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Abstract:
Making use of considerably improved measures of infrastructure, we assess the impact of infrastructure on bilateral trade for a panel of 37 developed and emerging economies during the period 1995-2011. We find significant and non-linear effects of overall infrastructure and infrastructure in transportation, communication, energy, and finance on trade in consumption goods, capital goods, and intermediates. Our major findings prove to be robust to various modifications and extensions of the gravity model. Importantly, we still observe significant and non-linear effects of infrastructure on bilateral trade after accounting for potential reverse causality.

Keywords: trade, infrastructure, transport, ICT, energy, finance

JEL classification: F14, O18

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1. Introduction

The verdict of Bougheas et al. (1999: 170) that "in the trade literature, the role of infrastructure remains largely unexplored" may be justified no longer. It is widely agreed by now that more and better infrastructure reduces trade-related transaction costs (e.g., Limão and Venables 2001; Vijil and Wagner 2012; Francois and Manchin 2013). Furthermore, several studies have found positive effects of infrastructure on international trade relations. The recent empirical literature focuses on the export performance of developing countries.[1] According to Limão and Venables (2001: 451), the "analysis of African trade flows indicates that their relatively low level is largely due to poor infrastructure." Likewise, Vijil and Wagner (2012), Portugal-Perez and Wilson (2012) as well as Francois and Manchin (2013) find that infrastructure is associated positively with the export performance of developing countries.[2]

All the same, the literature on the role of infrastructure for international trade is still subject to several limitations. First of all, almost all available studies rely on just a few indicators of infrastructure. For instance, the index of infrastructure used by Limão and Venables (2001) and Brun et al. (2005) is based on four indicators.[3] Francois and Manchin (2013) perform principal component analysis based on a slightly extended set of eight indicators of transport and communication infrastructure.[4] Second, the employed trade variable is rarely differentiated.[5] This could be problematic since infrastructure does not

[1] In contrast, Bougheas et al. (1999) use data from nine European countries to show that better infrastructure enhances bilateral trade by reducing transport costs. According to Brun et al. (2005), infrastructure has a positive impact on trade among rich and poor countries.

[2] Francois and Manchin (2013) and Wilson et al. (2005) find that this holds not only for South-South trade but also for Southern exports to the North.

[3] As proposed earlier by Canning (1998), Limão and Venables (2001), and Brun et al. (2005) use the density of roads, paved roads, and railways as well as the number of telephone lines per capita; see also Vijil and Wagner (2012). Bougheas et al. (1999) consider the length of the motorway network as a proxy for infrastructure (the stock of public capital is used as an alternative proxy).

[4] Similarly, Portugal-Perez and Wilson (2012) perform factor analysis based on four indicators of the quality of transport infrastructure and four ICT-related indicators. Fink et al. (2005) and Cristea (2015) focus on the costs of communication.

[5] It should be noted, however, that Fink et al. (2005) distinguish between trade in homogeneous and differentiated products. The authors show that communication costs have a stronger impact on trade in differentiated products.

necessarily have the same impact on trade in distinct product categories such as consumption goods, capital goods, and intermediates. Third, cross-section analyses, which dominated until recently, may provide limited – or even misleading – insights.[6] Finally, related to the previous point, the endogeneity of infrastructure is often neglected or, as stressed by Francois and Manchin (2013), addressed in ways that are not fully satisfactory.[7]

The present analysis attempts to overcome these limitations. We combine two new datasets to improve the measurement of infrastructure and assess its impact on disaggregated bilateral trade. We make use of the composite indices of infrastructure, recently developed by Donaubauer et al. (2015), to allow for a systematic and comprehensive measurement of overall infrastructure and infrastructure in four crucial sub-categories (transportation, communication, energy, and finance). Moreover, we perform separate estimations for three major categories of trade (consumption goods, capital goods, and intermediates) based on trade data from the World Input-Output Database (WIOD; see Timmer et al. 2015). Based on these data sources, we assess the impact of infrastructure on bilateral trade for a panel of 37 developed countries and emerging economies during the period 1995-2011. In addition to accounting for unobserved heterogeneity in bilateral trade patterns by country-pair fixed effects, we address potential reverse causality in several ways, inter alia by using innovative instruments for the countries' endowment with infrastructure in 2SLS estimations.

We find significant and non-linear effects of infrastructure on bilateral trade in consumption goods, capital goods, and intermediates. Our major findings prove to be robust to various modifications and extensions of the gravity model. Importantly, we still observe significant and non-linear effects of infrastructure on bilateral trade after accounting for potential reverse causality.

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[6] Prominent cross-country studies include Limão and Venables (2001) and Fink et al. (2005). Wilson et al. (2005) cover just two years (2000 and 2001), and Portugal-Perez and Wilson's (2012) analysis covers the short period 2004-2007.

[7] Portugal-Perez and Wilson (2012) provide the most notable exception; see Section 2 for a more detailed discussion of previous attempts to address endogeneity concerns.

We introduce the employed gravity model and the data in more detail in Section 2. The empirical results are presented and discussed in Section 3. Section 4 concludes.

2. Empirical model and data

The baseline specifications of the employed gravity model for bilateral trade between exporter $i = 1, \ldots, I$ and importer $j = 1, \ldots, J$ for $i \neq j$ in period $t = 1, \ldots, T$ are as follows:

$$Y_{ijt} = \nu + \alpha_1 gdp\_pc_{i,t-1} + \alpha_2 gdp\_pc_{j,t-1} + \alpha_3 infra_{i,t-1} + \alpha_4 \left(gdp\_pc_{i,t-1} \times infra_{i,t-1}\right) + \boldsymbol{\delta_1'} \boldsymbol{x}_{i,t-1} + \boldsymbol{\delta_2'} \boldsymbol{x}_{j,t-1} + \eta_{ij} + \theta_t + \varepsilon_{ij,t-1} \quad (1)$$

$$Y_{ijt} = \nu + \beta_1 gdp\_pc_{i,t-1} + \beta_2 gdp\_pc_{j,t-1} + \beta_3 infra_{j,t-1} + \beta_4 \left(gdp\_pc_{j,t-1} \times infra_{j,t-1}\right) + \boldsymbol{\delta_1'} \boldsymbol{x}_{i,t-1} + \boldsymbol{\delta_2'} \boldsymbol{x}_{j,t-1} + \eta_{ij} + \theta_t + \varepsilon_{ij,t-1} \quad (2)$$

We perform separate estimations for three major categories of trade: consumption goods, capital goods, and intermediates. Thus, $Y \in \{Y^{con}, Y^{cap}, Y^{int}\}$. The data are available from the World Input-Output Database (WIOD), which provides time series of world input-output tables (WIOT).[8] A WIOT is based on a set of national input-output tables that are connected with each other by bilateral international trade flows. Importantly, WIOD uses bilateral trade statistics to derive the contribution of countries of origin to imports for three distinct use categories (final consumption, investment, and intermediate use), by mapping products at the six-digit level on the basis of detailed product descriptions.

We are primarily interested in assessing the impact of infrastructure (*infra*) on bilateral trade in the three categories. Instead of relying on a few indicators of infrastructure, we make use of systematic and comprehensive measures of infrastructure available from Donaubauer et al. (2015). They construct a composite index and four sub-indices of infrastructure in transport, communication, energy, and finance. The indicators cover not only the quantity but also the quality of infrastructure. To combine the information from 30 different indicators,

[8] See Timmer et al. (2015) for details on this database. The data are available from: http://www.wiod.org/new_site/home.htm (accessed: August 2015).

Donaubauer et al. (2015) use an unobserved components model; that is, observed data on each area of infrastructure are a linear function of an unobserved common component of infrastructure and an error term. This approach, which resembles the construction of the well-known Worldwide Governance Indicators by Kaufmann et al. (2011), allows for a consistent picture of infrastructure on an annual basis for a large sample of developed and developing countries. Using the same methodology as in Donaubauer et al. (2015), the index has been updated to 2011 and re-scaled to values between 0 and 100, with higher values indicating better infrastructure. In addition to the overall index of infrastructure, we also use more specific indices for the four sub-categories to assess whether specific types of infrastructure are particularly important determinants of bilateral trade.

Apart from our focus on infrastructure, our empirical models are specified parsimoniously. According to Wilson et al. (2005: 849), "a correct specification of the gravity model is parsimonious in specific economic variables" and "rich in fixed effects." Likewise, Cheng and Wall (2005: 60) conclude that in order to control for heterogeneity in gravity models of trade, "the country-pair fixed-effects model is preferred statistically to all other specifications." Consequently, the models include only the trading partners' GDP per capita (*gdp_pc*) and a few other control variables that have been identified as potential determinants of bilateral trade in the related empirical literature.[9] GDP per capita is expected to have a positive impact on bilateral trade, not least because richer countries tend to have lower trade barriers than poorer countries. The vectors $\boldsymbol{x}$ include the populations (*pop*) and areas (*area*) of i and j as additional control variables.[10] The effects of population and geographical size are ambiguous: While more populated countries may have better trading opportunities due to specialized production patterns, larger countries tend to be less dependent on international

[9] Nevertheless, we perform a robustness test below by estimating an extended specification which includes the trading partners' geographical remoteness and import tariffs as well as a dummy variable set to one when the trading partners are members of a preferential trade agreement, and zero otherwise.
[10] The data on *gdp_pc*, *pop,* and *area* are taken from the World Bank's World Development Indicators (WDI), available at: http://data.worldbank.org/data-catalog/world-development-indicators (accessed: August 2015)

trade and more reliant on an internal division of labor. In line with Cheng and Wall (2005), we include country-pair fixed effects as well as time fixed effects. The exporter-importer pair fixed effects, η, control for all time-invariant characteristics of each country pair. Time fixed effects, θ, control for common shocks during our period of observation that affect all pairs in essentially the same way (such as the financial crisis in 2008).[11] Finally, the error term, ε, includes all aspects of bilateral trade not captured by our model.

