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Determinants of Transport Costs: Are They Uniform across Countries?

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Abstract The author shows with pooled OLS estimations based on transport margins from international social accounting data that investments in improved road infrastructure have the potential to significantly reduce transport costs. However, this result can only be clearly confirmed for industrial countries and is of primary importance for production and transportation of agricultural goods. For developing and transition countries, in contrast, the author finds other determinants such as weather conditions to be more important in determining transport costs. A key variable, especially in these countries, is corruption. Very high corruption has the potential to prevent positive effects from road infrastructure on transport costs or to even reverse them. This paper contributes to the literature on infrastructure investment by introducing and applying an internationally comparable measure of transport costs which can be calculated for a large and growing number of countries. The author concludes that investments in transport infrastructure can have substantial positive effects especially on agricultural production and the efficient marketing of agricultural products but only if specific additional conditions are given.

JEL O11, R42, O18

Keywords Infrastructure; transport networks; transport costs; agriculture; public investment; development

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“ IT COSTS MORE TO TRANSPORT A VEHICLE FROM ABIDJAN TO ADDIS ABABA THAN SHIPPING THE SAME VEHICLE FROM ABIDJAN TO JAPAN.”
Naude and Mathee (2007)

1 Introduction

Investment in infrastructure is often seen as a promising path for growth and development. Based on the experiences with large infrastructure investments in industrial countries, like e.g. the first transcontinental railroad in the U.S. finished in 1869, infrastructure projects are widely considered to induce large growth effects. However, the magnitude of the estimated effect differs quite substantially.

Classic studies in the field of economic history like Jenks (1944) or Fishlow (1965) for the United States and Fremdling (1977) for Germany argue that the connection of markets through railways had a massive influence on the industrialisation of the respective countries. Comparable studies also exist for the initial construction of motorways in industrial countries. In modern industrial economies infrastructure networks are still seen as important prerequisites for regional development. This is for example reflected in the large scale infrastructure programmes after German reunification and also in the inclusion of infrastructure into the aims of the Lisbon strategy:[1]

> Establishing an efficient trans-European transport network (TEN-T) is a key element in the relaunched Lisbon strategy for competitiveness and employment in Europe. If Europe is to fulfil its economic and social potential, it is essential to build the missing links and remove the bottlenecks in our transport infrastructure, as well as to ensure the sustainability of our transport networks into the future. (EUROPEAN COMMISSION)

The assumption that infrastructure reduces transport costs is also included in many gravity models in international trade. Infrastructure is included as an explanatory variable in some of these models which implicitly assumes that there is an influence of infrastructure on trade costs (See e.g. Portugal-Perez and Wilson, 2008).

Policy initiatives such as the WTO’s *Aid for Trade* program or the World Bank’s *Infrastructure Action Plan* emphasize the importance of infrastructure for developing countries. This political emphasis on infrastructure reflects the

[1] Source: European commission http://ec.europa.eu/transport/infrastructure/index_en.htm

widespread belief that the observed positive effects from infrastructure in developed countries apply to developing countries as well.

The literature usually argues that improvements in the road network reduce transport costs and transport times. The studies on Americas railways distinguish three types of effects from infrastructure improvements: the direct effect on transport costs which is argued to reduce transaction costs and thus increase the volume and number of transactions, the *backward linkage* through increased demand for resources and factors needed for infrastructure construction and the *forward linkage* effect which summarizes the induced additional economic activities due to the presence of infrastructure. The importance of the direct cost reducing effect (which is also a prerequisite for *forward linkage* effects) has been stressed in many subsequent studies.

Reduced transport costs are e.g. mentioned as important results from infrastructure investment in developing countries in Escobal and Ponce (2002) and Teravaninthorn and Raballand (2009). However, even for industrial countries, concrete estimations for the travel cost reduction from better roads are scarce. This is partly due to the fact that time series based studies for distinct countries cannot provide internationally applicable results. There are a number of studies in the international trade literature that quantify the tariff equivalent costs of poor roads on international trade but these cannot provide any insight concerning *intranational* transport and often focus on industrial countries alone (See e.g. Yeats, 1980; Limao and Venables, 2001; Portugal-Perez and Wilson, 2008).[2] Evidence on the effects of better roads in developing countries is mixed.[3] Existing country studies use substantially differing approaches to measure transport costs and hence it is difficult to conclude whether the determinants of transport costs are the same for developing and developed countries and even within these groups.

This paper contributes to the literature by developing and applying an internationally comparable measure of transport costs and estimating the effect of the length of transport ways on this measure across countries. Pooled estimations of the influence of transport network density on the transport margin show that better transport networks reduce transport costs. The effect is stronger for agricultural sectors compared to a weighted measure for all sectors. The observed effect from infrastructure on transport costs differs substantially across country groups. It cannot be confirmed unconditionally for developing and transition countries. In

[2] The application of a comparable approach on intranational transport costs would require very detailed data.

[3] See Estache (2006) for a comprensive survey of the literature.

their case, other determinants such as weather conditions have a strong influence on transport costs as well. Most importantly, in low and middle income countries the effectiveness of road infrastructure strongly depends on the level of corruption. In highly corrupt countries the effect might be reversed and a higher level of infrastructure comes along with higher transport costs.

2 Literature and theoretical background

The literature on the effects from infrastructure investments states that improving the length and quality of roads and railroads would lead to higher output and lower poverty. The reasoning behind this is a combination of different positive effects. Roads in general and paved roads in particular improve the connection between producers, markets and consumers. Enhancements of the roads and railroads of a country should hence lead to a more efficient allocation of goods and services.

Most macroeconomic studies on the effects of infrastructure follow the so-called production function approach based on Aschauer (1989) who applied the method to U.S. time series data. These studies estimate a national production function where GDP or growth depend not only on labour, capital and technology but also on public capital. Public capital is usually measured using the perpetual inventory method, i.e. aggregating past investment flows. This approach has been applied to developed and developing countries, to time-series, cross-section and panel data and there seems to be a consensus on the positive effect from public capital on output even though the magnitude of this effect is disputed (See e.g. Hulten, 1996; Ram, 1996). Hulten (1996) finds that the effect of public capital on growth is much lower if the sample comprises developing countries. He argues that this is due to less efficient planning and use in these countries. Also Aschauer (2000) states that it might be crucial whether existing infrastructure is used efficiently. Still, the methodology is only capable to investigate the effect of public capital as an entity instead of the effects of better transport networks in particular. This caveat is mentioned e.g. by Calderon and Serven (2008).

In addition to the considerable macroeconomic literature there exists a variety of country and case studies evaluating specific projects or programs. Examples for industrial countries are: Holl (2007); Linneker and Spence (1996) and Vesper and Zwiener (1991). Recent examples for developing countries are Olsson (2009) who analyses the Philippines, Escobal and Ponce (2002) who compare three African countries, Fan et al. (1999) for India or Fan (2008) for Uganda. For all of these countries it has been found that especially rural roads provide an instrument to reduce rural poverty and promote growth but only Olsson (2009) and Escobal and Ponce (2002) try to establish a more concrete chain of effects that explains the overall positive influence of roads. While Olsson (2009) offers theoretical reflections on this aspect, Escobal and Ponce (2002) estimate the effect of the road status on travel times and do not find a robust effect across the three countries in their sample.

Olsson (2009) argues that the positive aggregate effect of better and longer roads is based on an improved cost efficiency in transporting goods to markets. The lower transport costs are explained by shorter travel times combined with less loss on the road, direct market access even for small scale producers, reduced information asymmetries and quicker adaption to changes in supply and demand. In addition, Olsson (2009) expects that the economy undergoes structural changes as technologies spread more easily across the country.

Canning and Bennathan (1999) and Canning and Bennathan (2004) investigate the impact of transportation networks on growth and come to the conclusion that investment in transport infrastructure implies growth effects but only in combination with other public and human capital. The rate of return to infrastructure is found to be lower than the rate of return to other forms of public capital. They also find that for some middle income countries infrastructure investment is at a sub-optimal level, leaving the countries with severe infrastructure shortages.

