Road infrastructure in Europe and Central Asia: Does network quality affect trade?

by

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SUMMARY

Washington, October 2006

ABSTRACT

We examine the impact of road network quality on intra-regional trade in Europe and Central Asia. Computerized mapping techniques are used to compile a new database of minimum-distance routes connecting 138 cities in 27 countries. Inter-country road quality indices reflecting both average and minimum quality on each route are then calculated. Gravity model results show that upgrading roads to the current regional average could increase trade substantially: up to about 60% of baseline trade or up to approximately $65 billion. This total includes an estimate of the costs of upgrading road quality networks in the region. Moreover, results indicate modernizing road infrastructure in the region could produce greater benefits than comparable programs of tariff reduction or streamlining customs regulations. Infrastructure spillovers are found to be significant: 60% of the overall trade gains could be captured by upgrading road infrastructure in three countries—Albania, Hungary and Romania.

Keywords: International Trade; Europe and Central Asia; Road Transport; Trade Facilitation; Gravity Model.

* The authors are respectively Consultant and Lead Economist (DECRG). This work is part of a broader project on trade facilitation and development supported through a Trust Fund of the UK Department for International Development. Support from the World Bank's Research Support Budget is gratefully acknowledged. Sincere thanks to Piet Buys, Uwe Deichmann and David Wheeler (World Bank) for their advice and assistance with the data and analytical framework, and to Yu Cheng Kuo for helping with compiling the road distance database. We are also grateful to Andreas Kopp (OECD-ECMT), Henry Kerali, Bernard Hoekman, Beata Smarzynska Javorcik, David Cieslikowski, Tsukasa Hattori, Leonardo Iacovone and Souleymane Coulibaly (World Bank) for their comments and suggestions, as well as to seminar participants in Washington, DC. Ayako Suzuki and Witold Czubala provided very helpful and expert research assistance.

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1. INTRODUCTION

Provision of good-quality, well-maintained and efficient transport infrastructure is one important way in which governments can help firms engage more actively in international trade. Indeed, at a time when tariff barriers are in general at historically low levels in many countries, it is likely that transport and transaction costs often represent more serious impediments to exports than do traditional trade policy measures (see e.g., Hummels, 2001; Anderson & Van Wincoop, 2004). In Eastern Europe and Central Asia (ECA), this argument has particular importance given the trade dependence of many countries in the region. From Table 1, which shows the ratio of merchandise exports to GDP for the 27 regional economies analyzed in this paper, we can see that ECA countries are generally more trade-dependent than the world and income group averages. In most cases, they have become increasingly so over the last decade.

Notwithstanding this, the transport sector in a number of ECA countries remains subject to high costs. According to Molnar and Ojala (2003), for example, transport costs in Central Asia and the Caucasus are at least three times higher than those prevailing in developed countries. This is due, in part, to a combination of corruption, inefficient customs procedures and regulations, small and fragmented transport sectors, underdeveloped multi-modal interfaces and physical infrastructure impediments. Moreover, a high proportion of ECA countries (11 out of 27) suffer from being landlocked. This is known to imply particular difficulties in terms of integration into the trading system (Raballand, 2003; Cadot *et al.*, 2006). Most notably, the ability of landlocked countries to access world markets depends not only on the quality of their own infrastructure, but also on that of countries through which their goods must transit. This phenomenon is all the more serious when, as in Central Asia, political instability often leads exporters to favor overland routes into Europe to sea-based routes passing through the Persian Gulf (Cadot *et al.*, 2006).

Data from recent editions of the Doing Business Report (World Bank, 2006 & 2007) can be used to provide a simple but compelling overview of the difficulties ECA countries face when it comes to trade. These reports—which are based on surveys of the private sector—show that delays at export in the ECA region are more than twice as long as in the OECD. At import they are more than three times as long (see Table 2). Taking the US dollar price of exporting and importing a container of goods in 2006 as a baseline, the same source shows that the cost of trading in the ECA region is approximately double the average rate among OECD countries. In sum, the cost of exporting from ECA countries appears little different from that in Sub-Saharan Africa (SSA), while the cost of importing is similar to that in South Asia.

The contrast with traditional trade policy measures in the ECA region is striking. Protection is higher than the OECD average, but can nonetheless be characterized as generally moderate. Table 3 reproduces extracts from the Overall Trade Restrictiveness Index (OTRI) of Kee *et al.* (2006), which represents the uniform tariff required in each country to achieve an equivalent level of total imports as under current policy settings. When only tariffs are considered, the ECA countries' average OTRI comes out at approximately 7%, compared with 5.5% for the OECD. Even with the inclusion of non-tariff barriers, the comparison is 12% (ECA) versus 11% (OECD). Table 3 shows that although these averages conceal considerable cross-country heterogeneity, the overall picture that emerges is one of moderate trade protection in the region—in contrast to the very high trade and transport costs referred to above.

It is also important to examine the trade policy barriers faced by regional exporters in trading with the rest of the world. To do this, we use the Market Access OTRI (MAOTRI) of Kee *et al.* (2006), which represents the uniform tariff required in the rest of the world in order to achieve an equivalent level of total exports from a given country as under current policy settings. It is therefore an appropriate summary measure of the average degree of restrictiveness faced by exporters in any given country vis-à-vis the rest of the world. Table 4 shows that ECA countries do not in general face inordinately high barriers in the world market when compared with those faced by exporters in OECD countries. The average MA-OTRI for the ECA region is 9.4% (tariffs only) or 16.4% (tariffs and NTBs), which compares quite favorably with the corresponding rates of 7% and 13% for the OECD.

Summarizing the above, it is clear that ECA exporters face significant hurdles. However, a comparison with those faced by exporters in OECD countries is instructive. In terms of "traditional" trade policy (i.e., tariffs and the like), ECA countries do not fare too much worse than their OECD counterparts, regardless of whether the metric used is their own trade restrictiveness or that of their trading partners. On the other hand, transport costs are very high relative to the OECD, and the cost of moving goods across borders is correspondingly greater. The region therefore has considerable progress left to be made in terms of the broad trade facilitation agenda, which we take to include a wide range of policy measures designed to reduce trade costs. The breadth of this definition means that the range of policies to be considered under the heading of trade facilitation runs from streamlining of customs regulations procedures (i.e., the sense in which the term is used at the WTO) to improvement of the domestic regulatory environment, or upgrades of trade related infrastructure. Given that the ECA region is starting from a relatively low baseline in terms of tariffs but a relatively high one in terms of trade and transport costs, it seems plausible that the impact of policy interventions in the latter domain might be greater than in the former. In other words, there would seem to be real scope for the ECA region to reap significant gains from additional investments in infrastructure and trade facilitation.

As the above discussion makes clear, the question of policy reform in this area is a complex and multifaceted one. In order to make the best use both of available financial resources and political capital, it is important for policymakers to target reforms at points where the expected net payoff is high relative to other possibilities. To do that, they need assessments of the relative costs and benefits of different reform possibilities. Our paper seeks to inform that process in the ECA region by providing a quantitative assessment of the potential intra-regional trade gains from upgrading road transport infrastructure—a particularly important part of national trade infrastructure for many ECA countries, for the reasons set out above. We then compare the gains from a hypothetical infrastructure upgrade with the possible outcomes from alternative reforms, such as reducing tariffs or streamlining customs procedures.