We follow the standard approach in gravity models and include the control variables for both the importing and exporting country in a pair simultaneously. As concerns infrastructure as our variable of principal interest, we deviate from this approach in our basic estimations by including the index of infrastructure for either the importing or the exporting country. However, we subsequently treat the infrastructure variable in the same way as the control variables by including the index for both countries of a pair simultaneously after having found negligible evidence for possible collinearity:

$$Y_{ijt} = \nu + \boldsymbol{\gamma}_1 gdp\_pc_{i,t-1} + \boldsymbol{\gamma}_2 gdp\_pc_{j,t-1} + \boldsymbol{\gamma}_3 infra_{i,t-1} + \boldsymbol{\gamma}_4 infra_{j,t-1} + \boldsymbol{\gamma}_5 \left(gdp\_pc_{i,t-1} \times infra_{i,t-1}\right) + \boldsymbol{\gamma}_6 \left(gdp\_pc_{j,t-1} \times infra_{j,t-1}\right) + \boldsymbol{\delta}_1' \boldsymbol{x}_{i,t-1} + \boldsymbol{\delta}_2' \boldsymbol{x}_{j,t-1} + \eta_{ij} + \theta_t + \varepsilon_{ij,t-1} \quad (3)$$

Finally, in order to assess whether the importance of infrastructure for trade varies with per-capita income, we account for non-linear effects of infrastructure on bilateral trade. Specifically, we follow Portugal-Perez and Wilson (2012) and include an interaction term between the index of infrastructure and the country's GDP per capita.[12]

We estimate equations (1)-(3) using data on bilateral trade between 37 countries during the period 1995-2011.[13,14] All variables (including our trade measures) in equations

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[11] Alternatively, we include country fixed effects for both the exporting and the importing country. See below for the justification of this alternative. Note also that we cluster standard errors at the level of country pairs in our basic estimations. We consider alternative ways of clustering among our robustness tests below.

[12] In contrast to Portugal-Perez and Wilson (2012), we consider this interaction for both the exporting country and the importing country.

[13] The countries in the sample are the following: Australia, Austria, Belgium, Bulgaria, Brazil, Canada, China, Cyprus, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, India, Indonesia, Ireland, Italy, Japan, Korea, Lithuania, Latvia, Mexico, the Netherlands, Poland, Portugal, Romania, Russia, Slovakia, Slovenia, Spain, Sweden, Turkey, the United Kingdom, and the United States.

[14] Appendix table A1 presents summary statistics, and Appendix table A2 presents bivariate correlations.

(1)-(3) enter in logged form. Additionally, all covariates are lagged by one period.[15] The sample and time period are determined by the availability of trade data from WIOD. Due to the availability of data on bilateral trade for basically all dyads and time periods, our analysis does not suffer from a substantial loss of observations that is frequently caused by the presence of many zeroes in empirical studies of international trade.[16] In order to keep the notation simple, we suppress the fact that the coefficients, country-pair fixed-effects, time-fixed effects, and the error term vary for different choices of Y.

Infrastructure cannot reasonably be assumed to be exogenous, as has been done at least implicitly in various earlier studies (e.g., Limão and Venables 2001; Wilson et al. 2005). While we routinely address unobserved heterogeneity by including country-pair fixed effects, reverse causality cannot be excluded considering that closer international trade ties are likely to increase the political demand for better infrastructure. As noted by Francois and Manchin (2013), none of the available strategies to mitigate endogeneity are fully satisfactory.[17] Keeping this caveat in mind, we pursue different avenues to reduce endogeneity concerns in subsequent steps of our analysis. First of all, we perform a strict exogeneity test suggested by Wooldridge (2002). Second, we exclude pairs of major trading partners which may be the main drivers of the political demand for better infrastructure. Third, we apply longer lags of up to four years since reverse causality should be less pronounced when using longer lags of infrastructure as covariates. Finally, we perform 2SLS estimations by instrumenting

[15] Note that the inclusion of lags does not reduce the number of observations as we have data on all covariates for the period 1990-2011. As can be seen in Table A1, the minima and maxima of some of the re-scaled infrastructure variables deviate slightly from the extremes of the interval [0;100]. In these cases, the values of zero and 100 are located in the pre-sample period.

[16] The share of zeros in all observations is very low (0.02 and 0.03 percent) for trade in intermediates and consumption goods, and only slightly higher (0.30 percent) for trade in capital goods.

[17] Specifically, Francois and Manchin (2013: 168) argue that it is "very hard to find suitable instruments for infrastructure quality" and opt for lagged values of principal components of infrastructure. Vijil and Wagner (2012) use the proportion of land area within 100 km of the coast or a navigable river as an instrument of infrastructure. Bougheas et al. (1999) use lagged values of infrastructure plus an instrumental seemingly unrelated regression estimator with the sum of the geographical size of country pairs as an instrument for infrastructure. However, geographical characteristics are also likely to affect trade. More convincingly, Portugal-Perez and Wilson (2012) perform a robustness test by examining the effect of trade facilitation on the exports of new products.

infrastructure with political fractionalization and the degree of political checks and balances (see sub-section *Reverse causality concerns* of Section 3 for details).

3. Results

Baseline estimations

Table 1 presents the results of our baseline estimations using a parsimonious specification of the augmented gravity model. Apart from our variables of principal interest, we consider both trading partners' GDP per capita, population, and area as control variables. In contrast, we enter either the exporting country's or the importing country's endowment with infrastructure, as measured by our index of overall infrastructure, and the interaction of infrastructure with the corresponding country's GDP per capita.[18]

As discussed in Section 2, we consider bilateral trade in three distinct product categories as alternative dependent variables: trade in consumption goods in columns (1) and (2), trade in capital goods in columns (3) and (4), and trade in intermediates in columns (5) and (6). The results for the control variables are largely as expected. In particular, the exporting and the importing country's GDP per capita prove to be significantly positive at the one percent level. This holds for all three product categories, although the coefficients on GDP per capita are larger for trade in capital goods than for trade in consumption goods and intermediates. The evidence on the population size of trading partners is more ambiguous. It is mainly a larger population of the exporting country that is positively associated with bilateral trade in capital goods and intermediates, though not with trade in consumption goods. The importing country's population typically proves to be statistically insignificant. The negative coefficients on the geographic size of partner countries are hardly surprising. As

[18] In presenting our empirical results, we follow the widely used practice of indicating significance levels at the ten, five, and one percent level. It should be noted, however, that estimation errors become smaller with larger sample size. Consequently, even a small difference of an estimated coefficient from zero may produce a large test statistic in large samples such as ours so that it becomes easier to arrive at significant effects at conventional confidence levels. Against this backdrop, we would like to stress that every coefficient on infrastructure that is significant at the one percent level in any of our tables is significant at higher levels as well. The corresponding results are available upon request.

noted before, larger countries tend to be less dependent on international trade relations, making more use of internal specialization and trading opportunities. Moreover, geographic size is typically associated with higher transport costs which depend not only on the bilateral distance between the economic centers of trading partners, captured by the country-pair effects, but also on distances within countries.

Turning to our explanatory variables of principal interest, our baseline results underscore the relevance of augmenting the gravity model by the partner countries' endowment with infrastructure. The coefficients on our index of overall infrastructure prove to be significantly positive, at the five percent level or better, with just two exceptions. The evidence is strongest for trade in capital goods. More surprisingly perhaps, the exporting country's infrastructure seems to be relevant for bilateral trade in consumption goods, while the importing country's infrastructure seems to be relevant for trade in intermediates.[19] However, the coefficients on the index of infrastructure must not be regarded in isolation as the effect of infrastructure on trade is non-linear. Specifically, the interactions between overall infrastructure and the corresponding country's GDP per capita suggest that the relevance of overall infrastructure for bilateral trade tends to decline with rising per capita income of the trading partners. It is quite intuitive that the marginal effects of infrastructure decline once countries have reached a sufficiently high level of economic development which tends to be associated with advanced infrastructural facilities.