While there exists strong empirical support for the general idea that improved roads lead to higher production and welfare, there is only a very limited number of studies that directly investigate the infrastructure - transport cost link. The link has been investigated for large past infrastructure projects in distinct countries like the U.S. railways or the Eastern German motorways but to our knowledge an international comparison of the transport cost effects of infrastructure investment is still due. This might be mainly due to the fact that data on transport costs across a large number of different countries is not available especially not for developing and transition countries.

The recent literature is rather vague about the exactly quantified relation between increased expenditure on infrastructure and the effect on transport costs. For developing countries there exist only very few studies. Escobal and Ponce (2002) and Teravaninthorn and Raballand (2009) focus on developing countries and especially on Africa. They apply a completely different methodology compared to most studies for industrial countries. In a case study of several international transport corridors in Africa Teravaninthorn and Raballand (2009) find that an improvement of the roads from “fair” to “good” reduces the transport cost by approximately 15%. Other concrete cross-country estimations that include intranational transport costs and not only international transport costs do not exist to our knowledge.

The measures for transport costs used in the different country and regional studies referenced above are very heterogeneous. Some rely on vehicle operation costs, others use freight rates or travel times. Hence, it is difficult to obtain a general result from comparing such country studies. However, it seems important to know whether the positive impact of infrastructure projects in industrial countries could possibly be replicated in developing countries. Summarizing the recent literature on infrastructure in developing countries Estache (2006) concludes that "the knowledge gap is not a small one".

3 Econometric design

3.1 Specification

Against this background this paper attempts to quantify the effect from better and longer roads on transport costs directly and investigates whether there exist systematic differences between industrial countries and developing and transition countries.

As an internationally comparable measure of transport costs we will use the transport margin (m). We calculate this margin as the sectoral spending on transportation relative to overall sectoral production costs[4] and aggregate this over comparable sectors.

$$m_{i,s} = \frac{\text{transport related production costs in sector } s \text{ in country } i}{\text{total production cost in sector } s \text{ in country } i} \tag{1}$$

The transport margin thus comprises all elements of transport costs that have been reported as spending on road, air and water transportation, transportation related services and maintenance of transport vehicles. It indirectly covers wages paid to the labour and capital involved in transportation. The measure is not able to account for indirect costs of long transport ways such as the loss of perishable goods or the foregone profit due to the time spent on the road that could not be used

[4] The spending on transportation contains both the transportation used as input in the respective sector and the corresponding demand for transport services which is required to transport the good to its designated sales market. Only SAMs that include transport separate from trade services have been used in order to cover transportation expenditure alone.

productively (if not comprised in labour cost in transportation). As we calculate the cost measure relative to total sectoral cost we consider it highly comparable across countries even if production technologies differ substantially.[5]

Information on sectoral spending on transportation can be obtained from social accounting data. Social Accounting Matrices (SAMs) are available for a large number of countries and for several years and provide detailed sectoral information on the demand for transport services.[6] This allows to build a dataset on international transport spending. The underlying SAMs differ in their level of disaggregation but can be aggregated to a comparable structure.

In a pooled estimation for 64 countries from all over the world and three periods we investigate the effect of transport density on these transport margins. This is a straight-forward way to test the aforementioned theoretical reflections.[7]

We estimate the following equation for each s separately:

$$ln(m_{i,s}) = \alpha + \beta\, ln(transnet_i) + \gamma controls_i + \delta\, dummies_i + u_i \qquad (2)$$

As the dependent variable we use sectoral spending on transport services in country i relative to sectoral output in country i, i.e. the transport margin (m_i). We calculate this weighted average margin from input-output data both only for agricultural sectors ($s = ag$) and over all sectors ($s = all$), we use sectoral output as weights.

Our main independent variable of interest is the road network density ($transnet_i$) measured here as the length of paved roads[8] in km per surface in km^2. We expect that higher transport network densities are associated with lower transport margins as transport is easier and different locations are linked more directly. In addition, we expect this effect to be stronger in agricultural sectors as agricultural production is typically located in remote regions that benefit overproportionally from

[5] This also implies that, given that transport costs are measured in relative terms, they are robust concerning exchange rate conversion.

[6] The results found with this measure might also be useful in the specification of SAM-based CGE models such as Jensen (2009).

[7] We use pooled OLS instead of fixed effects because the dataset is highly unbalanced and missing are systematic with respect to the country group. A fixed effects estimation would be biased in favor of the developed countries. This point is explained in more detail below.

[8] As an alternative measure for transport infrastructure we use paved roads and railroads taken together. This does not have a substantial impact on the results. Given that roads and railroads are imperfect substitutes, an inclusion of the rail network as separate regressor would be ideal. Unfortunately, data on railroads in the WDI is highly incomplete and not reliable.

improvements in the transport network.

Several other variables should have an impact on transport costs. The GDP per capita ($gdpc_i$) as a proxy for the development of the economy but also for the overall transport demand is included as explanatory variable. One would expect that with higher overall transport demand, costs should decrease due to economies of scale. In contrast, if the level of technology is very low, an increasing GDP could also induce higher transport costs if transport is a very scarce service. This ambiguous ex ante expectation concerning the influence of $gdpc$ on transport costs might lead to a non-linear influence. We therefore test for non-linearity in *GDP* by including $gdpc^2$.[9]

In addition, we control for the degree of urbanization ($urban_i$) as a measure of dispersion of the market participants. Intuition suggests a negative coefficient for urbanization over all sectors. A higher degree of urbanization implies shorter transport ways and thus lower transport margins. However, the opposite is true in agricultural sectors: If the major part of the population lives in towns, food has to be carried long distances from the production site to the consumers. It might of course occur that a country with a high degree of urbanization has still long distances between these urban centers. We try to cover this effect of dispersion across the country by including population density in addition.

Moreover, we include the population density ($popdens_i$), measured as persons per km^2. On the one hand a higher population would mean higher transport requirements for transport of persons and thus imply a positive coefficient. On the other hand a smaller population might be spread across wide surfaces and thus need more transport which also induces higher transport costs and thus a negative coefficient for population density.

Climate conditions have a strong influence on both, the status of present roads and the possibility to use them. For this reason we include two climate variables: a temperature index and the yearly precipitation. The temperature index is calculated by adding up the squared maximum and minimum temperatures in degree Celsius for the respective year. Thus, extreme temperature conditions enter into the index with a higher weight and the index will rise both with very warm and very cold climate as both of these would hinder transportation. Precipitation is measured

[9] In contrast to most other variables, the exogeneity of GDP could be argued. Even though GDP should not be dependent on the transport cost variable, the two variables might be commonly affected by an omitted country- or time-specific influence which would lead to correlation between $gdpc$ and the error term. We hope to control for this possible endogeneity problem by including the country group and time fixed effects. Still results for $gdpc$ should be interpreted with some caution.

in total mm per m^2 per year. Very high levels of precipitation will lead to road erosion and thus higher transport costs.

As we will focus part of our investigation on transport costs in agricultural sectors we include the fraction of land dedicated to agricultural use ($agrland_i$) in these estimations. A higher share of agricultural land is expected to increase the efficiency of transport in these sectors and thus decrease agricultural transport costs.[10]

Some studies on public investment argue that the efficiency of the use of public capital is very important and that part of public investment is never used productively due to corruptive elites (See Hulten, 1996; Aschauer, 2000). For this reason we include *transparency international*'s *perceived corruption* index as an explanatory variable in some estimations. The index is defined between 0 and 10 where low values of the index are associated with very high levels of corruption.

As the sample comprises countries from all over the world, we include sets of dummy variables to control for structural differences between country groups. We alternatively include dummies for income groups, for geographical regions and for OECD member status.

We perform estimations both for the weighted margin aggregated over agricultural sectors only and for the weighted margin aggregated over all sectors. All estimations use pooled data and OLS with hetero-scedasticity-corrected standard errors (White procedure). Given the frequent and systematic missings in our panel data set a fixed effects estimation with cross-section fixed effects is not possible. Instead, we include country-group fixed effects and time fixed effects. Time fixed effects, however, have never been significant and thus results are not reported here.