A number of previous papers have investigated the trade impacts of infrastructure quality, including roads[1] Bougheas *et al.* (1999) construct a theoretical model of infrastructure and trade, then test it using a gravity model augmented to include data on the stock of public capital and the length of the road network in importing and exporting countries. Limao & Venables (2001) use data on road, rail and telephone network density to estimate the importance of infrastructure in explaining global transport costs. They also use a gravity model to investigate the direct trade impacts of infrastructure quality in exporting, importing and transit countries.

Cadot *et al.* (2006) adapt their approach to the Central Asian context and use alternative estimation methodologies for the gravity model. Nordas & Piermartini (2004), on the other hand, use the Limao & Venables (2001) approach with a broader range of infrastructure indicators, and attempt to identify the effects of individual components (road, rail, etc.). They focus on three broad product sectors, in order to examine possible heterogeneity that could be obscured by using total trade flows. They also account for the impact of tariffs. Whereas the preceding papers use simple averages in calculating an overall infrastructure index, Francois & Manchin (2006) use a principal components weighting scheme. They then estimate a gravity model that emphasizes threshold export propensity in addition to the intensity of observed flows, while also controlling for the effect of applied tariffs.

Two very recent papers consider the issue of road quality in isolation from other aspects of national infrastructure. The first of them, Coulibaly & Fontagne (2006), focuses on countries in West Africa. The authors find that a composite measure of road quality in the importing and exporting countries has a statistically significant (and negative) effect on trade, in the context of a gravity model. Transit effects are also found to be important, with the authors using a count of the number of borders crossed as a proxy. By contrast, Buys *et al.* (2006) examine road network quality across the whole of Sub-Saharan Africa (SSA). They use detailed road transport data to construct measures of international distance on an overland basis. They then build up a multi-dimensional measure of road quality, which is aggregated in such a way as to take proper account of transit effects. Results from their gravity model show that network quality has a significant impact on intra-regional trade, while simulations suggest that the net benefits of a road upgrade are very substantial.

In sum, there is considerable evidence to the effect that infrastructure matters for transport costs, and thus for trade flows. However, the relative trade benefits of upgrading infrastructure versus reducing tariffs or implementing trade facilitation measures, is less well understood[2]. Moreover, there is relatively little work focusing on road transport infrastructure in particular, notably outside the SSA region. In the ECA regional context, overland transport is particularly important in light of the significant number of landlocked countries in the region (11 out of the 27 included in our sample). This paper is intended to move forward in these directions, by focusing on road transport infrastructure in the ECA region and taking a comparative approach to the estimation of the benefits expected from an upgrade.

While our paper builds on the recent work by Buys *et al.* (2006), there are also some important differences. In particular:

- The focus of this paper is on an assessment of the relative benefits of different policy options, including a road network upgrade. We therefore include data on applied tariffs and trade facilitation in our model of intraregional trade, and conduct simulations of policy changes in each of the three areas;

- We pay particular attention to the identification of infrastructure bottlenecks, which in turn highlights important areas to target as part of a reform program;

- We establish the robustness of our results to different proxies for road network quality;

- Our model disaggregates trade data into broad product categories (BEC single digit);

- We rely on a theoretically-grounded version of the gravity model, due to Anderson & Van Wincoop (2003, 2004); and

- We ensure that our results are robust to the presence of zero trade flows by using Poisson and negative binomial quasi-maximum likelihood estimators.

Our paper proceeds as follows. We first use computer mapping software to construct a new database of road distances connecting 138 cities across 27 ECA countries. We aggregate inter-city distances to the country level, producing international distance measures that we show to be quite different from the standard measures used in applied international trade work (Section 2). We then construct two indices of road quality. The first proxies network quality by the percentage of national roads that are paved. The second includes in addition a measure of national capacity to maintain road infrastructure, as well as capability to limit unofficial payments. We then use national indices and the roads dataset to produce distance-weighted and minimum quality measures on a bilateral (country-pair) basis, taking account of actual overland transit routes (Section 3).

In Section 4, we use a gravity model of international trade to assess the impact of our new distance and quality measures on intra-regional trade, and to make comparisons with the impacts of traditional trade policy measures (tariffs) and inefficient customs clearance regulations (as measured by the number of documents required at export and import). After estimating a number of different specifications using various econometric methodologies, we conclude that an improvement in average or minimum road network quality is robustly associated with increased intra-regional trade. According to our preferred specification, the relevant elasticities are 0.8 (average quality) and 0.6 (minimum quality). Section 5 presents the results of simulation exercises in which we consider a hypothetical road network upgrade, and show that a large part of the gains can be appropriated to the region by focusing the intervention on a small number of countries. It is also demonstrated that the gross trade gains from comparable programs of tariff cuts and reductions in customs formalities are likely to be of lesser magnitude. Section 6 then provides a ballpark assessment of the likely costs involved in road network upgrading in the ECA region, using data compiled by the World Bank. We show that even once the direct costs are netted out, the benefits are still likely to be large compared with other scenarios. The paper concludes with some policy implications of our findings, as well as a number of suggestions for further research.

2. MAPPING ROAD NETWORKS IN EUROPE AND CENTRAL ASIA

The ECA road network is notable for its wide geographic extent. It extends from the Czech Republic in the West to Russia (Siberia) in the East, and from Turkmenistan in the South to the Baltic States and Russia in the North (see Table 1 for a full list of the countries included in our sample). Inter-city distances are often long. They span up to about 11 500 kilometers for the most distant city pair considered here (Tirana in Albania and Vladivostok in Russia). While the road network is extensive, it is also known to exhibit variable quality. This is particularly true in areas where the post-Communist transition has been long and difficult. The Communist legacy can also be seen particularly in Central Asia, where road links between those Republics and Moscow are often vastly superior to links among the Republics themselves (see Molnar and Ojala, 2003; ADB, 2006; and Cadot *et al.*, 2006 for further details).

Given these considerations, mapping the ECA network requires a considerable quantity of information which must then be summarized in ways useful in the context of modeling international trade flows within the region. As in Buys *et al.* (2006), we use a computerized map and spatial network analysis software to produce a minimum-distance network of roads in the ECA region. Our analysis covers 27 countries and connects 138 cities within those countries, i.e. all regional cities with a year 2000 population of over 300 000 people. This produces 9 453 inter-city routes along 2 411 individual arcs, represented graphically in Figure 1. For each route, we are able to identify the exact road distance travelled in each of the sample countries. For instance, the minimum distance route from Prague to Moscow includes 128.6 km of road travel in the Czech Republic, 723.6 km in Poland, 547.2 km in Belarus and finally 454.4 km in Russia. These transit distances will be of vital importance below, when we come to designing an appropriate weighting scheme for our road network quality indicators.