Against this backdrop, we calculate the marginal effects of overall infrastructure on trade over the range of the exporting or importing country's GDP per capita. The results are shown in Figure 1 where the broken lines represent the confidence interval of the marginal effects at the five percent level. Comparing the two graphs for a specific trade category, it appears that the importing country's infrastructure tends to be more important for bilateral trade relations than the exporting country's infrastructure. This holds for all three categories

[19] As will be shown below, this peculiarity disappears when accounting for longer lags.

of trade. Most surprisingly perhaps, the marginal effects of the importing country's infrastructure on trade in consumption goods in panel (a) prove to be significant over the large middle ground of GDP per capita (from about 3,000 to about 37,000 US$). In contrast, the marginal effects of the exporting country's infrastructure on trade in consumption goods in panel (b) are significantly positive only for exporting countries with fairly low GDP per capita (of up to 3,000 US$). As concerns trade in capital goods, we observe significantly positive marginal effects over a much wider range of the importing country's GDP per capita in panel (c), compared to the relatively narrow range of the exporting country's GDP per capita in panel (d). The differences between the marginal effects for the importing and exporting countries' infrastructure are less pronounced in panels (e) and (f) on trade in intermediates.

Collinearity and omitted variable bias

In this sub-section, we modify the basic specification of our model to address concerns about possible collinearity and omitted variable bias. Table 2 reports two robustness tests: In columns (1)-(3) we enter the exporter's and the importer's infrastructure as well as the interaction of infrastructure with the exporter's and importer's GDP per capita simultaneously. In columns (4)-(6) we maintain the previous modification and, additionally, expand our list of control variables.[20] We include an indicator variable set to one for pairs of countries that are members of a regional trade agreement (*rta*), and zero otherwise;[21] the geographical remoteness *(remote)* of both the exporter and importer in a country pair;[22] and

[20] The additional control variables are also lagged and considered in logs (except for *rta*).

[21] Our measure of regional trade agreements is taken from Mario Larch's RTA Database: http://www.ewf.uni-bayreuth.de/en/research/RTA-data/index.html (accessed: August 2015)

[22] We follow an approach that is frequently used in the literature (Gómez-Herrera 2013 is a recent example) and define remoteness for exporter *i* and importer *j* as:

$$remote_{i,t} = \sum_j \frac{d_{ij}}{\frac{gdp_{j,t}}{gdp_{ROW,t}}} \text{ and } remote_{j,t} = \sum_i \frac{d_{ji}}{\frac{gdp_{i,t}}{gdp_{ROW,t}}},$$

where d_{ij} and d_{ji} stand for the geographical distance between countries *i* and *j*, gdp_i and gdp_j denote country *i*'s and *j*'s GDP, and $gdp_{ROW,t}$ denotes the GDP of all countries in our sample.

the mean of applied tariff rates (weighted by the product import shares) in percent for both countries in a pair *(tariffs)*.[23]

Importantly, the simultaneous inclusion of the exporter's and importer's endowment with infrastructure in columns (1)-(3) does not affect the baseline findings on infrastructure and its interaction with GDP per capita. The signs and size of the coefficients are essentially as before. Consequently, the non-linearities prove to be robust and the marginal effects over the range of the exporter's and importer's GDP per capita change only slightly (not shown).[24] The baseline findings on infrastructure and its interaction with GDP per capita also hold in columns (4)-(6). The only notable change is that the importer's infrastructure now enters significantly positive in column (4), while the interaction with the importer's GDP per capita does not point to non-linearities. The coefficients on the three standard control variables change only slightly when comparing Tables 1 and 2.[25] As concerns the additional control variables, the results in columns (4)-(6) are plausible. In particular, the dummy variable on regional trade agreements proves to be highly significant and positive. In contrast, higher tariffs of both trading partners are associated with less bilateral trade.

Given that our baseline findings are hardly affected by including additional control variables we return to the parsimonious specification as in columns (1)-(3) of Table 2 in the following, in order not to lose about 3,000 observations.[26] However, we replace country-pair fixed effects by country fixed effects for both the exporter and the importer in a pair in Table

[23] Data are taken from the World Development Indicators (WDI).
[24] In unreported regressions, we replicate the estimations in columns (1)-(3) of Table 2 by clustering standard errors at the level of either the exporting country of the importing country, instead of clustering at the level of country pairs. This modification takes into account that bilateral trade relations of one particular country with different partners may be correlated with each other. The effects of this modification on our variables of principal interest are limited. It is only for trade in consumption goods that we no longer find significant effects of infrastructure and its interaction with GDP per capita when we cluster standard errors at the level of exporting countries. We still find significant and non-linear effects of infrastructure in all other estimations.
[25] The only notable exception relates to the exporter's population and geographical size in column (4) of Table 2. In contrast to Table 1, the coefficient on population is significantly negative in column (4) of Table 2, while the coefficient on *area* loses its significance.
[26] For the sake of brevity, we show all subsequent estimations with the infrastructure variables for exporters and importers included simultaneously. Additional estimations with the infrastructure variables included separately for either the exporting country or the importing country do not offer additional insights; these estimations are available on request.

3. Consequently, we now account for some widely used gravity-type variables which were absorbed by the previously included country-pair fixed effects. These include the (logged) geographical distance between the exporter and importer in a country pair (*dist*) and three dummy variables set to one for pairs sharing a common border (*contig*), a common language (*comlang*), and a colonial past (*colony*), and zero otherwise.[27] As expected, bilateral trade is negatively affected by a larger distance between the exporter and the importer,[28] while trade ties tend to be stronger between neighboring countries and when a former colony is part of a pair.

More interestingly, the modification of replacing pair fixed effects by country fixed effects considerably improves the explanatory power of the employed models. The R^2 statistics increase from around 0.5 – 0.6 in Tables 1 and 2 to almost 0.9 in Table 3, which suggests that a substantial proportion of the previously unexplained variation in bilateral trade is due to country-specific factors beyond those included as control variables in Tables 1 and 2. If these unobserved factors were also related to the endowment with infrastructure, our baseline estimates might be biased. However, the coefficients on infrastructure and its interaction with GDP per capita are essentially as before. Taken together, the findings in Table 3 suggest that our baseline results are unlikely to suffer from omitted variable bias. Remaining endogeneity concerns would then relate primarily to possible reverse causality, which is the issue to which we turn next.

Reverse causality concerns

To examine the possibility that our results are driven by reverse causality (i.e. the possibility that the positive correlation between infrastructure and trade is at least partly because closer

[27] Data are taken from CEPII. See Mayer and Zignago (2011) for a detailed description of the data.

[28] Depending on the three distinct product categories as alternative dependent variables (i.e. consumption goods, capital goods, and intermediates) the coefficient on *distance* varies between -1.11 and -1.17 and is highly significant in all cases. These magnitudes are very similar to those usually found in the literature (see e.g. Gómez-Herrera 2013).

trade relations provide incentives to improve infrastructure in order to reduce transaction costs) we conduct a strict exogeneity test as suggested by Wooldridge (2002).[29] We estimate various specifications of equation (3) augmented by a contemporaneous effect of infrastructure as well as up to three leads and lags of infrastructure for trade in consumption goods, capital goods, and intermediates (Table 4). In almost all cases, strict exogeneity is not rejected. Only when using one lead and one lag of infrastructure we find some evidence of reverse causality for the exporter's infrastructure in columns (1), (4) and (7) of Table 4. Although these test results suggest that our findings are unlikely to suffer from serious reverse causality problems, we address remaining concerns about reverse causality in alternative ways in the following.

In the first approach, we exclude pairs of major trading partners from the analysis. Arguably, the correlation between infrastructure and trade should become weaker if reverse causality plays a major role. The underlying assumption is that it should be the relatively important bilateral trade relations that are driving the demand of exporting and importing firms for better infrastructure and, thus, provide politically relevant incentives to improve the countries' endowment with infrastructure. In columns (1)-(3) of Table 5, we exclude pairs in which one trading partner accounts for more than 20 percent of the partner's total imports in a specific product category throughout the period of observation.[30] Subsequently, we exclude a larger number of pairs by reducing the threshold to ten percent of the partner's total imports (columns (4)-(6)), and to five percent of the partner's total imports (columns (7)-(9)).[31]

Our results prove to be surprisingly robust to the exclusion of pairs with major trading partners. The control variables are hardly affected when comparing Table 5 with columns (1)-

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[29] See also Baier and Bergstrand (2007) who apply this test in a gravity framework where they examine the effects of free trade agreements on trade flows.

[30] Applying the high threshold of 20 percent reduces the number of country pairs just slightly by 20-40, compared to the 1,332 pairs underlying the results in Tables 1 and 2. China and the United States are most often the exporting countries of these excluded pairs.

[31] For instance, 217 pairs are excluded in column (7) of Table 5, i.e., when applying the threshold of five percent to trade in consumption goods.

(3) of Table 2.[32] More importantly, the same holds for our variables of principal interest. Independent of the threshold applied for excluding country pairs, we again find that infrastructure matters for bilateral trade in all three categories. As before, both the exporter's and the importer's infrastructure enhance trade in capital goods, while the exporter's (importer's) infrastructure appears to be relevant for trade in consumption goods (trade in intermediates). Moreover, the non-linearities resulting from the significantly negative interactions between infrastructure and the country's GDP per capita in Table 5 are essentially the same as observed before.

