estimated for all the percentiles of the distribution of intraregional to extraregional 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.[8] The results are reported in Table 3.

Table 3: Identifying the Two Regimes

	Dummy at 50th Percentile	Estimated Threshold
Dummy*Log (Intra/Extra)	–0.44**	–0.41**
	(0.16)	(0.16)
(1-Dummy)*Log(Intra/Extra)	0.31**	0.32**
	(0.10)	(0.10)
R^2	0.55	0.55
Number of observations	354	354

Notes:

1. All columns contain region- and year-fixed effects.
2. Robust standard errors are in parentheses.
3. ** stands for statistical significance at the 1% level, and * for statistical significance at the 5% level.
4. In the first column, each year's median is used to split regions into high and low intraregional to extraregional trade costs.
5. In the second column, a Hansen (2000) threshold model is used.
6. The optimum threshold is estimated at the 54th percentile and is statistically different from zero (see also Figure 3).

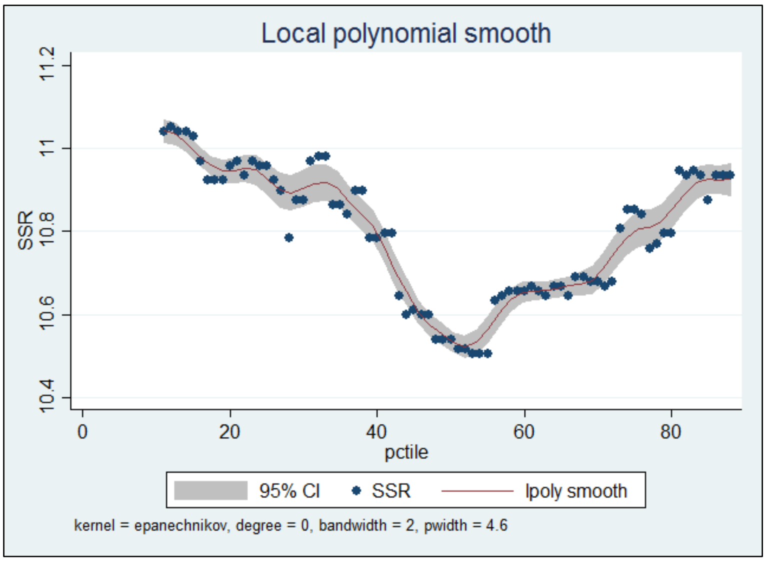
Source: Author's estimation.

The first column estimates equation 2 using an exogenous threshold at the median. It is the equivalent of the second column in Table 2 and confirms that for countries with intraregional to extraregional trade costs above the median, an increase in the ratio of intraregional to extraregional trade costs leads to a decline in GDP per capita, while for countries with a ratio of intraregional to extraregional 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 3 shows the sum of squared residuals of regressions for different percentiles. The minimum is achieved at 54%, 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.

[8] Following Hansen (2000), the statistical significance of the threshold is tested as follows. The threshold is statistically different from zero at the α% confidence level if the likelihood ratio statistics described by the 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 the threshold is set at 0, and *n* is the number of observations is greater than $-2\ln\left(1-\sqrt{1-\alpha}\right)$.

Figure 3: Sum of Squared Residuals of the Estimation of the Threshold Model



Note: Each blue dot gives the sum of squared residuals (SSR) of the regression for each percentile of the distribution of intraregional to extraregional trade costs. The sum of squared residuals is minimized at the 54th percentile. The red line provides the estimation of a local polynomial, and the gray area for the 95% confidence interval.

Source: Author's estimation.

Thus, the threshold model confirms that there are two regimes. For countries with relatively low intraregional to extraregional trade costs, the priority should be to reduce extraregional trade costs by investing in extraregional trade infrastructure so that the ratio increases and leads to increased GDP per capita. In countries with relatively high intraregional to extraregional trade costs, the priority should be to reduce intraregional trade costs by investing in intraregional infrastructure so that the ratio declines and leads to increased GDP per capita. These results confirm the theoretical predictions in Martin and Rogers (1995).

5. CONCLUSION

The survey of the literature on trade, infrastructure, and development shows that trade openness has, on average, had a positive impact on economic growth, but some important heterogeneity across countries exists in this relationship. In particular, how much countries benefit from further integration into global markets depends on the initial conditions in each country. Among these initial conditions, the quality of infrastructure matters. Microeconometric and macroeconometric evidence shows that better national and international infrastructure lead to higher levels of trade. This is also true for both soft and hard infrastructure associated with trade facilitation. Importantly, trade facilitation programs that aim to help small exporters have a large impact along the product- and market-extensive margins of small firms.

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

Using data on international trade costs estimated by Arvis et al. (2015), this paper further shows that this prediction is supported by data. Increases in the ratio of national to international trade costs hurt GDP per capita in countries with relatively high national to international trade costs, but helps GDP per capita in countries with relatively low national to international trade costs. This implies that in countries with relatively poor national infrastructure relative to international infrastructure, the priority should be given to improvements in national rather than international infrastructure. Similarly, in countries with relatively poor international infrastructure relative to national infrastructure, the priority should be given to improvements in international rather than national infrastructure.

Another implication of the Martin and Rogers (1995) model is that investment in soft infrastructure (e.g., trade facilitation programs) that aim to help exporters are growth-enhancing as long as they promote exports, which is supported by the existing empirical evidence. However, it is important to note that 90% of aid-for-trade is granted to hard infrastructure.

Sustainable development by definition is much broader than economic growth. The impact that investment in national versus international infrastructure may have on other dimensions of development is questionable. The relationship is unlikely to be linear, and further work should explore this question. Different trade-offs on investments in infrastructure must also be noted and explored: quality versus quantity, maintenance versus new infrastructure, financing with user fees versus 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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