It can immediately be seen both from Figure 1 and Table 3, which provides a breakdown of the number of cities per country in our database, that a few countries play a very significant role in driving our picture of the ECA road network. Given the minimum population threshold we have chosen, Russia, Ukraine and Poland alone account for 65% of the cities in our database (45% just in Russia). The flipside of this observation is that the comprehensiveness of our measure of the road network varies considerably across countries. While this means that our database abstracts considerably from reality by excluding many smaller cities—and by implication, a considerable part of the overall road network—we are confident nonetheless that our measure captures that part of the network that is of greatest relevance for the analysis we are interested in, namely, the international trade dimension. Moreover, such abstraction is necessary even in alternative measurement schemes, such as using the great circle distance between largest or capital cities.

The gravity model that will be estimated in Section 4 uses trade data aggregated to the national level. Our road distance data will therefore need to be aggregated to the same level. To do that, we adopt the convention that the distance between two countries will be treated as the unweighted mean of the minimum road distances between all relevant cities in those two countries, as in Buys *et al.* (2006)[3].

It is useful at this point to consider the relationship between the distance measures constructed as set out above, and the great circle distances more commonly used in the international trade literature. As a point of comparison, we use the great circle distance measures from the dataset assembled by the CEPII research center in Paris (Mayer & Zignago, 2006)[4]. Over the full sample, our measure correlates very strongly with CEPII's (0.93). However, the scatter plot in Figure 2 shows that it is important to look beyond the full sample correlation. It is clear that great circle distances are systematically lower than the road distances calculated as set out above[5]. The difference in sometimes large: over 500% in one case. Moreover, as inter-country distance increases, the difference between the two measures appears to increase correspondingly. In other words, our results would appear to suggest that great circle distances tend to systematically underestimate inter-country distances, at least in a context where road transport is important. While great circle distance might be an acceptable proxy for relatively short inter-country distances, there are real risks of downwards bias when those distances are long[6].

3. NETWORK QUALITY

Since we are interested in examining the extent to which upgrades of existing infrastructure have the potential to increase bilateral trade, it is important to establish an appropriate measure of road network quality in each country. To do that, we adopt two approaches. The first one simply uses the percentage of paved roads in each country as a proxy for network quality in that country (cf. Coulibaly & Fontagne, 2006). The second one follows Buys *et al.* (2006) in constructing a road quality index that takes account of three different dimensions: (1) percentage of paved roads, (2) maintenance capacity, and (3) control of unofficial payments.

We define a country's road quality index score Qj as a function of the percentage of paved roads in that country (Pj), its per capita GDP (Gj) and the World Bank's Country Policy and Institutional Capacity Index (Cj):

$$Q_j = P_j^{\alpha_1} G_j^{\alpha_2} C_j^{\alpha_3}$$

As in Buys *et al.* (2006), we set the alpha coefficients such that the quality index displays slightly increasing returns. Specifically, we impose $\alpha 1=0.8$, $\alpha 2=0.2$ and $\alpha 3=0.2$. Table 7 shows the results of these calculations, along with the raw data used. Our final quality index is produced by re-scaling country scores in such a way that the leading country (Slovenia in this case) is placed at 100.

The above measure is intuitively appealing, in that it captures the multi-dimensional nature of an infrastructure upgrade. In the ECA case in particular, there is extensive qualitative evidence to suggest that maintenance capacity and corruption are serious issues (Molnar and Ojala, 2003; Cadot *et al.*, 2006). However, the regression results obtained using such an index are not simple to interpret. It can always be argued that the relevant coefficient is in fact capturing the independent effects of the variables used to construct the index, rather than a genuine composite effect of road network quality. Similar difficulties apply to the interpretation of simulation results, since it is problematic to identify a change in the Buys *et al.* (2006) index with use of a single policy instrument. It is for that reason that we use both the percentage of paved roads and the Buys *et al.* (2006) index in what follows, in the hope that consistent results obtained using the two approaches will help buttress our conclusions and simplify interpretation.

In constructing the road quality dataset, we have drawn on a number of different sources. This is because information on the percentage of paved roads sometimes varies considerably both in the cross-sectional and temporal dimensions, for reasons that are not substantive. For instance, redefinition of the national road footprint can significantly alter the apparent percentage of paved roads, even though the physical state of a country's road system is unchanged. Table 6 provides a summary of paved road data for 2003 from three common sources, along with our consolidation. We have been guided in that exercise by expert opinion from within the World Bank, and as a result we believe that our measures represent a reasonable approximation to the reality on the ground. In light of the possibility for spurious variation in the paved roads indicator through time, in addition to the difficulty of obtaining continuous series, we have opted to compile our dataset for a single year only, namely 2003.

As in Buys *et al.* (2006), we use our regional mapping to construct indicators of paved roads and road quality on a bilateral basis, taking full account of transit. We calculate weighted average measures based on paved roads and our quality index in the exporting and importing countries, as well as in all transit countries between the two. Weights are attributed according to the road distance travelled in each country along the route, as a proportion of the total distance. In addition, we calculate minimum measures using the same information but taking the minimum of paved roads and the quality index respectively over the exporting and importing countries, as well as in all transit countries between the two. While Buys *et al.* (2006) used only the minimum measure in their regressions, we will use both. This choice represents an effort to capture the basic role of network quality as a trade facilitation mechanism. It also takes into consideration the fact that in extreme cases network performance can be determined by the quality of the weakest link in the chain running from exporter to importer. We have chosen to let the data decide the issue of the extent to which variations along these two dimensions are associated with larger or smaller trade flows.

Calculation of the minimum measures provides a useful basis for outlining some simple descriptive results. Table 8 shows, for example, that across 702 country-pair routes, around 65% of minimum paved roads percentages are attributable to just three countries: Albania, Hungary and Romania. When the Buys *et al.* (2006) index is used, around 60% of minimum quality routes are found to be related to Georgia, Romania and Uzbekistan. Therefore, if it is shown below that bottleneck effects (as measured by either the minimum quality index or the minimum paved roads percentage) have a significant impact on trade, then it could be expected that infrastructure upgrades in a small group of countries would have important spill-over effects for a large number of intra-regional trade relations. This is an issue to which we return in more detail below.

4. MODEL DESCRIPTION, ESTIMATION AND RESULTS

Our goal is to produce a set of policy-relevant results indicating the potential benefits from upgrading road infrastructure in the ECA region. We also want to compare those benefits with the likely results of tariff reductions and improvements in trade facilitation. To do this, we will use a commonly accepted modelling framework that is well grounded in terms of micro-foundations, namely the gravity model formulation due to Anderson & Van Wincoop (2003, 2004). While the basic gravity intuition remains unchanged—i.e., trade flows should vary proportionally with trading partners' GDPs and inversely with distance between them—this recent work has nonetheless prompted changes to standard practice in regard to estimation (see Baldwin, 2006 for a review). These changes are necessary to reflect the fact that trade flows between two countries depend not only on prices (and trade barriers) in those countries, but also on prices (and trade barriers) in all other countries.