We perform additional estimations by excluding all pairs of EU-15 partner countries (not reported).[33] The rationale is similar to that underlying the estimations reported in Table 5. We suspect that the relation between infrastructure and bilateral trade might weaken when excluding intra-EU pairs. Reverse causality is more likely for these pairs, considering that intra-EU trade relations are particularly close and could, thus, be driving the demand for better infrastructure. All the same, we essentially find the same picture on the role of infrastructure and its interaction with the countries' GDP per capita as before. In particular, we do not observe any relevant changes when trade in capital goods is restricted to pairs other than EU-15 pairs. The most notable change relates to trade in intermediates where the coefficients on infrastructure and its interaction with GDP per capita are statistically significant only at the ten percent level after excluding EU-15 pairs.

In Table 6, we pursue an alternative approach to mitigate concerns about reverse causality by modifying the lag structure of our empirical model. Specifically, we extend the lags of our index of infrastructure, GDP per capita, and the interaction between these two

[32] As concerns the statistical significance of coefficients, there is just one change in Table 5: the importing country's population is now significant at the ten percent level when applying the low exclusion threshold of five percent for trade in capital goods (column (8)).

[33] Note that trade within pairs of the 15 EU members as of 1995 represents intra-EU trade throughout our period of observation. The estimations without intra-EU trade are not shown for the sake of brevity, but they are available on request.

variables in three steps:[34] We use two-period lags in columns (1), (4), and (7) of Table 6; three-period lags in columns (2), (5), and (8); and four-period lags in columns (3), (6), and (9).

Extending the lags in this way has only minor effects on GDP per capita.[35] Furthermore, the results on the lagged effects of infrastructure and its interaction with GDP per capita on bilateral trade do not provide any evidence that our baseline results suffer from reverse causality. To the extent that reverse causality matters one would have expected a weaker or even insignificant association between infrastructure and trade when allowing for longer lags. In contrast, the evidence in Table 6 rather points to a stronger association with longer lags of infrastructure. In particular, the endowment with infrastructure of both the exporting and the importing country now matters for trade in consumption goods and trade in intermediates. In general, it appears that delayed effects of infrastructure on trade more than offset any potential reverse causality that may have affected our baseline results. At the same time, the interaction terms turn out to be statistically significant more often in Table 6, compared to columns (1)-(3) of Table 2, and the size of coefficients typically increases in absolute terms. Taken together, the previously observed non-linearities become more pronounced when allowing for longer lags. This implies that the findings from our baseline model can be regarded as lower-bound estimates of the true impact of infrastructure on trade.

As noted in Section 2, it is hard to find suitable instruments for infrastructure (Francois and Manchin 2013). Nevertheless, we report 2SLS estimations in Table 7 with an innovative attempt to instrument our index of infrastructure.[36] We make use of political

[34] The lags for other control variables are not extended.

[35] The same applies to *area* which controls for the countries' geographical size. In contrast, the coefficients on our third control variable, the countries' size in terms of population, are often affected – notably with four-period lags for infrastructure and GDP per capita.

[36] Note that we refrain from instrumenting GDP per capita and the interaction of infrastructure with GDP per capita. Apart from the lack of suitable instruments, the justification is that the coefficient on GDP per capita is unaffected when allowing for longer lags in Table 6. Accordingly, our results on GDP per capita are highly unlikely to suffer from reverse causality. Against this backdrop, it appears reasonable to treat this variable as exogenous. This implies that the interaction between infrastructure and GDP per capita is estimated consistently,

economy arguments on the determinants of the size of government budgets for foreign aid (Fuchs et al. 2014), assuming that similar factors tend to affect public financing of infrastructure. In particular, it is argued that the size of public spending increases with the degree of political fractionalization within governments and the intensity to which the executive branch is subject to political checks and balances. In the case of foreign aid, Round and Odedokun (2004) find that more fractionalized governments and policymakers facing more constitutional checks and balances are operating larger aid budgets. A similar reasoning is likely to hold with respect to public financing of infrastructure. Political fractionalization and veto power essentially means that public financing of infrastructure has to satisfy various interests within and outside the executive branch of governments which can be expected to increase the country's endowment with infrastructure.

Against this backdrop, we use *government fractionalization* (i.e., the probability that two deputies picked at random from among government parties will be of different political parties) and *checks and balances* (i.e., the extent of veto power and formal control on political decisions by the executive branch) in both the exporting and the importing country as our (four) instruments for infrastructure.[37] Both instruments are likely to influence a country's endowment with infrastructure, but unlikely to directly affect trade in consumption goods, capital goods, and intermediates. In all cases, the low *p*-values of the Kleibergen-Paap test for underidentification show that our instruments are jointly relevant. In addition, the *p*-values corresponding to Hansen's *J*-test indicate that we cannot reject instrument exogeneity in all specifications.

As can be seen in Table 7, our major results are qualitatively similar to the basic estimations in columns (1)-(3) of Table 2 when instrumenting our index of infrastructure. Once again we find significant and non-linear effects of infrastructure on bilateral trade

even though infrastructure is endogenous. For a detailed discussion of the differential impact of endogenous variables, see Kugler et al. (2013) and Nunn and Qian (2015).

[37] These variables are available from the Database of Political Institutions (Beck et al. 2001).

relations. Most surprisingly perhaps, these effects often appear to be more pronounced in Table 7. On the other hand, some of the coefficients on our variables of principal interest are no longer significant. For instance, the importing country's endowment with infrastructure and the interaction with GDP per capita are now statistically insignificant in the case of trade in capital goods. Importantly, the 2SLS estimations do not suggest that our basic results are systematically biased by reversed causality.

Specific components of infrastructure

In the final step of our empirical analysis, we distinguish between four components of infrastructure. More precisely, we replace the overall index of the countries' endowment with infrastructure by sub-indices of transport infrastructure, communication infrastructure, energy-related infrastructure, and financial infrastructure. In Table 8, we enter these sub-indices one by one. In all other respects, we use the basic specification of the estimation equation as in columns (1)-(3) of Table 2.

For three of the four components of infrastructure, the evidence presented in Table 8 is qualitatively similar to the baseline estimations with the overall index of infrastructure. In particular, the pattern shown in columns (5), (7), and (8) of Table 8 on the relevance of transport infrastructure, energy-related infrastructure, and financial infrastructure for trade in capital goods closely resembles the pattern for the overall index in column (2) of Table 2. The endowment of both the exporting and the importing country with these components of infrastructure clearly matters, while the observed non-linearities point to a declining importance of these components with rising GDP per capita of the corresponding country. The evidence on the relevance of transport infrastructure, energy-related infrastructure, and financial infrastructure for trade in consumption goods and intermediates is more ambiguous and often deviates from the pattern observed for the overall index in column (2) of Table 2. Yet, all estimated non-linearities for the effect of these three components on trade in consumption goods and intermediates again point to a declining importance with rising GDP per capita of the exporting and/or the importing country.

In contrast to the other components of infrastructure, there are several indications in Table 8 that the relevance of communication infrastructure increases with rising GDP per capita. This applies to the endowment with communication infrastructure of both the exporters and importers of consumption goods in column (2). The same pattern can be observed for the endowment with communication infrastructure of the exporters of capital goods and intermediates in columns (6) and (10), though not for the importers of these trade categories. Refined analyses going beyond the scope of our present paper may offer deeper insights into the peculiar role of communication infrastructure in exporting and importing countries for different categories of trade.

We perform additional estimations to test the robustness of our results for the components of infrastructure.[38] On the one hand, we consider the four components separately for either the exporting country or the importing country (as in Table 1 for the overall index of infrastructure). The coefficients on all four components of infrastructure and all interaction terms are affected only marginally by this modification. This applies to both the exporting and the importing country. On the other hand, we include all components of infrastructure (and the interactions with GDP per capita) for both the exporter and the importer simultaneously. Again, this modification has only minor effects on our variables of principal interest. The impact of communication infrastructure increases slightly for trade in consumption goods, compared to column (2) of Table 8, when considered together with the other three components of infrastructure. Similarly, the importance of transport infrastructure strengthens slightly for trade in capital goods and intermediates, compared to columns (5) and (9) of Table 8. In contrast, the role of energy-related infrastructure weakens for all three trade categories when considered together with the other components of infrastructure.

[38] These estimations are not shown in detail to save space; they are available on request.

4. Summary and conclusion

It is widely agreed that more and better infrastructure reduces trade-related transaction costs. However, the empirical literature on the role of infrastructure for international trade continues to suffer from several limitations. We contribute to overcoming these limitations by making use of considerably improved measures of infrastructure and assessing their impact on disaggregated bilateral trade for a panel of 37 developed and emerging economies during the period 1995-2011. In particular, we augment a standard gravity model by composite indices of infrastructure in transportation, communication, energy, and finance. In addition to accounting for heterogeneity in bilateral trade patterns by country-pair fixed effects, we address endogeneity concerns in several ways, inter alia by instrumenting the countries' endowment with infrastructure in 2SLS estimations.

It may be hardly surprising that we find a country's endowment with overall infrastructure to be positively associated with more intensive trade relations. This applies to trade in consumption goods, capital goods, and intermediates in almost equal measure. More interestingly, the effects of infrastructure prove to be non-linear. Considering specific components of infrastructure, we find similar patterns of declining marginal effects for transport infrastructure, energy-related infrastructure, and financial infrastructure, notably with regard to trade in capital goods. In sharp contrast, there are several indications that communication infrastructure becomes more important with rising per-capita income.