3.2 Data

We construct a panel data set from various sources.[11] The panel contains data for 64 countries and 3 years (1995, 2000, 2005). The panel is highly unbalanced and missings are systematic (OECD countries usually have a full set of observations whereas part of the non-OECD countries have only two or even only one observation). The explanatory variables are available for all countries and nearly all years. In contrast, Social Accounting data is not frequently surveyed in all countries. For

[10] We tried to include the number of motor vehicles per 1000 persons as a proxy for transport technology. However, this measure is only available for a very limited number of periods and countries and thus the results are not reliable. The results are shown in table 11 in the appendix.

[11] A detailed overview of the different data sources is included in table 7 in the appendix.

most developing and transition countries only one SAM is available.[12] In total, we have 135 observations.

The data on transport margins has been collected from input-output-tables from different sources, mainly the International Food Policy Research Institute (IFPRI), Eurostat and the OECD. Data on road and rail road length as well as most of the control variables are from the World Development Indicators (WDI) Database. The country classification in income groups follows the World Bank classification. The regional groups are chosen as in Fay and Yepes (2003). Tables 1 and 2 show descriptive statistics.

The spending for transport ranges between 0.4% and 15% of sectoral production costs, 3.5% on average, in agricultural sectors and between 1 and 15% over all sectors, 6% on average. The countries in our sample have on average, 788 m of paved roads per km^2 of surface where the lowest transport network density is at only 3m/km^2 and the highest at 6086 m/km^2. The GDP per capita lies between 254 US-$ and 51,934 US-$. On average, 168 persons live on one km^2 of surface. The least concentrated country is populated by only 2.4 persons/km^2 and the most densely populated has over 3100 persons on the same surface. On average, more than half of the population lives in towns, only 12% in the most rural country and over 97% in the most urbanized. The climate conditions vary substantially across the countries. The temperature index lies between 7 and 1600 degrees Celsius. The highest maximum mean temperature is at about 32°C, the lowest minimum mean temperature is at about -11°C.

[12] The availability of SAMs also determines the total number of countries, we can only use Social Accounting Matrices where transportation is explicitly included and not aggregated with trade services and which have been updated between the periods of our panel.

Table 1: Descriptive statistics - Dependent variables and control variables

Variable	transport margins		paved roads/ surface	gdp/ capita US$	population density	urban population as % of total	temperature index	precipitation in mm	Agricultural land as % of total	Motor vehicles per 1000 persons	% of labour force with tertiary education	Corruption index
Abbrev.	m_{ag}	m_{all}	transport	gdpc	popdens	urban	temp	precip	agrland	vehicl	edu	corrup
Mean	0.035	0.060	0.788	13264.90	167.99	65.67	503.27	937.49	44.57	384.65	24.86	5.80
Median	0.026	0.058	0.371	8197.10	95.18	67.40	372.69	746.175	49.57	442.00	23.80	5.70
Std. dev.	0.027	0.026	0.966	12440.90	378.32	18.63	407.66	530.80	20.52	210.98	12.87	2.50
Min	0.004	0.011	0.003	253.48	2.43	12.02	6.85	54.74	3.298	8.00	3.00	1.50
Max	0.149	0.147	6.086	51934.26	3112.25	97.26	1595.14	2922.00	84.88	738.00	83.200	10.00
# obs	135	135	135	135	135	135	113	114	133	58	107	120

Table 2: Descriptive statistics - Dummy variables

	Regional Dummies							Income dummies			Year dummies		
	Eastern Europe / Central Asia	Middle East / North Africa	Sub Sahara Africa	Latin America	High Income	East Asia / Pacific	South Asia	High	Middle	Low	1995	2000	2005
Mean	0.141	0.007	0.074	0.111	0.578	0.037	0.052	0.578	0.348	0.074	0.336	0.343	0.321
Median	0.000	0.000	0	0	1	0	0	1	0	0	0	0	0
Std. dev.	0.350	0.086	0.251	0.316	0.495	0.190	0.223	0.495	0.479	0.251	0.474	0.477	0.469
Min	0	0	0	0	0	0	0	0	0	0	0	0	0
Max	1	1	1	1	1	1	1	1	1	1	1	1	1
# obs	19	1	10	15	78	5	7	78	47	10	45	46	44
# countries	9	1	7	12	29	3	3	29	27	8			

The sample consists of 64 countries of which 29 are high, 27 middle and 8 low income countries, the low and middle income countries are located as follows: three Eastern Asian and three Southern Asian countries, nine eastern European and Central-Asian countries, twelve Latin American countries, one Middle East and seven countries from Sub-Sahara Africa. Given the fact that the sample is biased in favour of high income countries (app. 60% of the observations are from high income countries) we include income group dummies to control for this and estimate country-group wise in addition to the pooled estimation. The observations with very low margins, very high temperatures and very low degrees of urbanization have been excluded from the relevant regressions after distributional tests.

4 Results

4.1 Pooled estimation

Table 3 summarizes the regression results for different specifications with the transport margin in agricultural sectors (m_{ag}) as dependent variable in specifications (1)-(5). This margin in agriculture should be more sensitive to bad roads compared to m_{all} which is the weighted average of the transport margins in all sectors.[13] All variables have been used in natural logarithms such that the results can be interpreted as elasticities.[14]

The regressions clearly show that for the complete sample an increased availability of roads significantly reduces the transport margin in agricultural sectors. This effect is robust in a number of different specifications. The sign remains negative across the different estimations. However, the effect is only significant if we control for distinct country characteristics such as the income group classification or the geographical location.[15] All these may be interpreted as indicators that clearly differ between industrialized and developing countries. The estimated elasticity of the transport cost measure with respect to changes in the road density lies between 0.077 and 0.334 in absolute terms. This implies that an

[13] Results for all sectors are described in the columns (6)-(10) in table 3, results for other specifications are shown in tables 8, 11 and 12.

[14] In addition, the use of logarithms significantly reduces the number of outliers which is important here, given the rather small sample and the fact that there is a large difference in magnitude between the different variables ($gdpc$ has much higher absolute values than the other variables).

[15] The coefficient is also significantly negative if we control for the level of education in the labour force. The education variable itself is, however, not siginificant. This result is shown in table 11 in the appendix.

increase in the road network by 1% would imply a decrease in transport spending between 0.08% and 0.33%.

The other explanatory variables clearly add explanatory power to the estimation but are mostly insignificant. We find a fairly robust positive relationship between the degree of urbanization and transport costs in agricultural sectors, which is related to the fact that in highly urbanised countries the distance between production site and sales market for agricultural products is highest and thus for agricultural products transport costs are higher.

Results for the impact of GDP per capita are ambiguous. In order to check whether this is due to a non-linear relationship between GDP and transport costs, we add $gdpc^2$ in estimation (a12). The coefficients for $gdpc$ and $gdpc^2$ have opposing mathematical signs, which is an indicator for a non-linear relationship between the dependent variable and the GDP per capita. However, none of the two coefficients are significant and the squared term adds only little explanatory power.[16]

The inclusion of the climate indicators seems to be important as these significantly increase the explanatory power even though they are only significant in equation (3). Both high temperatures and high quantities of precipitation increase transport costs, which is intuitive as these extreme weather conditions hinder transport even if roads are appropriate. A high share of agriculturally used land is associated with slightly lower transport margins in agriculture, supposedly due to economies of scale. The effect is not significant in the complete sample.

The two dummy variables for low and middle income countries are negative and the low income dummy is highly significant. If these dummies are alternatively split into five regional dummies for the low and middle income countries, only the Latin America dummy and the South Asia dummy are significant and the overall explanatory power of the estimation is lower. However, the significance of these dummies for income groups or geographical location is a strong indication for a substantial difference between high income countries on the one hand and developing and transition countries on the other hand.

[16] See table 11 in the appendix.