The basic form of our model comes directly from Anderson & Van Wincoop (2003, 2004) and can be expressed as follows:

$$(1)\ \log\left(X_{ij}^{k}\right)=\log\left(E_{j}^{k}\right)+\log\left(Y_{i}^{k}\right)-\log\left(Y^{k}\right)+(1-\sigma_{k})\log\left(t_{ij}^{k}\right)-(1-\sigma_{k})\log\left(P_{j}^{k}\right)-(1-\sigma_{k})\log\left(\Pi_{i}^{k}\right)+\varepsilon_{ij}^{k}$$

Where:

X_{ij}^{k} = Exports from country i to country j in sector k

Y_i^k = Output of country i in sector k

E_j^k = Expenditure of country j in sector k

Y^k = Aggregate (world) output in sector k

σ_k = Elasticity of substitution in sector k

t_{ij}^{k} = Trade costs facing exports from country i to country j in sector k

$$\left(P_j^k\right)^{1-\sigma_k} = \sum_{i=1}^{N} \Pi_i^{\sigma_k-1} \omega_i^k \left(t_{ij}^k\right)^{1-\sigma_k}$$

$$\left(\Pi_i^k\right)^{1-\sigma_k} = \sum_{j=1}^{N} P_j^{\sigma_k-1} \omega_j^k \left(t_{ij}^k\right)^{1-\sigma_k}$$

ω_i^k = Country i's output share in sector k

ω_j^k = Country j's expenditure share in sector k

ε_{ij}^{k} = Random error term, satisfying the usual assumptions

It is common in applied work to specify the trade cost function in the following way (dropping the sector superscripts for simplicity):

$$(2)\quad \begin{aligned} t_{ij}^{k} &= d_{ij}^{\rho}\tau_{ji}^{\theta}\prod_{m=1}^{M}\left(b_{m}^{z_{ij}^{k,m}}\right) \\ \Leftrightarrow \log\left(t_{ij}^{k}\right) &= \rho\log\left(d_{ij}\right)+\sum_{m=1}^{M}\log\left(b_{m}\right)z_{ij}^{k,m} \end{aligned}$$

Where:

ρ = elasticity of exports with respect to distance

d_{ij} = distance between countries i and j.

b_m = set of m constants

z_{ij} = set of observable bilateral determinants of trade costs

Combining (1) and (2) gives the baseline "theoretical" gravity model:

$$(3)\quad \begin{aligned} \log\left(X_{ij}^{k}\right) &= \log\left(E_{j}^{k}\right)+\log\left(Y_{i}^{k}\right)-\log\left(Y^{k}\right)+\left(1-\sigma_{k}\right)\left[\rho\log\left(d_{ij}\right)+\sum_{m=1}^{M}\log\left(b_{m}\right)z_{ij}^{k,m}\right]-\ldots \\ &\ldots-\left(1-\sigma_{k}\right)\log\left(P_{j}^{k}\right)-\left(1-\sigma_{k}\right)\log\left(\Pi_{i}^{k}\right)+\varepsilon_{ij}^{k} \end{aligned}$$

As is commonplace in the gravity literature, we use fixed effects to take account of the combined impact of output and expenditure in both countries across the various sectors under consideration. This gives a final estimating equation of much simpler form, in which we specify reduced-form coefficients and substitute the trade cost observables we intend to use in this case[7]:

$$(4)\quad \begin{aligned} \log\left(X_{ij}^{k}\right) &= c+\delta_{i}+\delta_{j}+\delta_{k}+\beta_{1}\log\left(dist_{ij}\right)+\beta_{2}\log\left(paved\_ave\right)+\beta_{3}\log\left(paved\_\min\right)+\ldots \\ &\ldots+\beta_{4}\log\left(1+tariff\right)+\beta_{5}\log\left(docs\right)+\beta_{6}border+\beta_{7}colony+\beta_{8}language+\varepsilon_{ij}^{k} \end{aligned}$$

Our data and sources are set out in detail in Table 10. For bilateral trade, we use the value of 2003 imports by BEC sector, taken from the WITS database[8]. Whenever import data are missing, we use export (mirror) data. Trade cost dummies based on geographical and historical factors (contiguity, colonization and common language) are drawn from the CEPII distance database (Mayer and Zignago, 2006). Distance is measured using average intercity road distances obtained by computer mapping, as set out above. Paved_ave and Paved_min refer to our average and minimum paved road percentages respectively (see above). They will be used interchangeably with q_ave and q_min, which refer to our average and minimum network quality indices, calculated in the way set out above, following Buys *et al.* (2006). Our tariff variable is drawn from effective applied tariffs as recorded in the WITS-TRAINS database. As a robustness check, we use both simple (tariff) and trade-weighted (tariffw) averages. For an indicator of trade facilitation, we use data from the 2006 Doing Business Report (World Bank, 2006) on the number of documents required to export and import (docs)[9]. We prefer that measure to the more commonly used indicator of time to export and import (Djankov *et al.*, 2006; Nordas *et al.*, 2006) because it does not suffer from endogeneity to trade flows in the same way. It also represents a very intuitive measure of the impact of trade facilitation in the sense of streamlining customs procedures and formalities.

4.1. Standard OLS results

As a starting point, we perform OLS regressions of (4), using a variety of different specifications[10]. For the moment, missing and zero trade flows are simply dropped from the sample; this is an issue to which we will return below. Results are reported in Tables 11 (percentage paved roads) and 12 (Buys *et al.*, 2006 quality index). All estimated coefficients carry the signs expected from theory, and have economically reasonable magnitudes in light of previous work in this area. In particular, the tariff and trade facilitation variables are uniformly negative. Even though only the former is statistically significant, the magnitude of the latter is still highly significant in economic terms. We also note that the distance coefficient is considerably larger in absolute value than the central tendency of the literature, which is around -0.9 (see the meta-analysis of Disdier & Head, 2005, which covers 1 467 estimates from 103 published papers). This is perhaps an indication that measuring distances using detailed overland transport data can make a difference to the perceived impact of distance on trade flows.

In Table 11, the percentage of paved roads variables have a uniformly positive impact on intraregional trade flows. While the magnitudes of both the minimum and weighted average measures are relatively stable across specifications, only the minimum indicator is statistically significant (at the 5% or 1% level depending on the specification). By contrast, the Buys *et al.* (2006) quality index used for the regressions in Table 12 is not statistically significant in either minimum or weighted average form. Nonetheless, the magnitudes involved could be argued to be economically significant, equating to elasticities of 0.5 to 1 in the case of average quality, and 0.08 to 0.22 for minimum quality.

On the whole, we take the results in Tables 11-12 as providing some preliminary evidence in favor of the proposition that road quality (in addition to tariffs and trade facilitation) has a significant impact on trade flows. However, in common with many gravity estimates, the models presented in Tables 11 and 12 have simply dropped zero trade flows or missing values from the dataset. In this case, our dataset contains approximately 1 500 zeros or missing flows—around one-third of the potential data, in other words[11]. Dropping such a large amount of information from the estimation sample clearly has the potential to influence results, and it would be desirable to perform some robustness checks in this regard.