Our major findings prove to be robust to various modifications and extensions of the gravity model. Most importantly, we still observe significant and non-linear effects of infrastructure on bilateral trade when controlling for potential reverse causality. The results hold when we (i) exclude pairs with major trading partners who may be driving the demand for better infrastructure, (ii) extend the lags of our variables of principal interest to up to four years, and (iii) instrument the index of infrastructure with political fractionalization as well as political checks and balances. Taken together, it appears that the findings from our baseline model represent lower-bound estimates of the true impact of infrastructure on trade.

Future research may proceed in different directions. On the one hand, refined analyses may offer deeper insights into the peculiar role of communication infrastructure in relatively advanced countries for specific categories of trade. On the other hand, enlarging the country sample would allow focusing on trade items of particular relevance for poorer countries. Finally, the improved measurement of infrastructure allows for analyses on its role in other fields of international transactions such as in- and outflows of foreign direct investment as well as the allocation and effectiveness of foreign aid.

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Table 1 — Overall infrastructure and trade: Baseline results

	Consumption goods		Capital goods		Intermediates	
	(1)	(2)	(3)	(4)	(5)	(6)
$gdp\_pc_{i,t-1}$	1.86***	1.44***	3.59***	2.61***	1.82***	1.67***
	(0.18)	(0.08)	(0.25)	(0.11)	(0.17)	(0.07)
$gdp\_pc_{j,t-1}$	1.44***	1.26***	1.83***	2.33***	1.37***	1.69***
	(0.10)	(0.21)	(0.14)	(0.27)	(0.09)	(0.17)
$infra_{i,t-1}$	1.14***		2.76***		0.49	
	(0.39)		(0.62)		(0.36)	
$infra_{j,t-1}$		0.11		2.51***		0.97**
		(0.51)		(0.57)		(0.41)
$pop_{i,t-1}$	-0.41	-0.39	1.51***	1.59***	0.72**	0.74***
	(0.33)	(0.32)	(0.43)	(0.43)	(0.29)	(0.29)
$pop_{j,t-1}$	0.59	0.47	0.97**	0.69	0.02	-0.03
	(0.36)	(0.36)	(0.46)	(0.46)	(0.29)	(0.29)
$area_{i,t-1}$	-7.16**	-7.16**	-20.02***	-20.19***	-0.47	-0.60
	(3.34)	(3.34)	(3.47)	(3.57)	(3.25)	(3.27)
$area_{j,t-1}$	-25.64***	-24.72***	-5.17	-3.36	-10.79***	-10.61***
	(4.32)	(4.28)	(4.87)	(4.83)	(3.24)	(3.19)
$gdp\_pc_{i,t-1} \times infra_{i,t-1}$	-0.13***		-0.31***		-0.05	
	(0.04)		(0.07)		(0.04)	
$gdp\_pc_{j,t-1} \times infra_{j,t-1}$		0.01		-0.25***		-0.11**
		(0.06)		(0.06)		(0.05)
Constant	385.54***	380.15***	229.08***	215.01***	105.01*	103.18*
	(68.96)	(68.41)	(77.03)	(77.42)	(58.75)	(58.28)
No. of observations	22,135	22,135	22,076	22,076	22,138	22,138
No. of country pairs	1,332	1,332	1,332	1,332	1,332	1,332
Within-R^2	0.57	0.57	0.48	0.48	0.64	0.64

Notes: This table reports the estimates of equations (1) and (2). Coefficients are estimated with the fixed effects estimator including time fixed effects. The dependent variable Y denotes bilateral trade in either consumption goods, capital goods, or intermediates, so that $Y \in \{Y^{con}, Y^{cap}, Y^{int}\}$. Cross-sectional units $i = 1, \dots, 37$ and $j = 1, \dots, 37$ indicate the exporting and importing country, respectively. The sample period $t = 1, \dots, 17$ represents time instances between 1995 and 2011. Heteroskedasticity-robust standard errors are reported in parentheses. Significance at the one, five, and ten percent level is indicated by ***, ** and *, respectively.

Table 2 — Overall infrastructure and trade: Extended specifications

	Consumption goods	Capital goods	Inter-mediates	Consumption goods	Capital goods	Inter-mediates
	(1)	(2)	(3)	(4)	(5)	(6)
$gdp\_pc_{i,t-1}$	1.85***	3.61***	1.83***	1.74***	3.20***	1.80***
	(0.18)	(0.25)	(0.17)	(0.20)	(0.27)	(0.19)
$gdp\_pc_{j,t-1}$	1.27***	2.36***	1.69***	1.63***	2.66***	1.89***
	(0.21)	(0.27)	(0.17)	(0.22)	(0.30)	(0.18)
$infra_{i,t-1}$	1.14***	2.84***	0.51	1.06**	2.24***	0.54
	(0.39)	(0.61)	(0.36)	(0.43)	(0.68)	(0.41)
$infra_{j,t-1}$	0.14	2.60***	0.98**	0.97*	3.43***	1.46***
	(0.51)	(0.57)	(0.41)	(0.53)	(0.66)	(0.46)
$rta_{ij,t-1}$				0.24***	0.50***	0.20***
				(0.06)	(0.08)	(0.05)
$remote_{i,t-1}$				0.33	0.25	-0.34
				(0.30)	(0.41)	(0.31)
$remote_{j,t-1}$				0.34	-1.26***	-0.36
				(0.35)	(0.44)	(0.28)
$tariffs_{i,t-1}$				-0.04***	-0.06***	-0.03
				(0.01)	(0.02)	(0.02)
$tariffs_{j,t-1}$				-0.05**	-0.05*	-0.06***
				(0.02)	(0.02)	(0.02)
$pop_{i,t-1}$	-0.41	1.49***	0.71**	-0.74**	0.25	0.60**
	(0.33)	(0.42)	(0.29)	(0.34)	(0.42)	(0.31)
$pop_{j,t-1}$	0.47	0.69	-0.03	0.43	0.99**	0.17
	(0.36)	(0.46)	(0.29)	(0.36)	(0.47)	(0.29)
$area_{i,t-1}$	-7.14**	-19.96***	-0.47	-1.50	-12.51***	3.43
	(3.29)	(3.42)	(3.25)	(2.95)	(3.14)	(3.05)
$area_{j,t-1}$	-24.72***	-3.36	-10.60***	-21.58***	-1.04	-6.34**
	(4.28)	(4.86)	(3.20)	(3.61)	(4.31)	(2.89)
$gdp\_pc_{i,t-1} \times infra_{i,t-1}$	-0.13***	-0.32***	-0.06	-0.11**	-0.24***	-0.06
	(0.04)	(0.07)	(0.04)	(0.05)	(0.07)	(0.05)
$gdp\_pc_{j,t-1} \times infra_{j,t-1}$	0.01	-0.25***	-0.11**	-0.09	-0.35***	-0.16***
	(0.06)	(0.06)	(0.05)	(0.06)	(0.07)	(0.05)
Constant	376.62***	204.70***	100.46*	260.50***	104.50	-0.29
	(67.98)	(76.26)	(58.15)	(58.14)	(68.22)	(53.21)
No. of observations	22,135	22,076	22,138	19,089	19,050	19,091
No. of country pairs	1,332	1,332	1,332	1,332	1,332	1,332
Within-R^2	0.57	0.49	0.64	0.59	0.49	0.65

Notes: This table reports the estimates of equation (3). See also the notes to Table 1.

Table 3 — Overall infrastructure and trade: Country fixed effects

	Consumption goods	Capital goods	Intermediates
	(1)	(2)	(3)
$gdp\_pc_{i,t-1}$	1.90***	3.58***	1.86***
	(0.18)	(0.25)	(0.17)
$gdp\_pc_{j,t-1}$	1.28***	2.31***	1.70***
	(0.22)	(0.27)	(0.17)
$infra_{i,t-1}$	1.27***	2.82***	0.56
	(0.40)	(0.61)	(0.36)
$infra_{j,t-1}$	0.14	2.48***	1.00**
	(0.52)	(0.58)	(0.42)
$pop_{i,t-1}$	-0.39	1.65***	0.74**
	(0.33)	(0.43)	(0.29)
$pop_{j,t-1}$	0.40	0.49	-0.08
	(0.36)	(0.46)	(0.29)
$gdp\_pc_{i,t-1} \times infra_{i,t-1}$	-0.14***	-0.32***	-0.06
	(0.05)	(0.07)	(0.04)
$gdp\_pc_{j,t-1} \times infra_{j,t-1}$	0.01	-0.24***	-0.11**
	(0.06)	(0.07)	(0.05)
$dist_{ij,t-1}$	-1.11***	-1.16***	-1.17***
	(0.05)	(0.06)	(0.05)
$contig_{ij,t-1}$	0.31**	0.16	0.26*
	(0.15)	(0.17)	(0.14)
$comlang_{ij,t-1}$	0.26	-0.05	0.16
	(0.18)	(0.19)	(0.17)
$colony_{ij,t-1}$	0.29*	0.38**	0.33**
	(0.16)	(0.19)	(0.15)
Constant	-12.91	-80.98***	-27.42***
	(10.20)	(12.99)	(8.24)
No. of observations	22,135	22,076	22,138
No. of country pairs	1,332	1,332	1,332
Within-R^2	0.87	0.86	0.88

Notes: This table reports the estimates of equation (3) including country FE. See also the notes to Table 1.