Table 3: Results from pooled OLS regression whole sample

Spec. No.	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
dependent	$ln(m_{ag})$	$ln(m_{ag})$	$ln(m_{ag})$	$ln(m_{ag})$	$ln(m_{ag})$	$ln(m_{all})$	$ln(m_{all})$	$ln(m_{all})$	$ln(m_{all})$	$ln(m_{all})$
# of obs	113	114	114	105	105	114	106	106	105	105
ln(trans)	-0.102	-0.292***	-0.297***	-0.336***	0.167	-0.195***	-0.167***	-0.168***	-0.194***	-0.183
	(-1.083)	(-3.757)	(-3.317)	(-4.386)	(0.841)	(-4.36)	(-3.71)	(-3.358)	(-4.812)	(-1.304)
ln(gdpc)	-0.219*	-0.126	-0.107	-0.061	-0.009	0.134*	-0.95*	0.155	-1.37**	-1.382**
	(-1.887)	(-0.947)	(-0.878)	(-0.299)	(-0.045)	(1.688)	(-1.723)	(1.82)	(-2.336)	(-2.441)
ln(popdens)	0.085	0.129*	0.112	0.145**	0.206***	0.108***	0.086**	0.095**	0.133***	0.135***
	(0.925)	(1.806)	(1.434)	(2.116)	(3.494)	(3.13)	(2.351)	(2.567)	(4.254)	(4.472)
ln(urban)	1.129***	0.118	1.797***	0.137	0.331	-0.394	-0.129	0.049	0.012	0.019
	(3.047)	(0.28)	(3.648)	(0.295)	(0.719)	(-1.476)	(-0.508)	(0.206)	(0.062)	(0.094)
ln(temp)	0.033	0.028	0.061*	0.038	0.005	0.003	0.002	-0.004	0.035	0.034
	(0.701)	(0.817)	(1.69)	(0.975)	(0.124)	(0.093)	(0.058)	(-0.143)	(1.3)	(1.193)
ln(precip)	0.139	0.015	0.22*	-0.004	0.08*	-0.156**	-0.192***	-0.178*	-0.186**	-0.185**
	(1.366)	(0.155)	(1.678)	(-0.031)	(1.587)	(-2.009)	(-2.802)	(-1.704)	(-2.6)	(-2.367)
ln(agrland)	-0.17									
	(-1.462)									
$ln(gdpc)^2$							0.061**		0.085**	0.086***
							(2.001)		(2.584)	(2.694)
ln(corrup)				-0.224	-0.712**				-0.089	-0.101
				(-0.68)	(-2.011)				(-0.588)	(-0.504)
ln(corrup)*ln(transp)					-0.304***					-0.007
					(-3.041)					(-0.095)
low income		-2.742***		-2.886***	-1.654**	-1.15***	-1.182**		-1.382***	-1.357**
		(-5.222)		(-4.985)	(-2.145)	(-2.926)	(-2.62)		(-2.945)	(-2.258)
middle income		-0.359		-0.437	-0.269	-0.271	-0.177		-0.358	-0.354
		(-1.539)		(-1.154)	(-0.901)	(-1.387)	(-1.014)		(-1.621)	(-1.505)
East Asia/Pacific			0.094					0.239		
			(0.019)					(0.933)		
Europe/Centr. Asia			-0.095					-0.241		
			(-0.405)					(-0.991)		
Latin America			-0.959***					-0.186		
			(-2.56)					(-0.867)		
South Asia			1.352***					0.307		
			(2.608)					(0.991)		
Sub Sah. Africa			-0.005					-0.245		
			(-0.006)					(-0.927)		
constant	-7.29***	-3.854***	-12.716***	-4.154***	-0.526***	-1.908*	2.006	-3.762***	3.025	3.05
	(-4.753)	(-2.782)	(-5.798)	(-2.492)	(-3.068)	(-1.77)	(0.801)	(-3.427)	(1.155)	(1.184)
R^2	0.194	0.344	0.321	0.398	0.408	0.195	0.228	0.19	0.267	0.267
adj. R^2	0.140	0.294	0.248	0.335	0.345	0.134	0.155	0.103	0.189	0.18

t-statistics in parantheses, ***, **, * indicate significance on 1%, 5% and 10% level respectively

Results for the impact of GDP per capita are ambiguous. In order to check whether this is due to a non-linear relationship between GDP and transport costs, we add $gdpc^2$ in estimation (a12). The coefficients for $gdpc$ and $gdpc^2$ have opposing mathematical signs, which is an indicator for a non-linear relationship between the dependent variable and the GDP per capita. However, none of the two coefficients are significant and the squared term adds only little explanatory power.[17]

The inclusion of the climate indicators seems to be important as these significantly increase the explanatory power even though they are only significant in equation (3). Both high temperatures and high quantities of precipitation increase transport costs, which is intuitive as these extreme weather conditions hinder transport even if roads are appropriate. A high share of agriculturally used land is associated with slightly lower transport margins in agriculture, supposedly due to economies of scale. The effect, however, is rather low and is not significant in the complete sample.

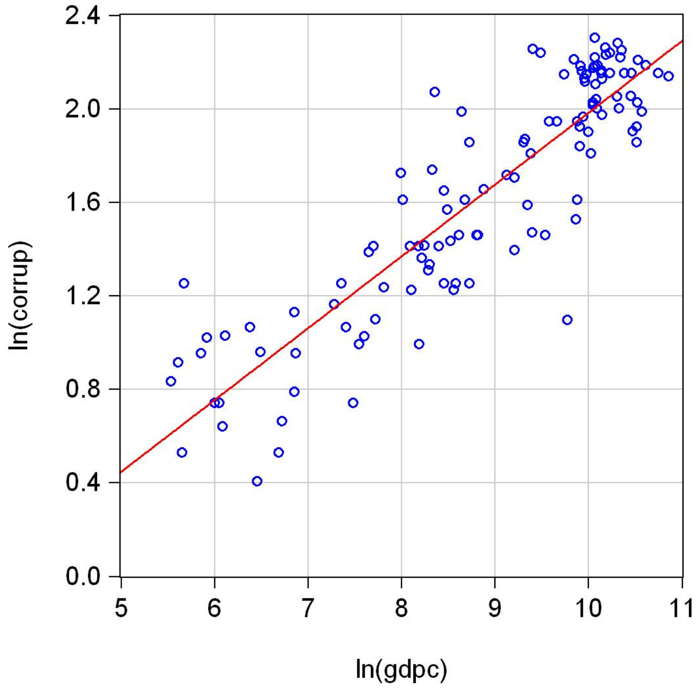
The two dummy variables for low and middle income countries are negative and the low income dummy is highly significant. This means that low and middle income countries differ from high income countries regarding transport costs. If these dummies are alternatively split into five regional dummies for the low and middle income countries, only the Latin America dummy and the South Asia dummy are significant and the overall explanatory power of the estimation is lower. However, the significance of these dummies for income groups or geographical location is a strong indication for a substantial difference between high income countries on the one hand and developing and transition countries on the other hand.

One possible explanation for differences in transportation costs between high income and middle and low income countries, apart from the climate (which adds some explanatory power but is not significant), might be that high levels of corruption lead to higher transaction costs and longer transport times due to frequent controls on the way. It might also be the case that the level of road provision is not optimal in these countries (See Canning and Bennathan, 2004) or that roads are not used efficiently due to corruption. Indeed, corruption is strongly negatively correlated with GDP per capita (see figure 1) and might thus explain the significance of the income dummies if it plays a role in determining transport

[17] See table 11 in the appendix.

costs.[18]

Figure 1: Correlation between corruption and GDP per capita



In order to take this into account we include *transparency international's perceived corruption index* into estimations (4) and (5). The inclusion of the index increases the adjusted R^2 by 1.7 percentage points. The coefficient has the expected negative sign but is not significant.