4.2. Poisson PML results

Our preferred approach to the "zero trade" problem draws on recent work by Santos Silva & Tenreyro (forthcoming)[12]. First, note that prior to taking logarithms of both sides, (4) can be expressed in the following non-linear form:

$$(5) \qquad trade0_{ij}^{k} = \exp\left(x_{ij}^{k}\beta\right) + \omega_{ij}^{k}$$

We use the notation *trade*0 to indicate that the trade flow variable in (5) includes both non-zero and zero flows. By $x_{ij}^{k}\beta$, we mean the set of explanatory variables in (4) and their coefficients, appropriately rearranged. The error term is indicated as ω_{ij}^{k} in order to distinguish it from the additive error term in the log-linearized model, ε_{ij}^{k}. Santos Silva & Tenreyro (forthcoming) show that only under very restrictive assumptions on the error term ω_{ij}^{k} will OLS estimation of a log-linearized version of (5) give consistent parameter estimates. However, non-linear estimation of (5) is numerically equivalent to pseudo-maximum likelihood (PML) estimation of the Poisson model for count data (e.g. Davison & MacKinnon, 2004, p. 476), under the assumption that the conditional mean is proportional to the conditional variance (i.e. $E[trade0_{ij}^{k}|x_{ij}^{k}] = V[\widehat{trade0}_{ij}^{k}|x_{ij}^{k}]$).

Santos Silva & Tenreryo (forthcoming) therefore argue that use of such an estimator with trade data in levels (including zeros) should produce superior estimates to those obtained with OLS under log-linearization. Their Monte Carlo simulation evidence supports that proposition under a variety of empirically relevant parameterizations.

We therefore re-estimate equation (4) replacing log(*trade*) with *trade*0 as the dependent variable. All independent variables remain the same (i.e. in logarithms). Table 13 reports results using the percentage of paved roads as a proxy for network quality, while Table 14 uses the Buys *et al.* (2006) quality index. In both cases, we find a number of significant differences in the parameter estimates compared with OLS (as was the case in Santos Silva & Tenreyro, forthcoming). In particular, the distance coefficient—while still negative and statistically significant at the 1% level—is considerably smaller in absolute value under Poisson PML estimation than under OLS. On the other hand, the applied tariffs variable is considerably larger in absolute value in the former case than in the latter. With the exception of colonization (which is not statistically significant), the set of geographical controls enter the regression with similar coefficients to the OLS case. More surprising is the coefficient on our trade facilitation variable, which now carries an unexpected positive sign (but is still statistically insignificant).

In both tables, our proxies for average road network quality are consistently significant at conventional levels, and have considerably larger magnitudes than with OLS estimation. However, our minimum road quality proxies are now generally insignificant at the 10% level. When the percentage of paved roads is used, the Poisson PML coefficient tends to be smaller than its OLS counterpart, whereas the reverse is true for the Buys *et al.* (2006) quality index. Given that these two measures can be viewed as alternative ways of attempting to measure the same underlying quantity, it is difficult to be entirely comfortable with such a qualitative difference in terms of the estimation results. Combined with the unexpected positive coefficient on the number of documents at export and import, these results suggest that it may be important to reconsider our specification.

4.3. Negative binomial PML results

One common problem with Poisson models is that real-world data often tend to be over-dispersed (i.e. have variance greater than their mean). In such circumstances, the Poisson PML estimator will often still be consistent, but may suffer from bias (e.g. Cameron & Trivedi, 2001). One way of dealing with this problem is to use the alternative negative binomial PML estimator[13]. Poisson is a special case of the negative binomial, with over-dispersion parameter equal to zero. By testing the significance of that parameter—which is estimated by the negative binomial PML model—it is possible to have an idea of the extent to which Poisson results might be impacted by over-dispersion.

We therefore re-estimate the gravity model using the negative binomial PML estimator. Results are presented in Tables 15-16. A likelihood ratio test of the hypothesis that the data are not over-dispersed (based on Table 15, column 1) is strongly rejected (prob=0.00). This suggests that there may be good reasons for preferring the negative binomial estimates to Poisson in this case.

On a substantive level, results in Tables 15-16 are more internally consistent, and accord more closely with our priors, than do the Poisson PML estimates in Tables 13-14. In particular, the coefficient on documents at export and import is now negative and statistically significant, in line with results from previous work (Djankov *et al.*, 2006; Nordas *et al.*, 2006). Of the geographical controls, contiguity is still insignificant though much smaller in magnitude than under OLS, while colonization carries an unexpected negative sign (but is statistically insignificant). Our common language dummy remains statistically significant, and of comparable magnitude to the OLS case.

The parameters of primary interest, namely, those relating to trade policy and road network quality, paint a relatively clear and consistent picture across Tables 15 and 16. In all cases, tariffs are negative and statistically significant. Customs related regulatory procedures are also negative in all cases, but are only statistically significant under certain specifications using the percentage of paved roads rather than the Buys *et al.* (2006) quality index. Both average and minimum network quality variables are positive in all cases. However, only the percentage of paved roads variables are statistically significant in all cases. For the Buys *et al.* (2006) index, only the weighted average is statistically significant.

4.4. Summary

In this section, we have presented estimates of 12 different models, containing various combinations of the variables of interest, in order to gauge the effect of the exclusion of certain variables (and, by implication, expansion of the effective sample) on our core parameter estimates. We have also applied three different estimation methodologies, in particular to deal with the problems of zero bilateral trade flows and over-dispersion in trade data[14].

Using the percentage of paved roads as a proxy for network quality, we find parameter estimates in the range 0.18 to 1.84 for the weighted average, and 0.2 to 0.89 for the minimum. In the former case, 10 out of 15 estimates are significant at the 10% level, while in the latter it is 13 out of 15. If the Buys *et al.* (2006) multidimensional network quality indicator is used in place of the paved roads variables, we find parameter estimates ranging from 0.53 to 2.74 (average) and 0.04 to 0.77 (minimum), with 11 and 2 out of 15 respectively being statistically significant at the 10% level.

We interpret the general thrust of these results as providing strong evidence for two propositions. Firstly, that the average quality of the road network between the importer and the exporter is positively related to trade flows between those countries. And secondly, the minimum quality of the road network between the importer and the exporter is also positively related to trade flows between those countries. Both propositions hold regardless of whether network quality is measured using the percentage of paved roads, or the composite quality index due to Buys *et al.* (2006), although they are noticeably stronger in the former case. Moreover, our results are robust to changes in effective sample and estimation methodology, and take account of the independent trade impacts of geographical features, trade policy and customs procedures.

While these propositions represent interesting results in as far as they go, they need to be backed up by relevant policy simulations using the models we have estimated. This will give an idea of the relative dollar amounts that could be associated with policy actions in the area of road network quality, trade policy and trade facilitation. It is to that task that the next Section turns.

5. POLICY SIMULATIONS

In this Section, we use counterfactuals to present indications of the trade benefits that could result from upgrading road infrastructure in the ECA region. We then compare them with the benefits from alternative policy reforms in the areas of tariffs and import/export procedures. It is important to highlight that while similar approaches have been taken in the previous literature (e.g., Wilson *et al.*, 2005), the issue of producing such indications from a reduced-form econometric model is not without its difficulties. In particular, policy simulations are required to assume that all estimated parameters remain constant following the policy change (Lucas, 1976)[15]. Moreover, our simulations will be undertaken on the basis that all other factors except the one under simulation remain constant. Finally, our econometric model is effectively a reduced form version of a considerably more complex structural system and as such does not incorporate all of the restrictions that flow from that structure. As a result, the simulation results that we produce should be taken as indicative of the orders of magnitude involved only. Given the scope of this work, our simulation results do not measure economic welfare, but focus exclusively on projected trade impacts. Nonetheless, comparison of results across simulations is likely to prove a useful tool in assessing different policy options, in particular for rank-ordering interventions according to a given criterion.