Table 4 — Strict exogeneity tests

	Consumption goods			Capital goods			Intermediates		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
$infra_{i,t+3}$			-0.01			0.18***			-0.01
			(0.04)			(0.06)			(0.03)
$infra_{i,t+2}$		-0.09**	-0.09***		-0.10	-0.18***		-0.02	-0.02
		(0.04)	(0.03)		(0.06)	(0.05)		(0.03)	(0.03)
$infra_{i,t+1}$	-0.06*	-0.03	0.00	-0.10*	-0.02	-0.02	-0.05	-0.04	-0.01
	(0.04)	(0.03)	(0.03)	(0.06)	(0.04)	(0.04)	(0.03)	(0.03)	(0.03)
$infra_{i,t}$	0.01	-0.02	-0.02	-0.04	-0.11**	-0.08	0.00	-0.03	-0.03
	(0.03)	(0.03)	(0.03)	(0.05)	(0.05)	(0.05)	(0.02)	(0.02)	(0.02)
$infra_{i,t-1}$	0.01	-0.08***	-0.18***	0.10*	-0.10**	-0.26***	0.03	-0.04*	-0.12***
	(0.03)	(0.03)	(0.03)	(0.05)	(0.04)	(0.05)	(0.03)	(0.02)	(0.02)
$infra_{i,t-2}$		0.18***	0.04		0.38***	0.05		0.13***	0.01
		(0.03)	(0.03)		(0.05)	(0.04)		(0.03)	(0.02)
$infra_{i,t-3}$			0.27***			0.53***			0.21***
			(0.03)			(0.05)			(0.03)
$infra_{j,t+3}$			0.07			-0.18***			0.06
			(0.05)			(0.06)			(0.04)
$infra_{j,t+2}$		-0.02	-0.05		-0.06	-0.00		-0.02	-0.04
		(0.04)	(0.03)		(0.07)	(0.06)		(0.04)	(0.04)
$infra_{j,t+1}$	0.04	0.05	0.04	0.23***	0.23***	0.27***	0.05	0.06**	0.05
	(0.04)	(0.03)	(0.03)	(0.06)	(0.05)	(0.05)	(0.04)	(0.03)	(0.03)
$infra_{j,t}$	0.15***	0.15***	0.15***	0.32***	0.29***	0.30***	0.09***	0.08***	0.07***
	(0.04)	(0.03)	(0.03)	(0.05)	(0.05)	(0.05)	(0.03)	(0.03)	(0.03)
$infra_{j,t-1}$	0.06	0.04	0.01	0.03	-0.00	0.01	-0.06	-0.07**	-0.09***
	(0.05)	(0.04)	(0.04)	(0.05)	(0.05)	(0.05)	(0.04)	(0.03)	(0.03)
$infra_{j,t-2}$		0.02	-0.03		0.09*	0.14***		0.01	-0.05*
		(0.04)	(0.03)		(0.05)	(0.05)		(0.03)	(0.03)
$infra_{j,t-3}$			0.06*			-0.08			0.13***
			(0.04)			(0.05)			(0.03)
Constant	448.26***	631.35***	2,471.03***	259.14***	328.41***	1,428.38***	186.31***	443.82***	2,210.23***
	(71.83)	(86.18)	(386.24)	(80.75)	(101.91)	(534.60)	(63.28)	(78.00)	(337.89)
No. of observations	20,803	19,471	18,071	20,744	19,412	18,012	20,806	19,474	18,074
No. of country pairs	1,332	1,332	1,332	1,332	1,332	1,332	1,332	1,332	1,332
Within-R^2	0.56	0.56	0.55	0.48	0.48	0.47	0.63	0.63	0.63
Strict exogeneity test for *i*	0.34	0.00	0.00	0.07	0.00	0.00	0.39	0.00	0.00
Strict exogeneity test for *j*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Notes: This table reports the estimates of equation (3), augmented by leads and lags of *infra.* Control variables are not shown. We report *p*-values for the strict exogeneity test following Wooldridge (2002). See also the notes to Table 1.

Table 5 — Overall infrastructure and trade: Excluding pairs with major trading partners

	Consumption goods	Capital goods	Intermediates	Consumption goods	Capital goods	Intermediates	Consumption goods	Capital goods	Intermediates
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	>20 %	>20 %	>20 %	>10 %	>10 %	>10 %	>5 %	>5 %	>5 %
$gdp\_pc_{i,t-1}$	1.91***	3.64***	1.85***	1.93***	3.66***	1.85***	1.82***	3.69***	1.69***
	(0.19)	(0.25)	(0.17)	(0.19)	(0.26)	(0.17)	(0.21)	(0.28)	(0.18)
$gdp\_pc_{j,t-1}$	1.29***	2.35***	1.69***	1.32***	2.39***	1.73***	1.30***	2.30***	1.70***
	(0.22)	(0.28)	(0.17)	(0.23)	(0.29)	(0.18)	(0.25)	(0.31)	(0.19)
$infra_{i,t-1}$	1.18***	2.91***	0.53	1.22***	2.94***	0.49	1.01**	2.82***	0.24
	(0.39)	(0.62)	(0.37)	(0.40)	(0.63)	(0.37)	(0.42)	(0.65)	(0.39)
$infra_{j,t-1}$	0.17	2.59***	0.97**	0.21	2.66***	1.03**	0.10	2.52***	0.91*
	(0.52)	(0.59)	(0.42)	(0.55)	(0.62)	(0.44)	(0.59)	(0.65)	(0.48)
$pop_{i,t-1}$	-0.35	1.51***	0.75***	-0.33	1.54***	0.69**	-0.37	1.58***	0.61**
	(0.33)	(0.43)	(0.29)	(0.34)	(0.44)	(0.30)	(0.34)	(0.45)	(0.30)
$pop_{j,t-1}$	0.50	0.73	-0.01	0.51	0.77	-0.09	0.67	0.90*	0.03
	(0.36)	(0.47)	(0.29)	(0.38)	(0.49)	(0.30)	(0.42)	(0.53)	(0.33)
$area_{i,t-1}$	-7.49**	-23.14***	-0.84	-8.35**	-25.51***	-1.68	-12.04**	-30.43***	-7.09
	(3.54)	(3.88)	(3.60)	(4.11)	(4.40)	(4.66)	(5.25)	(6.58)	(6.35)
$area_{j,t-1}$	-24.39***	-2.94	-10.52***	-24.65***	-1.35	-11.30***	-27.72***	-3.20	-12.16***
	(4.38)	(4.89)	(3.28)	(4.52)	(5.43)	(3.44)	(5.13)	(5.44)	(3.75)
$gdp\_pc_{i,t-1} \times infra_{i,t-1}$	-0.13***	-0.33***	-0.06	-0.14***	-0.33***	-0.05	-0.12**	-0.32***	-0.02
	(0.05)	(0.07)	(0.04)	(0.05)	(0.07)	(0.04)	(0.05)	(0.07)	(0.04)
$gdp\_pc_{j,t-1} \times infra_{j,t-1}$	0.00	-0.25***	-0.11**	-0.00	-0.26***	-0.11**	0.01	-0.24***	-0.10*
	(0.06)	(0.07)	(0.05)	(0.06)	(0.07)	(0.05)	(0.06)	(0.07)	(0.05)
Constant	374.49***	237.97***	103.02*	387.14***	245.11***	125.41*	471.56***	326.38***	204.71**
	(70.81)	(80.28)	(61.81)	(77.38)	(89.92)	(73.40)	(92.31)	(108.77)	(92.50)
No. of observations	21,784	21,425	21,793	20,755	20,566	20,708	18,483	18,740	18,745
No. of country pairs	1,311	1,293	1,311	1,250	1,242	1,247	1,115	1,134	1,131
Within-R^2	0.57	0.48	0.64	0.57	0.48	0.64	0.55	0.48	0.63

Notes: This table reports the estimates of equation (3), excluding country pairs which account for more than 20, 10, or 5 percent of country *i*'s total imports. See also the notes to Table 1.