As we believe that the effectiveness of roads might be conditional on the absence of corruption we include an interaction term between the corruption index and the road density in the last specification. Surprisingly, this strongly affects the results. The explanatory power rises, the coefficient of road density switches from significantly negative to insignificantly positive and the coefficient of the corruption index increases and is now significant, too. The positive coefficient for

[18] Please note the corruption index is defined between 0 and 10 where high levels of the index stand for low levels of corruption.

road density indicates that at very high levels of corruption (i.e. corruption index $= 0$) an increase in road density could increase transport costs. Calculating the mean effect of road density on transport margins in agriculture at mean corruption level gives a coefficient for $ln(trans)$ of -0.331 with a t-value of -4.786.[19] In other words the effectiveness of roads is strongly conditional on the absence of corruption, at the mean corruption level in the complete sample, the cost reduction from a 1% increase in road density is roughly 0.3%. However the income group dummies remain significant even though their influence is lower if corruption is controlled for.

Medium and low income countries have lower levels of agricultural transport costs, the OECD member status does not influence the results. Time fixed effects have not been significant.[20]

The relation between the transport network density and the transport costs for the complete sample is confirmed not only for the agricultural sectors but also for the weighted transport expenditure of all sectors. These results are shown in the last five colums of table 3. We consistently find negative coefficients for transport networks as well. However, the influence of transport networks on the weighted transport costs in all sectors is much lower. In addition, the explanatory power of the estimations is substantially lower compared to the estimations for the agricultural sector.

Interestingly, the non-linearity of transport costs with respect to $gdpc$ is significantly confirmed here in contrast to the results for m_{ag}. The GDP has a significant influence on transport costs in four out of the ten specifications. The influence of GDP is positive and switches to negative if $ln(gdpc)^2$ is included. The influence of $ln(gdpc)^2$ is significantly positive if included. This indicates a diminishing negative influence of the GDP on transport costs. I.e. countries with higher levels of GDP have, in general, lower transport costs, but the relationship is decreasing with rising levels of GDPC. The signs of most other coefficients are in line with the results for agricultural transport costs but the magnitudes are lower as well. Time fixed effects have been insignificant here, either. We do observe a significant coefficient for the low income dummy but not for the middle income dummy. Geographical dummies do not have significant influences on transport costs over all sectors.

[19] All mean effects are summarised in table 6.
[20] Not shown here to simplify the exposition.

The results for the inclusion of corruption are not robustly confirmed here. Even though the inclusion of corruption increases the explanatory power, the coefficient of the index as well as the one of the interaction term are insignificant and close to zero. However, calculating the effect of transport on the margin at mean corruption gives a coefficient of -0.194 with a t-value of -4.735. As this mean effect of transport networks on the margin is comparable to the result in equation (9) (without corruption) we do not confirm an interaction effect here, the effect of roads on transport costs is unaffected by corruption.

The somehow weaker results for the weighted transport margin in all sectors might partly result from the fact that the production structure differs substantially across countries and thus, as we use sectoral production as weights, the transport cost measure is very heterogeneous compared to agricultural production which is more comparable across countries.

4.2 Country group estimations

The fact that the income groups have been found to be consistently significant as well as some of the geographical dummies even after controlling for a number of country characteristics like climate, population density, urbanization, land use, education and corruption indicates that there might be a structural difference in the determinants of transport costs between high income countries and developing and transition countries. Hence, we divide our sample into a high income and a medium and low income sample.[21] We run the same regressions as shown above in order to isolate country group specifics. We indeed find substantial differences between the two subsamples.

Table 4 shows the results for the margin in agricultural sectors. Estimations (1) - (5) are for the high income countries only, whereas estimations (6) to (11) only comprise low and medium income countries.[22]

It is obvious that the two samples produce quite differing results. For *high income countries* we mostly confirm the results obtained in the complete sample. We find a significantly negative relationship between road infrastructure and transport costs. The estimated coefficients are even higher compared to table 3.

[21] The descriptive statistics for the two subsamples are shown in the appendix in tables 9 and 10.
[22] Note, to simplify matters not all specifications presented above for the whole sample are replicated here. We only show those with most explanatory power.

Table 4: Results from pooled OLS regression for margin in agricultural sectors, subsamples

Spec. No.	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
dependent	$ln(m_{ag})$	$ln(m_{ag})$	$ln(m_{ag})$	$ln(m_{ag})$	$ln(m_{ag})$	$ln(m_{ag})$	$ln(m_{ag})$	$ln(m_{ag})$	$ln(m_{ag})$	$ln(m_{ag})$	$ln(m_{ag})$
Sample	high	high	high	high	high	low&med.	low&med.	low&med.	low&med.	low&med.	low&med.
# of obs	78	73	73	69	69	57	35	36	37	32	32
ln(trans)	-0.227*	-0.463***	-0.38***	-0.56***	0.439	-0.013	0.271	0.302*	0.203	0.228*	1.578**
	(-1.689)	(-7.831)	(-5.724)	(-9.046)	(0.415)	(-0.142)	(2.111)	(1.898)	(1.465)	(1.898)	(2.256)
ln(gdpc)	-0.383*	-0.074	-0.199	0.313	0.282	0.092	-0.095	-0.413	-0.097	-0.482	-0.334
	(-1.99)	(-0.493)	(-1.366)	(1.569)	(1.508)	(0.477)	(-0.219)	(-0.816)	(-0.276)	(-1.031)	(-0.674)
ln(popdens)	0.031	0.193***	0.169***	0.207***	0.265***	0.112	0.001	-0.241	-0.199	-0.035	-0.318
	(0.277)	(4.046)	(4.101)	(4.099)	(3.06)	(0.781)	(0.053)	(-0.693)	(-0.7)	(-0.132)	(-0.872)
ln(urban)	0.863*	0.831	1.123*	1.407**	1.329**	0.571	1.055	1.406	2.476***	1.586	0.815
	(1.699)	(1.559)	(1.932)	(2.326)	(2.191)	(1.322)	(1.091)	(1.302)	(3.037)	(1.567)	(0.694)
ln(temp)		0.105*	0.208**	0.071	0.071		0.874***	0.969***	0.827***	0.97***	0.817***
		(1.925)	(2.097)	(1.344)	(1.29)		(3.665)	(4.39)	(4.108)	(3.981)	(3.981)
ln(precip)		0.078	0.116	0.223	0.201		-0.145	-0.552**	-0.328	-0.461	-0.537**
		(0.335)	(0.494)	(0.927)	(0.861)		(-0.464)	(-2.445)	(-1.298)	(-1.344)	(-2.048)
ln(agrland)			-0.245*					0.419			
			(-1.695)					(0.851)			
ln(corrup)				-1.452***	-1.382***					0.585	-2.478
				(-3.883)	(-3.971)					(0.766)	(-1.571)
ln(corrup)*ln(transp)					-0.496						-1.084**
					(-0.943)						(-2.005)
East Asia/Pacific									0.794*		
									(1.928)		
Latin America									-0.321		
									(-0.533)		
South Asia									1.954***		
									(4.536)		
Sub Sah. Africa									1.294***		
									(3.083)		
C	-3.903*	-8.592***	-8.451***	- 12.898***	- 12.536***	-6.925***	- 10.907***	-8.14***	-14.72***	-9.116***	-0.662
	(-1.811)	(-3.738)	(-3.485)	(-4.708)	(-4.735)	(-4.2)	(-4.44)	(-3.238)	(-5.495)	(-3.433)	(-0.131)
R^2	0.211	0.372	0.404	0.493	0.503	0.145	0.442	0.293	0.651	0.407	0.435
adj.R^2	0.168	0.315	0.339	0.435	0.437	0.079	0.323	0.069	0.517	0.234	0.197

t-statistics in parenthesis, ***, **, * indicate significance on 1%, 5% and 10% level respectively

Still, the influence of GDP per capita is ambiguous. Densely populated countries have higher transport costs in agriculture as well as highly urbanised countries. Supposedly this is due to the fact that agricultural products have to be carried long ways in these countries. In contrast, higher shares of agriculture in total land use lead to lower transport costs in this sector, which may be attributed to economies of scale in transportation.

We also confirm the positive influence of corruption on transport costs (negative coefficient). However, we do not observe an interaction effect. The coefficient of the interaction term is insignificant and its inclusion adds virtually no explanatory power.

The picture is quite different for the middle and low income sample. Here we mostly find positive but sometimes insignificant coefficients for the road density. Hence, in middle and low income countries additional roads have no effects on transport costs or may even increase these.