Before embarking on the simulation exercise, it is necessary to make some choices in terms of the parameter set that will be used. Given the importance of being able to compare the impacts of different policy options, we limit consideration to those models including variables on tariffs, customs procedures and road network quality. Since the main thrust of our estimation results suggests that both minimum and average quality effects are important, we also exclude from consideration those specifications that contain one or the other, but not both simultaneously. While coefficients differ little according to whether simple or average weighted tariffs are used, we tend to prefer the former specification since the weighting scheme at least has the benefit of exogeneity.

Taking all such considerations into account leaves us with Models 1 and 7, estimated using OLS, Poisson PML and negative binomial PML. In terms of estimation methodology, we prefer negative binomial PML for the reasons set out in the previous Section. We have therefore decided to present simulation results using parameters from Table 15 column 1 and Table 16 column 1. The difference between the two relates only to the choice of road quality indicator: percentage of paved roads in the first case, and the Buys *et al.* (2006) index in the second. If it is necessary to choose between these two formulations, we would opt for the former. This is because it represents a single policy variable, for which a counterfactual can be given a precise interpretation. The Buys *et al.* (2006) index renders that task more difficult, since the policy simulation really includes not only a road upgrade, but also an increase in national per capita income and an improvement in governance. Nonetheless, we will present both sets of results for the sake of completeness.

As noted above, when describing the quality component of our dataset, it appears that a small handful of countries are associated with a large proportion of minimum quality scores on the ECA road network as mapped here (see Tables 8-9). Combining that result with our regressions showing the importance of minimum road network quality in determining trade flows suggests that it may be possible to capture part of the gains from a region-wide upgrade by focusing on infrastructure quality in just a small selection of countries. Indeed, given that road upgrades are a costly exercise—an issue to which we return below—it may be of considerable interest to policymakers to have an indication of the extent to which investing in roads in a small number of critical countries has the capacity to be bring important trade benefits for the region as a whole. We therefore identify two initial policy simulations that are of particular interest against this background:

I. Road networks in all ECA countries are upgraded to the sample mean or median, namely 74.52% or 85% of paved roads, or quality index scores of 58.45 or 52.39 respectively[16]; and

II. Road networks in the critical countries identified in Tables 8-9 only are upgraded to the same levels as in I[17].

The motivation for these simulations is that raising each country's level of road network quality to the currently prevailing mean (or median) in the region represents an ambitious but feasible scenario. Concretely, this means that under Simulation I, 13 ECA countries receive an upgrade, while under Simulation II it is limited to only three. By focusing on such benchmarks, we can also set up comparable reform scenarios for the other policy actions under consideration. Alternative benchmarks, such as an increase or decrease of x% in each indicator, results in simulations that are, in our view, less easily comparable than the ones under consideration here. In taking such an approach, we are following previous practice in the trade facilitation literature (e.g., Wilson *et al.*, 2005).

Concretely, the simulations are conducted as follows. Firstly, the policy shock is set up by recalculating both weighted average and minimum quality measures for all inter-country routes, in exactly the same way as described above. The only difference is that country scores below the thresholds listed above are increased to the relevant threshold level before recalculation. Next, percentage changes in average and minimum quality are calculated. These are then translated into percentage changes in bilateral trade values using our trade data and the estimated elasticities from our preferred regression models in Tables 15-16 column 1. In the case of the paved roads variables, the elasticities are 0.79 (average) and 0.60 (minimum), while for the composite quality index they are 1.29 and 0.08 respectively. Finally, estimated bilateral trade impacts are summed to give the estimated overall increase in intra-regional trade.

Results from the two simulations are presented in Tables 18 and 19. The first result that emerges from both Tables is that the potential trade gains from an ambitious but feasible program of road upgrades are large in absolute terms. These are highly variable, however, according to whether the paved roads data or the Buys *et al.* (2006) index is used. As discussed above, we believe the use of the paved roads data in the context of these simulations is preferable. Based on those data, it is reasonable to consider positive impacts of the order of 50%-60% of baseline trade, or between US$55 and $75 billion based on total intra-regional trade in 2003. While this is a large number, it aligns very well with the 60% figure obtained using different means by Cadot *et al.* (2006) for transit infrastructure in Central Asia. In any case, it should be noted that our figures are based exclusively on the projected increase in intra-regional trade. The estimation does not consider the flow-on effects to extra-regional trade. In sum, there are good reasons for considering them as a lower bound on expected total trade benefits from a road network upgrade.

A comparison of results from Simulations I and II also makes clear the crucial role played by just three countries in driving the above estimates. Focusing a road upgrading program of similar ambition on Albania, Hungary and Romania could bring intraregional trade benefits equal to over 50% of those projected from the full-blown, region-wide program in Simulation I. Given the significant cost reduction likely to result from focusing infrastructure investments on three countries rather than 13—a point to which we return below—the expected return on investment from such a focused program is likely to be impressive from a regional point of view.

In order to provide some context for the above results, we also conduct simulations designed to assess the projected trade impacts of policy changes affecting applied tariffs and documents required at export and import (trade facilitation):

III. Applied tariffs in all ECA countries are cut such that no tariff above 8% (approximate regional mean) or 6.5% (approximate regional median) *ad valorem* is applied; and

IV. The number of documents required to export is reduced in all countries to no more than 8 (mean) or 7 (median), and the number of documents to import is reduced to no more than 12 (mean) or 11 (median).

Results for both simulations are again reported in Tables 18-19. Focusing on the results obtained using paved roads data, it is striking that the increases in intra-regional trade associated with region-wide improvements in both traditional and "new" trade policies are considerably lower than for a road upgrade program conducted on a comparable scale. Trade flow changes from the tariff scenario are in the region of 6% to 8%—nearly an order of magnitude smaller, in other words, than the trade increases that flow from an infrastructure upgrade. The impact of trade facilitation measures is, however, considerably stronger than for a tariff reduction, of the order of 20%-30% of baseline trade. It therefore compares favorably with the gains to be expected from a three country road upgrade, but is still dwarfed by the gains from a region-wide upgrade.

Although the foregoing has focused on results obtained using paved roads data, rather than the Buys *et al.* (2006) index, it is also possible to draw some useful conclusions from simulations conducted using the latter measure. Although the results of a road upgrade are considerably less impressive—6% to 8% of baseline trade—they are nonetheless significant in dollar terms, and in the mean-based scenarios exceed the expected gains from tariff cuts. Once again, however, the expected gains from trade facilitation measures are quantitatively large—15% to 30% of baseline trade. In other words, both sets of results support the view that tariff reductions are by no means the only effective way of lowering trade costs and encouraging regional economic integration. Both infrastructure development and customs streamlining have important roles to play—and combined, their impacts are likely to exceed those stemming from tariff reforms.

Tables 18-19 also bring into focus the importance of minimum quality, or bottleneck, effects in driving the region-wide gains from a road upgrade. The main reason for the substantial difference in the projected impact of the road upgrade from one Table to the other is the strong difference in the coefficient on minimum quality in the two cases: it is much stronger when paved roads data are used. In sum, the spillover benefits of a road upgrade in one country are magnified the greater is the importance of minimum road quality across transit countries in determining bilateral trade flows.