Table 6 — Overall infrastructure and trade: Extended lags

	Consumption goods			Capital goods			Intermediate goods		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
$gdp\_pc_{i,t-2}$	1.72***			3.43***			1.83***		
	(0.17)			(0.22)			(0.16)		
$gdp\_pc_{j,t-2}$	1.23***			2.23***			1.62***		
	(0.21)			(0.25)			(0.16)		
$gdp\_pc_{i,t-3}$		1.71***			3.49***			1.78***	
		(0.16)			(0.21)			(0.15)	
$gdp\_pc_{j,t-3}$		1.25***			2.04***			1.63***	
		(0.20)			(0.24)			(0.16)	
$gdp\_pc_{i,t-4}$			1.90***			3.71***			1.93***
			(0.16)			(0.19)			(0.14)
$gdp\_pc_{j,t-4}$			1.33***			1.99***			1.70***
			(0.20)			(0.25)			(0.16)
$infra_{i,t-2}$	1.48***			3.45***			1.17***		
	(0.39)			(0.58)			(0.36)		
$infra_{j,t-2}$	0.35			3.39***			1.49***		
	(0.51)			(0.57)			(0.41)		
$infra_{i,t-3}$		1.99***			4.59***			1.62***	
		(0.38)			(0.53)			(0.34)	
$infra_{j,t-3}$		0.88*			3.52***			2.21***	
		(0.48)			(0.56)			(0.39)	
$infra_{i,t-4}$			2.99***			6.10***			2.56***
			(0.39)			(0.53)			(0.35)
$infra_{j,t-4}$			1.86***			4.30***			2.97***
			(0.48)			(0.57)			(0.39)
$pop_{i,t-1}$	-0.66**	-1.06***	-1.66***	1.25***	0.70	-0.24	0.51*	0.11	-0.53*
	(0.33)	(0.34)	(0.35)	(0.43)	(0.43)	(0.45)	(0.29)	(0.30)	(0.30)
$pop_{j,t-1}$	0.24	-0.18	-0.80**	0.11	-0.41	-0.93**	-0.29	-0.69**	-1.15***
	(0.36)	(0.36)	(0.35)	(0.46)	(0.46)	(0.45)	(0.29)	(0.29)	(0.29)
$area_{i,t-1}$	-6.05*	-5.78*	-6.95**	-18.17***	-17.77***	-20.21***	0.27	0.22	-1.24
	(3.29)	(3.28)	(3.26)	(3.54)	(3.63)	(3.67)	(3.28)	(3.33)	(3.35)
$area_{j,t-1}$	-24.38***	-24.73***	-25.96***	-3.25	-5.11	-7.74*	-10.65***	-10.90***	-12.09***
	(4.21)	(4.17)	(4.12)	(4.60)	(4.47)	(4.60)	(3.24)	(3.28)	(3.30)
$gdp\_pc_{i,t-2} \times infra_{i,t-2}$	-0.15***			-0.36***			-0.12***		
	(0.04)			(0.06)			(0.04)		
$gdp\_pc_{j,t-2} \times infra_{j,t-2}$	-0.02			-0.35***			-0.16***		
	(0.06)			(0.06)			(0.04)		
$gdp\_pc_{i,t-3} \times infra_{i,t-3}$		-0.20***			-0.48***			-0.16***	
		(0.04)			(0.06)			(0.04)	
$gdp\_pc_{j,t-3} \times infra_{j,t-3}$		-0.08			-0.38***			-0.24***	
		(0.05)			(0.06)			(0.04)	
$gdp\_pc_{i,t-4} \times infra_{i,t-4}$			-0.32***			-0.65***			-0.27***
			(0.04)			(0.06)			(0.04)
$gdp\_pc_{j,t-4} \times infra_{j,t-4}$			-0.19***			-0.47***			-0.33***
			(0.05)			(0.06)			(0.04)
Constant	368.21***	383.45***	432.97***	197.41***	236.00***	324.57***	100.21*	118.08**	169.20***
	(67.50)	(67.18)	(66.34)	(74.63)	(74.10)	(75.43)	(59.02)	(59.81)	(59.97)
No. of observations	21,993	21,783	21,573	21,937	21,729	21,519	21,996	21,786	21,576
No. of country pairs	1,332	1,332	1,332	1,332	1,332	1,332	1,332	1,332	1,332
Within-R^2	0.57	0.56	0.55	0.48	0.47	0.47	0.63	0.62	0.61

Notes: This table reports the estimates of equation (3) using extended lags for *gdp_pc* and *infra*. See also the notes to Table 1.

Table 7 — Overall infrastructure and trade: 2SLS estimations

	Consumption goods	Capital goods	Intermediates
	(1)	(2)	(3)
$gdp\_pc_{i,t-1}$	1.87***	7.10***	1.49***
	(0.57)	(0.88)	(0.56)
$gdp\_pc_{j,t-1}$	3.36***	2.43**	3.12***
	(0.78)	(1.04)	(0.73)
$infra_{i,t-1}$	1.23	13.34***	-0.45
	(1.67)	(2.57)	(1.63)
$infra_{j,t-1}$	6.41***	3.04	5.27**
	(2.26)	(3.05)	(2.11)
$pop_{i,t-1}$	-0.39	1.10***	0.79***
	(0.33)	(0.42)	(0.29)
$pop_{j,t-1}$	0.23	0.65	-0.18
	(0.38)	(0.47)	(0.30)
$area_{i,t-1}$	-7.10**	-18.38***	-0.54
	(3.42)	(3.24)	(3.32)
$area_{j,t-1}$	-23.91***	-3.46	-10.08***
	(4.05)	(5.05)	(3.07)
$gdp\_pc_{i,t-1} \times infra_{i,t-1}$	-0.14	-1.47***	0.05
	(0.18)	(0.28)	(0.18)
$gdp\_pc_{j,t-1} \times infra_{j,t-1}$	-0.69***	-0.30	-0.58**
	(0.25)	(0.34)	(0.23)
No. of observations	21,357	21,301	21,358
No. of country pairs	1,332	1,332	1,332
Within-R^2	0.57	0.48	0.64
Underidentification test	0.00	0.00	0.00
Hansen *J*-test	0.71	0.55	0.58

Notes: This table reports the estimates of equation (3). We instrument *infra* with *government fractionalization* and *checks and balances* and report *p*-values for the underidentification test for instrument relevance and Hansen's *J*-test on instrument exogeneity. See also the notes to Table 1.

Table 8 — Components of infrastructure and trade

	Consumption goods				Capital goods				Intermediates			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
$gdp\_pc_{i,t-1}$	1.53***	0.78***	2.33***	2.06***	4.02***	1.39***	4.61***	4.34***	2.04***	1.03***	2.43***	2.16***
	(0.24)	(0.14)	(0.21)	(0.17)	(0.31)	(0.17)	(0.27)	(0.22)	(0.20)	(0.13)	(0.20)	(0.14)
$gdp\_pc_{j,t-1}$	2.48***	0.67***	2.51***	1.66***	2.65***	1.50***	2.91***	2.47***	1.65***	1.26***	2.19***	1.59***
	(0.25)	(0.18)	(0.27)	(0.19)	(0.34)	(0.22)	(0.31)	(0.22)	(0.21)	(0.15)	(0.21)	(0.15)
$infra^{tra}_{i,t-1}$	0.19				3.43***				0.87*			
	(0.53)				(0.71)				(0.45)			
$infra^{tra}_{j,t-1}$	2.72***				1.99***				0.69			
	(0.61)				(0.76)				(0.51)			
$infra^{com}_{i,t-1}$		-0.56**				-0.78**				-0.74***		
		(0.26)				(0.32)				(0.24)		
$infra^{com}_{j,t-1}$		-1.13***				0.57				0.43*		
		(0.34)				(0.37)				(0.25)		
$infra^{ene}_{i,t-1}$			2.16***				5.29***				1.90***	
			(0.51)				(0.68)				(0.46)	
$infra^{ene}_{j,t-1}$			2.86***				3.16***				2.18***	
			(0.61)				(0.72)				(0.49)	
$infra^{fin}_{i,t-1}$				1.40***				4.41***				1.19***
				(0.38)				(0.56)				(0.33)
$infra^{fin}_{j,t-1}$				0.47				2.23***				0.43
				(0.50)				(0.53)				(0.41)
$pop_{i,t-1}$	-0.36	-0.16	-0.55*	-0.14	1.64***	1.94***	1.44***	2.36***	0.78***	1.00***	0.64**	0.94***
	(0.32)	(0.33)	(0.32)	(0.33)	(0.43)	(0.43)	(0.42)	(0.43)	(0.29)	(0.29)	(0.29)	(0.29)
$pop_{j,t-1}$	0.49	0.95***	0.51	0.75**	1.02**	0.88*	1.04**	1.06**	0.01	-0.07	-0.03	0.19
	(0.35)	(0.37)	(0.36)	(0.37)	(0.45)	(0.46)	(0.46)	(0.45)	(0.29)	(0.29)	(0.28)	(0.29)
$area_{i,t-1}$	-7.07**	1.14	-3.63	-5.48*	-18.67***	-3.93	-13.50***	-16.65***	-0.20	6.87**	2.23	0.41
	(3.37)	(3.50)	(3.20)	(3.32)	(3.61)	(3.56)	(3.32)	(3.24)	(3.26)	(3.30)	(3.18)	(3.25)
$area_{j,t-1}$	-24.47***	-17.44***	-22.07***	-24.76***	-4.30	1.62	-2.41	-4.09	-10.49***	-7.71**	-8.14***	-10.23***
	(4.27)	(4.43)	(3.92)	(4.21)	(4.81)	(4.83)	(4.79)	(4.55)	(3.21)	(3.28)	(3.01)	(3.25)
$gdp\_pc_{i,t-1} \times infra^{tra}_{i,t-1}$	-0.02				-0.37***				-0.10*			
	(0.06)				(0.08)				(0.05)			
$gdp\_pc_{j,t-1} \times infra^{tra}_{j,t-1}$	-0.28***				-0.22***				-0.07			
	(0.07)				(0.08)				(0.06)			
$gdp\_pc_{i,t-1} \times infra^{com}_{i,t-1}$		0.10***				0.17***				0.11***		
		(0.03)				(0.04)				(0.03)		
$gdp\_pc_{j,t-1} \times infra^{com}_{j,t-1}$		0.16***				-0.02				-0.03		
		(0.04)				(0.04)				(0.03)		
$gdp\_pc_{i,t-1} \times infra^{ene}_{i,t-1}$			-0.26***				-0.61***				-0.23***	
			(0.06)				(0.08)				(0.05)	
$gdp\_pc_{j,t-1} \times infra^{ene}_{j,t-1}$			-0.33***				-0.35***				-0.25***	
			(0.07)				(0.08)				(0.06)	
$gdp\_pc_{i,t-1} \times infra^{fin}_{i,t-1}$				-0.17***				-0.53***				-0.14***
				(0.04)				(0.06)				(0.04)
$gdp\_pc_{j,t-1} \times infra^{fin}_{j,t-1}$				-0.06				-0.22***				-0.06
				(0.05)				(0.06)				(0.04)
Constant	363.18***	180.36**	286.37***	342.75***	185.93**	-47.50	93.37	144.83**	92.27	-23.74	27.49	75.80
	(68.47)	(70.69)	(63.47)	(67.50)	(77.90)	(77.26)	(74.85)	(71.76)	(58.30)	(59.55)	(55.88)	(58.82)
No. of observations	22,135	22,063	22,135	21,791	22,076	22,004	22,076	21,744	22,138	22,066	22,138	21,794
No. of country pairs	1,332	1,332	1,332	1,332	1,332	1,332	1,332	1,332	1,332	1,332	1,332	1,332
Within-R^2	0.58	0.58	0.58	0.58	0.48	0.50	0.49	0.50	0.64	0.65	0.64	0.64