We do not find significant effects of $gdpc$ or population density but we confirm the cost increasing influence of urbanization. The climate indicators especially the temperature index are the only determinants that are significant in most specifications to the contrary of the high income and the complete sample results. For the low and middle income sample we find a strong cost increasing influence of temperature and a cost-reducing influence of precipitation.

The inclusion of corruption increases the explanatory power. However corruption is only significant if the interaction term is included as well. In this case we find a very high and positive coefficient for roads and high and negative coefficients for corruption and the interaction term. The R^2 is much higher compared to the other specifications, except for equ. (9). Thus, for transport costs in the agricultural sector in developing and transition countries we cannot confirm that roads reduce these. However, we clearly find that corruption hinders improvements in transport costs. At the mean level of corruption in this sample, the effect of transport infrastructure on transport margins in agriculture is 0.3341 with a t-value of 2.06. Thus, the mean level of corruption in developing countries is so high that additional roads are not only inefficient concerning transport costs in agriculture, they even increase costs in this sector, supposedly due to inefficient allocation of road investments. At very high levels of corruption (index close to 0) additional roads may even increase transport costs overproportionally (coefficient > 1).

Table 5: Results from pooled OLS regression for margin in all sectors, subsamples

Spec. No.	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
dependent	$ln(m_{all})$	$ln(m_{all})$	$ln(m_{all})$	$ln(m_{all})$	$ln(m_{all})$	$ln(m_{all})$	$ln(m_{all})$	$ln(m_{all})$	$ln(m_{all})$
Sample	high	high	high	high	low&med.	low&med.	low&med.	low&med.	low&med.
# of obs	78	73	71	71	57	39	39	34	34
ln(trans)	-0.033	-0.137***	-0.109***	0.483	-0.051	-0.414***	-0.375**	-0.434***	0.269
	(-0.333)	(-2.956)	(-2.685)	(1.07)	(-0.648)	(-4.126)	(-2.671)	(-5.349)	(0.729)
ln(gdpc)	-0.09	0.1	0.121	0.102	0	0.098	0.096	0.356*	0.439**
	(-0.751)	(1.273)	(1.525)	(1.378)	(0.001)	(0.504)	(0.356)	(1.737)	(2.212)
ln(popdens)	-0.042	0.078***	0.093***	0.128***	-0.026	0.932***	1.151***	0.996***	0.849***
	(-0.517)	(2.736)	(3.156)	(2.973)	(-0.202)	(4.468)	(4.814)	(4.861)	(3.349)
ln(urban)	0.207	0.18	0.399**	0.353**	0.048	0.73*	1.044*	0.63	0.219
	(0.582)	(0.609)	(2.247)	(2.086)	(0.277)	(1.824)	(1.985)	(1.565)	(0.487)
ln(temp)		-0.101***	-0.079***	-0.079***		0.081**	0.049	0.159**	0.073
		(-3.718)	(-3.109)	(-3.169)		(2.155)	(1.136)	(2.313)	(0.923)
ln(precip)		-0.082	-0.187*	-0.2**		-0.494***	-0.793***	-0.521***	-0.554***
		(-0.766)	(-1.964)	(-2.131)		(-3.468)	(-4.122)	(-2.902)	(-3.423)
ln(corrup)			-0.013	0.028				-0.775	-2.382**
			(-0.06)	(0.132)				(-1.457)	(-2.685)
ln(corrup)*ln(transp)				-0.294					-0.566*
				(-1.305)					(1.95)
Europe/Centr. Asia							-0.943**		
							(-2.579)		
Latin America							-0.279		
							(-0.668)		
South Asia							-0.697		
							(-1.626)		
Sub Sah. Africa							-0.26		
							(-0.782)		
constant	-2.661*	-3.824***	-4.399***	-4.184***	-3.218**	-8.532***	-7.761***	-9.828***	-5.412
	(-1.729)	(-3.515)	(-3.445)	(-3.364)	(-2.465)	(-5.151)	(-2.987)	(-5.739)	(1.666)
R^2	0.053	0.235	0.319	0.335	0.035	0.363	0.452	0.474	0.541
adj. R^2	0.001	0.165	0.241	0.246	-0.04	0.244	0.256	0.332	0.395

t-statistics in parantheses, ***, **, * indicate significance on 1%, 5% and 10% level respectively

What has been found for the margin in agricultural sectors for the two country groups is not true for the weighted margin over all sectors. For both income groups we confirm the negative influence of road infrastructure on tranport costs but with weaker explanatory power and lower coefficients. We consistently confirm the cost-increasing influence of population density and urbanization.

The countries differ in the influence of climate and in the influence of corruption. We find a strong influence of temperature on transport costs in both country groups but with opposing signs. In high income countries higher temperatures reduce the transport margin whereas in middle and low income countries higher temperatures increase the transport margin. This may be explained by differences in technology. For precipitation, the influence is low and partly insignificant in industrialised countries but highly negative in developing countries.

We cannot confirm the positive influence of corruption for high income countries, but we find it to be of importance for middle and low income countries, we see a rise in R^2 after inclusion of the corruption index. Still, the corruption index is only significant after controlling for an interaction between corruption and roads. The coefficient for road networks becomes insignificant. Calculating mean effects for table 5 leads to a coefficient of transport at mean corruption of -0.089 in high income countries and -0.380 in middle and low income countries. Hence, the inefficiency of road allocation that has been found for the agricultural sector in developing and transition countries does not apply for the margin in all sectors. Still, we confirm the interaction effect and find roads impact to be conditional on corruption, only the mean level of corruption is not prohibitive for cost reduction in all sectors but only in agricultural sectors.

Table 6: Effects of ln(transnet) on transport margin at mean corruption

Specification	Sample	Coefficient	t-statistic	P-Value
$ln(m_{ag})$	all	-0.331***	-4.786	0.000
$ln(m_{all})$	all	-0.194***	-4.735	0.000
$ln(m_{ag})$	high	-0.527***	-7.516	0.000
$ln(m_{all})$	high	-0.089**	-1.999	0.050
$ln(m_{ag})$	low&med	**0.334****	2.061	0.051
$ln(m_{all})$	low&med	-0.380***	-3.516	0.000

4.3 Robustness

All estimations have been done using heteroscedasticity-robust standard-errors. The results are perfectly robust disregarding whether the Newey-West-specification or the White-specification is used. Based on the Jarque-Bera-Test, we do not reject the null-hypothesis of normally distributed residuals in any of our estimations.

The results are also robust with respect to the sample. We have run estimations excluding the smallest and largest countries and obtained similar results as shown here. However, we are not able to exclude more than one of the developing countries at a time given the small number of developing countries in the sample.

As the quality of roads has an influence on transport costs, too (this is e.g. found by Teravaninthorn and Raballand, 2009, and others) and this aspect is not covered by our approach we have included either the share of paved roads in the total network of the respective country or the share of expressways in the paved network of the country in equations (a20)-(a21) and (a23)-(a24) in table 6 in the appendix as measures for the average road quality in the country. These explanatory variables add slightly to the explanatory power but do not change the general results described above. However, data on the expressways was only available for the years 2000 and 2005 and thus the inclusion of this indicator reduces the number of observations substantially. The same is true for the number of vehicles in a country which might be used as a proxy for the availability of transport technology. However the data in the WDI on vehicles is very incomplete.

In order to address the problem that the sample splitting leads to a substantially reduced number of degrees of freedom we have alternatively estimated equations (a22) and (a25) with triple interaction terms including the income group dummys. The results are in table 6 and are not in contradiction to the results found with separate samples. In addition it is visible that the influence of corruption is mainly driven by the low income countries. However, the mean effect is also significant for middle income countries (not shown).

5 Conclusions

We have shown by means of pooled OLS estimations in a sample comprising high, medium and low income countries that investments in longer and better roads have the potential to significantly reduce the transport spending. However, this result is of particular importance for agricultural production and transportation of agricultural goods. Even though the negative effect of roads on transport costs is confirmed for all sectors, the importance of the effect is substantially lower on average compared to agricultural transport costs. Other explanatory variables might be more important in industrial sectors.