5.1. The cost dimension

The policy simulations we have just discussed focus exclusively on the intraregional trade benefits that could be expected from the different policy options under consideration. However, in order to make a balanced assessment of those options, it is necessary to have information on both benefits and costs.

This is all the more true when one of the options—an infrastructure upgrade—has much higher direct costs than do the others[18].

Our purpose here is not to provide a detailed cost breakdown of the type that would be required before undertaking a particular road upgrade project. Our analysis has taken place at a considerably higher level of generality, and in particular has not delved into the state of individual road arcs. For that reason, our assessment of the costs will focus on producing a ballpark figure only, in the interests of establishing an order of magnitude such that the benefits and costs can then be sensibly compared[19].

The World Bank's ROad Costs Knowledge System (ROCKS) provides the starting point for our analysis[20]. ROCKS is a standardized database of costs associated with various types of road works. It classifies individual projects by country and type of work, and allows the user to obtain cost per km information in a common (real) currency. Most database entries also include extensive additional information as to the tasks performed, as well as geographical conditions that can be expected to affect costs.

Since we do not have information on the exact work that would need to be performed on each road arc in order to bring it up to the level of quality assumed in our counterfactuals, we simply assume that all arcs in countries undergoing an upgrade would require development or reconstruction work in terms of the ROCKS classification. This classification includes partial and full widening and/or reconstruction work, along with improvements to the road surface. In other words, the types of work that we are considering could reasonably be expected to lie towards the high end of the full range of unit costs in ROCKS, excluding those relating to entirely new construction projects.

Table 20 provides US$ per km cost data from ROCKS based on the types of work we have identified. We only take account of actual, incurred costs (not estimates), and focus on those from Eastern Europe and the Former USSR; the Western Europe and World cost columns are provided for reference only[21]. Based on this data, the range of expected unit costs for the countries under consideration here runs from around $36,000 per km to $666,000 per km, with an average of approximately $269,000 per km. We use these baselines to provide low, average and high cost estimates for the road upgrades implied by our Simulations I and II. (In the latter case, results are based on the critical countries identified using the minimum percentage paved roads criterion, and not the minimum Buys *et al.*, 2006 index.) We take the length of road to be upgraded in each country as the total length of arcs passing through that country as per our computerized map described above. In other words, we do not calculate the cost of upgrading the entire road network in each country, but only those parts of it connecting cities with year 2000 population above 300,000 people.

Results are presented in Table 21. Since our range of unit costs covers a wide variety of work types, the total cost estimates cover a correspondingly broad range. Focusing on mean unit costs for the region, we can see that a full upgrade (i.e., 13 countries) would involve a total cost of the order of US$8 billion. By contrast, focusing on three countries only would reduce that cost very considerably, to just over US$3 billion. Comparing these numbers with Table 18 shows that even once the costs of an upgrade are netted out, the trade benefits to the region from a road upgrade are very substantial: of the order of $45-$65 billion for a region wide program, and $30-$35 billion for a three country program, without allowing for any amortization of the cost of the upgraded road network over its expected lifespan.

6. CONCLUSIONS AND DIRECTIONS FOR FURTHER RESEARCH

This paper has extended and built upon recent work by Buys *et al.* (2006) on road transport infrastructure and trade, by adapting it to the context of the ECA region. It has been shown that an ambitious but feasible road upgrade program in ECA has great potential to boost intra-regional trade—by as much as 50% to 60%. Moreover, it is possible for the region to reap a large proportion of the overall gains by focusing attention on just three countries which both reflect important transit corridors and significant limitations in terms of infrastructure quality: Albania, Hungary and Romania. Such a concentrated program of road upgrading would come at significantly reduced cost (perhaps 40%) compared with attaining the same level of road quality on a region-wide basis, yet would bring around 50% of the total expected trade benefits.

The results presented here suggest a number of considerations for decision-making in this area. Firstly, road quality and infrastructure clearly matter for trade in the ECA region. In quantitative terms, our simulation results suggest that a feasible but ambitious scenario of road upgrading is likely to bring great intra-regional trade benefits than comparable actions affecting either tariffs or customs procedures. In any case, and regardless of which parameter estimates we use, the combined impact of upgrading road network quality and improving trade facilitation appear likely to produce gains well in excess of those that could be expected from comparable tariff reductions. Such a result aligns generally well with the recent literature on trade facilitation using CGE models. These suggest that the expected gains from such measures may indeed be of greater quantitative significance than those from liberalization of "traditional" trade policy measures (see e.g. Hertel & Keeney, 2005; Kinneman & Lodefalk, 2006). It is also consistent with other recent work that has shown the importance of transit country conditions, in particular in the Central Asia region (Cadot *et al.*, 2006).

A second important policy implication that emerges from our findings is that when transiting is taken into account, a large part of the trade benefits from infrastructure upgrading is driven by a small number of countries in the ECA region. This highlights the fact that infrastructure projects can have important intra-regional spillover effects. These factors should be taken into account when assessing costs and benefits of various options for trade facilitation and development assistance strategies. Where such spillover effects of road infrastructure upgrading are present, there may be a strong argument for regional coordination and shared funding responsibilities (see Schiff & Winters, 2002 for a review of the issues involved). In the present case, that suggestion takes on particular importance in light of the fact that Hungary is now a member of the EU, while Romania is soon to be such. It could be argued that allocation of EU funding should take into account the potential trade impacts not only on a national level, or even in terms of national-EU interactions, but also through the links that these countries have more broadly in the ECA region.

A final policy message that could usefully be highlighted given our results is that the trade benefits that flow from infrastructure upgrades can be obtained by countries acting unilaterally, or through regional instances. As is the case for many policy measures that come under the broad heading of trade facilitation, it is not necessary to wait for multilateral or regional agreement before taking action to bring about greater integration into the trading system. Indeed, national and regional trade facilitation programs sponsored by the World Bank, regional development banks, bilateral donors, and public-private partnerships, for example, could be seen as important ways in which countries and regions can position themselves so as to reap maximum benefit from future rounds of multilateral liberalization.

While our results are highly suggestive in policy terms, there nonetheless remain a number of important research questions to be considered in future work. The trade facilitation literature has shown that according to country circumstances, the various modes of transport—road, rail, sea and air—can all be important determinants of trade performance (e.g., Wilson *et al.*, 2005). Future research could usefully focus on the relative benefits and costs of upgrading infrastructure quality for each mode. As there is likely to be considerable variance in results across countries, regions and even sectors, it will be necessary to take a detailed approach to these questions, including through an attempt to account for the interactions amongst the different modes.

The present paper has focused exclusively on intra-regional trade. It will be important in future work to consider in addition the impacts of infrastructure upgrades on extra-regional trade. To do this, it will be necessary to compile a detailed dataset that interfaces road and international air or sea routes, taking account of the location of principal sea and air ports. By helping move towards a more complete picture of the benefits of infrastructure upgrades, such an exercise would provide important additional information for policymakers.