Notes: This table reports the estimates of equation (3), replacing the overall index of the countries' endowment with infrastructure by sub-indices of transport infrastructure, communication infrastructure, energy-related infrastructure, and financial infrastructure. See also the notes to Table 1.

Table A1 — Summary statistics (variables not in logs)

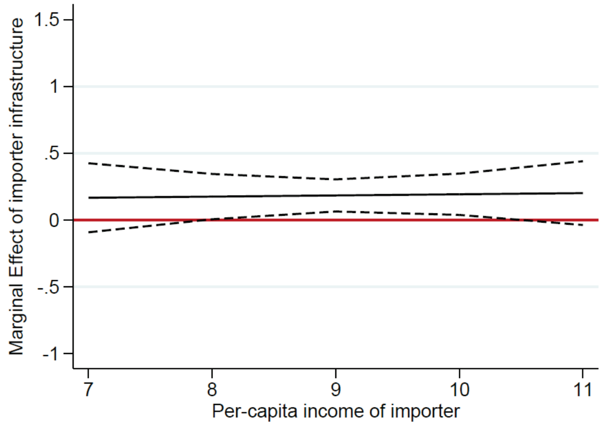
	No. of observations	Mean	Std. dev.	Min	Max
Y^{con}	22,644	1,150.01	3,986.58	0.00	119,000.00
Y^{cap}	22,644	685.17	3,048.26	0.00	98,164.76
Y^{int}	22,644	2,819.21	9,179.34	0.00	212,000.00
gdp_pc	22,464	20,959.44	10,617.71	1,404.23	43,635.59
$infra$	22,644	44.26	20.91	1.71	98.33
$infra^{tra}$	22,644	39.46	17.74	0.41	97.45
$infra^{com}$	22,608	45.89	18.49	0.00	100.00
$infra^{ene}$	22,644	40.88	18.68	0.19	100.00
$infra^{fin}$	22,572	50.18	19.73	0.00	100.00
pop	22,644	111,000,000	268,000,000	855,000	1,344,130,000
$area$	22,644	2,040,000	3,950,000	9,250	17,100,000

Table A2 — Correlation matrix

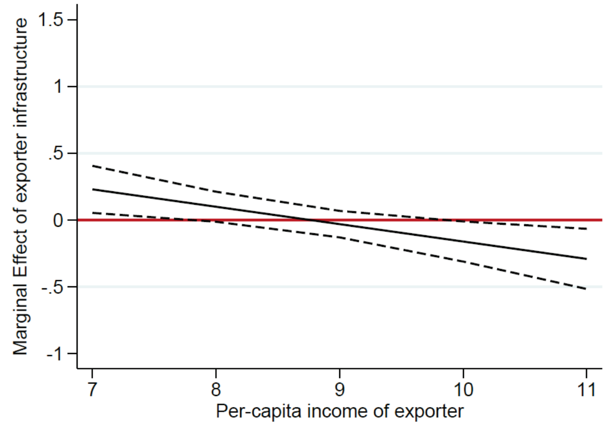
	Y^{con}	Y^{cap}	Y^{int}	gdp_pc	$infra$	$infra^{tra}$	$infra^{com}$	$infra^{ene}$	$infra^{fin}$	pop	$area$
Y^{con}	1.00										
Y^{cap}	0.90	1.00									
Y^{int}	0.93	0.90	1.00								
gdp_pc	0.23	0.33	0.24	1.00							
$infra$	0.30	0.41	0.29	0.75	1.00						
$infra^{tra}$	0.21	0.29	0.19	0.45	0.78	1.00					
$infra^{com}$	0.18	0.29	0.19	0.88	0.71	0.40	1.00				
$infra^{ene}$	0.18	0.30	0.23	0.77	0.69	0.41	0.73	1.00			
$infra^{fin}$	0.36	0.40	0.32	0.44	0.71	0.37	0.37	0.40	1.00		
pop	0.37	0.36	0.40	-0.41	-0.16	-0.11	-0.42	-0.27	0.22	1.00	
$area$	0.20	0.18	0.29	-0.31	-0.18	-0.26	-0.31	-0.09	0.13	0.80	1.00

Figure 1 — Marginal effects of infrastructure on bilateral trade over the range of GDP per capita

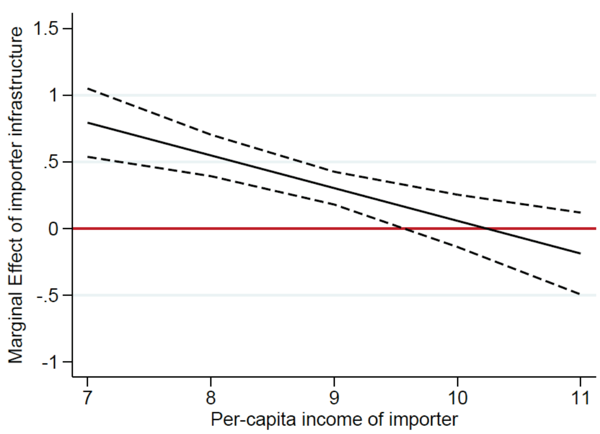
(a) Trade in consumption goods, infrastructure and GDP per capita of the importing country



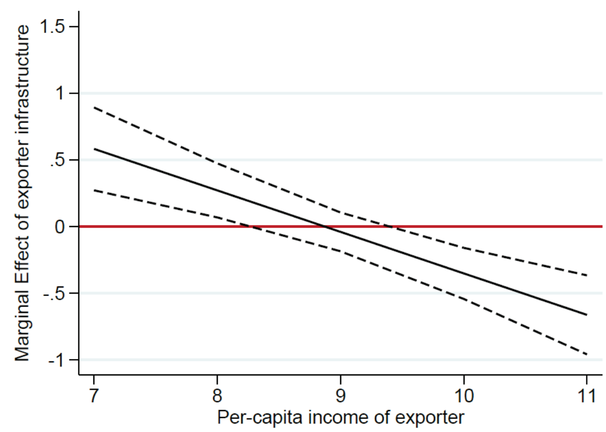
(b) Trade in consumption goods, infrastructure and GDP per capita of the exporting country



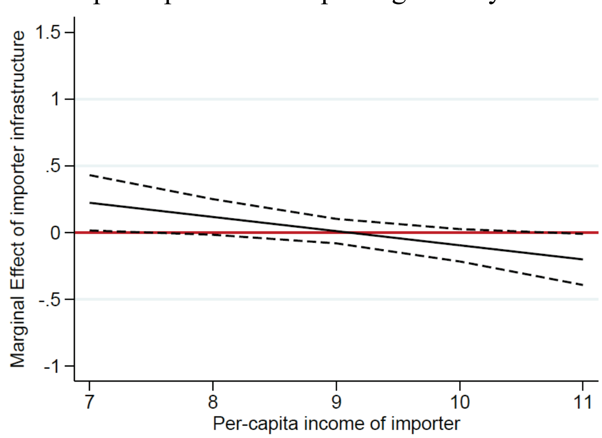
(c) Trade in capital goods, infrastructure and GDP per capita of the importing country



(d) Trade in capital goods, infrastructure and GDP per capita of the exporting country



(e) Trade in intermediates, infrastructure and GDP per capita of the importing country



(f) Trade in intermediates, infrastructure and GDP per capita of the exporting country