These results for the complete sample and the confirmation of these for the high income sample show that our proxy for transport costs, the transport margin, is a good and internationally comparable measure of transaction costs from transportation. Our results are in line with most findings for high income countries that use other measures such as the tariff equivalent costs of bad roads or vehicle operation costs.

Splitting the sample into high income countries on the one hand and low and medium income countries on the other hand reveals substantial differences between country groups. In low and medium income countries we find climate and most importantly the level of perceived corruption to be more important in determining transport costs than the availability of infrastructure. We find substantial differences between industrial and developing and transition countries that should be taken into account when infrastructure projects are planned in low and middle income countries.

We find an interaction effect between road status and corruption that might lead to negative effects from roads at very high levels of corruption, supposedly due to inefficient planning and non-maintenance of existing roads. The effectiveness of infrastructure programs might thus be conditional on the reduction of corruption in these countries. This is in line with Aschauer (2000) and Hulten (1996) who argue concerning public investment in general that not only the amount of public capital is important but also how efficiently it is invested and used. Especially in the agricultural sector in developing and transition countries this interaction effect is crucial. The mean level of corruption is so high that it is prohibitive for cost reductions in agriculture. Thus, the agricultural sector in these countries does not benefit from higher levels of infrastructure and this is partly due to corruption.

This paper contributes to the literature on infrastructure investment by developing and applying an internationally comparable measure of transport costs which can be calculated for a large and growing number of countries. We isolate important determinants of transport costs and provide an insight on sectoral differences concerning roads' effect on transport costs. Most importantly, we find strong support for the hypothesis that the positive experiences from large infrastructure programs in industrial countries cannot easily be applied to developing and transition countries as other important circumstances should be present as well.

We conclude that investment in transport infrastructure can have highly positive effects especially on agricultural production and the efficient marketing of agricultural products. However, this is conditional on low levels of corruption and efficient planning and use of the infrastructure as well as on the climatic circumstances.

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6 Appendix

Table 7: Data sources & description

Variable	Country	Data Source	Description
transport margins (m)	Argentina	IFPRI	Own calculations based on the Social Accounting Matrices or Input-Output tables. Calculation: For each sector we compute: Sectoral spending on transport/Total sectoral production and marketing cost, we then aggregate the margins by calculating an output-weighted average.
	Australia	OECD	
	Austria	Eurostat	
	Bangladesh	IFPRI	
	Belgium	Eurostat	
	Bolivia	IFPRI	
	Brazil	IFPRI	
	Bulgaria	Eurostat	
	Canada	OECD	
	Chile	IFPRI	
	China	OECD	
	Colombia	IFPRI	
	Costa Rica	IFPRI	
	Czech Republic	Eurostat	
	Denmark	Eurostat	
	Egypt	IFPRI	
	El Salvador	IFPRI	
	Estonia	Eurostat	
	Finland	Eurostat	
	France	Eurostat	
	Germany	Eurostat	
	Ghana	IFPRI	
	Great Britain	Eurostat	
	Greece	Eurostat	
	Honduras	IFPRI	
	Hungary	Eurostat	
	India	National statistics	
	Indonesia	IFPRI	
	Ireland	Eurostat	
	Israel	OECD	
	Italy	Eurostat	
	Japan	OECD	
	Kenya	IFPRI	
	Latvia	Eurostat	
	Lithunia	Eurostat	
	Luxemburg	Eurostat	
	Macedonia	Eurostat	
	Malta	Eurostat	
	Mexico	IFPRI	
	Netherlands	Eurostat	
	New Zealand	OECD	
	Nigeria	IFPRI	
	Norway	OECD	
	Paraguay	IFPRI	
	Peru	IFPRI	
	Poland	Eurostat	
	Portugal	Eurostat	
	Romania	Eurostat	
	Russia	National statistics	
	Slovakia	Eurostat	
	Slovenia	Eurostat	
	South Africa	IFPRI	
	Spain	Eurostat	
	Sweden	Eurostat	
	Switzerland	National statistics	
	Tanzania	IFPRI	
	Thailand	IFPRI	
	Turkey	Eurostat	
	Uganda	IFPRI	
	Ukraine	National statistics	
	Uruguay	IFPRI	
	USA	OECD	
	Vietnam	IFPRI	
	Zambia	IFPRI	

road density (transp)	all	World development indicators	The road density has been calculated based on the indicators: "roads, total network","roads, paved percent" and "surface, total". It is defined as paved roads/km^2 surface
GDP per capita (gdpc)	all	World development indicators	GDP per capita in constant US$
population density (popdens)	all	World development indicators	
Temperature index (temp)	all	World metereological organization	The index has been calculated as yearly maximum squared + yearly minimum squared
Precipitation (precip)	all	World metereological organization	Precipitation per year in mm
urbanization (urban)	all	World development indicators	urban population as % of total
agricultural land(agrland)	all	World development indicators	Agricultural land as % of land area
Corruption	all	Transparency international	The perceived corruption index is defined between 0 and 10 where 10 means "no corruption"
Education (edu)	all	World development indicators	% of labor force with tertiary education
Motor vehicles (vehicl)	all	World development indicators	Motor vehicles per 1000 persons
% Paved roads (paved)	all	World development indicators	Paved roads as % of total network
% Expressways (exprway)	all	CIA World Factbook	Expressways as % of total paved network

Table 8: Results from pooled OLS regression whole sample - additional specifications

Spec. No.	(a1)	(a2)	(a3)	(a4)	(a5)	(a6)	(a7)	(a8)	(a9)	(a10)
dependent	$ln(m_{ag})$	$ln(m_{ag})$	$ln(m_{ag})$	$ln(m_{ag})$	$ln(m_{ag})$	$ln(m_{all})$	$ln(m_{all})$	$ln(m_{all})$	$ln(m_{all})$	$ln(m_{all})$
	135	135	135	135	114	135	135	135	135	114
	-0.077**	-0.087*	-0.074	-0.061	-0.152*	-0.007	-0.045	-0.026	-0.026	-0.141***
	(-2.003)	(-1.738)	(-0.718)	(-0.633)	(-1.727)	(-0.284)	(-1.392)	(-0.414)	(-0.408)	(-3.041)
		0.02	0.01	-0.175	-0.16		0.076*	0.063	0.06	0.17**
		(0.301)	(0.109)	(-1.611)	(-1.459)		(1.932)	(1.038)	(0.843)	(2.311)
			-0.02	0.002	0.083			-0.029	-0.029	0.096**
			(-0.172)	(0.02)	(0.877)			(-0.404)	(-0.397)	(2.131)
				0.901***	1.031***				0.014	-0.105
				(3.247)	(2.785)				(0.09)	(-0.518)
ln(temp)					-0.005					-0.01
					(0.073)					(-0.386)
ln(precip)					0.091					-0.123
					(1.278)					(-0.463)
constant	-3.749***	-3.935***	-3.751***	-5.921***	-7.909***	-2.916***	-3.632***	-3.364***	-3.398***	-3.592***
	(-45.391)	(-6.404)	(-2.748)	(-4.086)	(-5.037)	(-56.643)	(-9.601)	(-3.874)	(-3.657)	(-4.041)
R^2	0.029	0.03	0.031	0.108	0.174	0.001	0.035	0.038	0.038	0.122
adj. R^2	0.022	0.015	0.009	0.081	0.128	-0.007	0.021	0.016	0.009	0.072

t-statistics in parantheses, ***, **, * indicate significance on 1%, 5% and 10% level respectively

Table 9: Descriptive statistics high income sample

Variable	transport margins		paved roads/ surface	gdp/ capita US$	population density	urban population as % of total	Temperature index	precipitation in mm	Agricultural land as % of total	Motor vehicles per 1000 persons	% of labor force with tertiary education	Corruption index
Abbrev.	m_{ag}	m_{all}	transport	gdpc	popdens	urban	temp	precip	agrland	vehicl	edu	corrup
Mean	0.0314	0.0639	1.213	21120.54	217.34	73.61	340.12	876.16	42.40	524.77	26.86	7.27
Median	0.0241	0.0626	0.926	21330.45	109.58	73.90	295.30	747.00	49.18	521.00	26.50	7.55
Std. dev.	0.0247	0.0240	1.063	10737.43	479.02	11.88	218.30	419.41	21.04	110.15	12.49	1.80
Min	0.0035	0.0108	0.032	2858.17	2.43	49.50	6.85	383.92	3.40	256.00	8.60	2.99
Max	0.1289	0.1234	6.086	51934.26	3112.25	97.26	1068.50	2375.82	71.83	738.00	83.20	10.00
# obs	78	78	78	78	78	78	75	75	76	35	75	74

Table 10: Descriptive statistics low & middle income sample

Variable	transport margins		paved roads/ surface	gdp/ capita US$	population density	urban population as % of total	Temperature index	precipitation in mm	Agricultural land as % of total	Motor vehicles per 1000 persons	% of labor force with tertiary education	Corruption index
Abbrev.	m_{ag}	m_{all}	transport	gdpc	popdens	urban	temp	precip	agrland	vehicl	edu	corrup
Mean	0.0388	0.0561	0.1917	2288.48	97.79	54.26	20570.07	1055.42	47.28	171.41	20.19	3.37
Median	0.0378	0.0534	0.1067	1775.14	71.53	58.40	819.36	745.35	50.46	149.84	19.00	3.15
Std. dev.	0.0294	0.0281	0.2411	1858.78	128.09	20.67	87303.57	688.18	19.50	133.42	12.69	1.33
Min	0.0052	0.0120	0.0026	253.48	6.81	12.02	95.50	54.74	3.30	8.00	3.00	1.50
Max	0.1494	0.1472	1.0765	7197.17	872.09	90.50	417559.03	2922.00	84.88	467.00	66.10	7.94
# obs	57	57	57	57	57	57	40	39	57	23	32	46

Table 11: Results from pooled OLS regression for different additional specifications

Spec. No.	(a11)	(a12)	(a13)	(a14)	(a15)	(a16)	(a17)	(a18)	(a19)
dependent	$ln(m_{ag})$	$ln(m_{ag})$	$ln(m_{all})$	$ln(m_{all})$	$ln(m_{ag})$	$ln(m_{ag})$	$ln(m_{all})$	$ln(m_{ag})$	$ln(m_{all})$
sample	complete	complete	complete	complete	high	high	high	low&med.	low&med.
# of obs	45	114	49	89	73	31	35	28	33
ln(transp)	-0.493***	-0.287***	-0.222***	-0.184***	-0.447***	-0.564***	-0.088	0.067	-0.254
	(-4.482)	(-4.128)	(-3.455)	(-4.161)	(-5.133)	(-5.706)	(-0.534)	(0.214)	(-1.298)
ln(gdpc)	-0.034	-1.344	0.406**	0.235***	-4.423	0.312	0.179	-1.94	0.598
	(-0.111)	(-1.586)	(2.483)	(2.778)	(-1.335)	(0.986)	(0.776)	(-0.578)	(0.371)
ln(popdens)	0.242***	0.127*	0.137***	0.113***	0.176**	0.275***	-0.031	-0.197	0.538
	(4.015)	(1.797)	(2.75)	(3.146)	(2.421)	(3.996)	(-0.222)	(-0.332)	(1.39)
ln(urban)	-0.237	0.329	-0.484	-0.2	0.79	1.358	-0.014	-0.365	0.300
	(-0.219)	(0.856)	(-0.951)	(-0.532)	(1.62)	(1.637)	(-0.025)	(-0.38)	(0.652)
ln(temp)	0.134	0.039	-0.015	-0.079**	0.15*	0.037		0.517	0.077**
	(1.036)	(0.759)	(-0.368)	(-2.415)	(1.804)	(0.536)		(1.224)	(2.173)
ln(precip)	0.009	-0.008	0.004	-0.201**	0.042	0.032		-0.217	-0.387**
	(0.024)	(0.068)	(0.029)	(-2.111)	(0.203)	(0.119)		(-0.506)	(-2.264)
ln(edu)	0.058			-0.096					
	(0.178)			(-0.79)					
ln(vehicl)	0.794**		-0.306*			1.641***	-0.754		
	(2.62)		(-1.945)			(3.772)	(-1.652)		
ln(corrup)						-2.449***			
						(-3.528)			
$ln(gdpc)^2$		0.068			0.231			0.133	-0.031
		(1.454)			(1.314)			(0.581)	(-0.291)
low income		-3.071***	-0.999**						
		(-5.128)	(-2.104)						
middle income		-0.377	-0.199						
		(1.541)	(-0.548)						
constant	-9.494**	0.712	-3.37**	-2.701*	11.971	-19.746***	0.288	4.287	-7.493
	(-2.222)	(0.203)	(-2.609)	(-1.983)	(0.756)	(-4.766)	(0.083)	(0.321)	(-1.203)
R^2	0.427	0.357	0.377	0.25	0.389	0.736	0.177	0.443	0.257
adj. R^2	0.257	0.301	0.233	0.185	0.323	0.641	0.036	0.209	0.049

Table 12: Results from pooled OLS regression for different additional specifications

Spec. No.	(a20)	(a21)	(a22)	(a23)	(a24)	(a25)
dependent	$ln(m_{ag})$	$ln(m_{ag})$	$ln(m_{ag})$	$ln(m_{all})$	$ln(m_{all})$	$ln(m_{all})$
# of obs	105	63	105	105	63	105
ln(transp)	0.405*	0.357	-0.318***	-0.218	-0.028	-0.207***
	(1.981)	(1.000)	(-2.830)	(-1.424)	(-0.076)	(-2.747)
ln(gdpc)	0.016	0.357	-0.002	-1.301**	0.443	-1.574**
	(0.092)	(1.000)	(-0.010)	(-2.238)	(0.375)	(-2.449)
ln(gdpc)^2				0.080**	-0.007	0.093***
				(2.483)	(-0.109)	(2.700)
ln(popdens)	0.253***	0.274***	0.121*	0.165***	0.179***	0.145***
	(3.640)	(5.514)	1.662	(3.270)	(4.295)	(2.927)
ln(urban)	0.755**	0.402	0.083	0.124	0.180	0.115
	(2.135)	(0.681)	(0.167)	(0.513)	(0.750)	(0.529)
ln(temp)	-0.025	-0.019	0.107*	0.027	0.015	0.004
	(-0.557)	(-0.344)	(1.769)	(1.011)	(0.447)	(0.143)
ln(precip)	0.184	0.350	-0.048	-0.153*	-0.035	-0.151**
	(1.225)	(1.258)	(-0.366)	(-1.949)	(-0.257)	(-2.161)
ln(corrup)	-0.91***	-1.121*	-0.201	-0.090	-0.212	-0.074
	(-2.765)	(-1.900)	(-0.584)	(-0.447)	(-0.695)	(-0.509)
ln(corrup)*ln(transp)	-0.45***	-0.42**		-0.018	-0.115	
	(-5.169)	(-2.344)		(-0.248)	(-0.609)	
ln(corrup)*ln(transp)*low			0.355			0.357***
			(1.628)			(5.720)
ln(corrup)*ln(transp)*med			0.139			-0.057
			(1.441)			(-1.046)
low income			-1.837	-1.146**		0.044
			(-1.577)	(-2.023)		(0.129)
middle income			-0.124	-0.343		-0.518
			(-0.336)	(-1.529)		(-1.618)
ln(paved)	0.106		-0.215	0.114		0.094
	(0.599)		(-1.230)	(0.822)		(0.665)
ln(exprway)		0.124			-0.112*	
		(1.181)			(-1.834)	
constant	-8.16***	-9.77***	-3.592	1.487	-7.531	3.203
	(-4.123)	(-3.505)	(-1.426)	(0.504)	(-1.424)	(0.993)
R^2	0.378	0.437	0.387	0.274	0.351	0.300
adj. R^2	0.320	0.342	0.307	0.179	0.226	0.200