Finally, the cost and benefit estimates that we have provided in this paper should not be regarded as the last word in terms of policy assessment. The available data does not allow us to pay detailed attention to the state of maintaining particular road links. We have had to rely on national aggregates in assessing the extent to which network quality matters for trade. The flipside of this is that our cost estimate does not take account of the actual work that would need to be performed as part of a concrete upgrade program, as opposed to the hypothetical version considered here. This means that there is still considerable need for case specific cost-benefit analyses to be undertaken in this area. They should be a vital input into the decision-making process.

NOTES

1. Fink *et al.* (2002a, 2002b), Clark *et al.* (2004) and Wilson *et al.* (2005) analyze the related issues of port efficiency, telecommunications costs and trade facilitation. Djankov *et al.* (2006) and Nordas *et al.* (2006) examine the impact of time as a trade barrier. In each case, the relevant dimension is found to have empirically significant trade impacts.

2. Although Nordas & Piermartini (2004) include applied tariffs in their gravity model, they do not specifically address the relative impacts of policy reforms. Francois & Manchin (2006) produce suggestive results in this area, based on their observation that variations in infrastructure quality account for a larger percentage of the variation in trade flows than do changes in foreign trade barriers. However, they do not undertake policy simulations of the kind we envisage here. The firm level data analyzed by Clarke (2005) produce results that go in the same direction.

3. In preliminary work (not reported), we experimented with two other methodologies. Neither weighting by city population, nor using the median rather than the mean, was found to significantly alter the distance measure (i.e., the correlation was in excess of 0.9, with no outliers).

4. We have obtained identical results using CEPII's alternative distance measures, including one that is weighted by population.

5. A simple OLS regression with great circle distance as the dependent variable, and road distance as the independent variable (with a constant) confirms this observation: while the constant is positive and significant at 1%, the coefficient on road distance is 0.66 (and also significant at 1%). A Wald test strongly rejects (1%) the joint hypothesis that the constant is zero and the coefficient on road distance is unity.

6. Once again, we need to highlight the importance that Russia plays in this result: it accounts for 11 out of 33 cases in which the difference between our distance measure and CEPII's is greater than 100%.

7. In fact, equation (4) contains a simplification. To be strictly consistent with the theory as set out above, it would be necessary to specify fixed effects by sector, importer-sector and exporter-sector, and to allow all of the trade cost coefficients to vary by sector (to take account of changes in the elasticity of substitution). Our simplification is intended to reduce the number of parameters, and to avoid the co-linearity problems that generally result when such a large number of parameters is included in a relatively small dataset.

8. It would be preferable from a theoretical point of view to use the value of exports on a fob basis, rather than the value of imports on a CIF basis. However, import data are generally believed to be more accurate than export data, and are therefore preferred here. This is a common expedient in the empirical literature, though it is not without its critics (e.g., Baldwin, 2006).

9. Due to lack of data availability, we use customs formalities in 2005 as a proxy for 2003. Similarly, when TRAINS data is missing for a given year, we take the most recent available data prior to 2003.

10. All estimations were performed in Stata 9.1SE using heteroskedasticity-robust standard errors with clustering by country pair. The tables of regression results report standard errors in italics underneath the corresponding parameter estimates. Statistical significance is indicated as follows: * (10%), ** (5%) and *** (1%). Estimated fixed effects are suppressed for the sake of brevity.

11. An additional problem in this case is missing data for the tariff and trade facilitation variables. These also reduce our sample size quite considerably, as can be seen by comparing the number of observations across models in Table 11 or 12. We attempt to deal with that issue by estimating a variety of specifications, some of which drop the offending variables and thereby enlarge the effective sample. While omitted variable bias is likely as a result of such an approach, the output in the various Tables suggests that it is not too serious in this case.

12. An alternative is to treat the "zero trade" problem as one of sample selection. This leads naturally to application of a Heckit-type estimator (e.g., Francois & Manchin, 2006). However, reliance only on the non-linearity of the inverse Mills ratio for identification in effect makes a strong distributional assumption that may often be rejected in practice (Davidson & MacKinnon, 2004, pp.488-489). At the same time, over-identification via variable exclusion has tended to rely on unconvincing assumptions in this area (e.g., that common religion impacts fixed but not variable trade costs, as in Helpman *et al.*, 2006). We therefore prefer the approach suggested by Santos Silva & Tenreyro (forthcoming), which does not suffer from such drawbacks.

13. Cravino *et al.* (2006) adopt a similar approach in the related area of foreign investment. In their Monte Carlo simulations, Santos Silva & Tenreyro (forthcoming) use models from the Gamma PML class, which are closely related to the negative binomial (Cameron & Trivedi, 2001).

14. As a final robustness check (not discussed in detail), Table 17 presents results for a model which includes a dummy variable to take account of EU accession. This was done in the interests of better controlling for unobserved heterogeneity on a country-pair basis. Given that our dataset is limited to a single year, it is not possible for us to control for all such factors. Nonetheless, the fact that our estimates change relatively little once an EU dummy is introduced provides some comfort with respect to the core estimates presented above.

15. Whether or not parameter changes following a policy shock are economically significant in particular circumstances is a point that we do not pursue here. We note, however, that the macro-econometrics literature is far from conclusive on this point (e.g., Estrella & Fuhrer, 2003).

16. For reference, these levels equate to (approximately) Poland and Croatia respectively in the case of paved roads, and Belarus and the Kyrgyz Republic in the case of the composite index.

17. For paved roads, the countries are Albania, Hungary and Romania. For the quality index, they are Georgia, Romania and Uzbekistan.

18. Both tariff reductions and trade facilitation also involve costs. In a direct sense, they are likely to be quite limited. Indirectly, or in a political economy sense, they may well be substantial from the point of view of individual actors. The political economy of reform affecting infrastructure, tariffs and procedural barriers is an area that would benefit from increased attention in the future, although it is outside the scope of this paper.

19. For an example of how this issue can be dealt with in a more detailed way, see Buys *et al.* (2006).

20. ROCKS can be obtained from: http://www.worldbank.org/transport/roads/rd_tools/rocks_main.htm.

21. We have also eliminated two outlying observations, with unit costs around double the next highest data point.

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TABLES AND FIGURES

Table 1. Merchandise exports as a percentage of gdp, 1995-2004 (Source: World Development Indicators.)

Country *or Region*	1995	2000	2004
Albania	41.37	36.60	37.73
Armenia	64.36	61.52	65.71
Azerbaijan	47.17	55.32	83.67
Belarus	74.20	125.40	131.50
Bosnia and Herzegovina	66.11	92.24	90.19
Bulgaria	84.04	89.74	100.88
Croatia	64.55	66.85	71.71
Czech Republic	84.00	109.81	129.11
Estonia	101.28	162.29	130.56
Georgia	20.05	32.09	47.98
Hungary	63.44	128.47	113.41
Kazakhstan	44.45	75.73	80.69
Kyrgyz Republic	56.05	77.32	75.28
Latvia	59.59	65.35	80.73
Lithuania	84.66	81.42	96.81
Macedonia, FYR	65.69	94.90	84.70
Moldova	90.42	96.94	106.36
Poland	38.21	48.39	67.70
Romania	51.27	63.21	76.74
Russian Federation	35.91	57.84	48.11
Serbia and Montenegro	7.82	63.17	65.56
Slovak Republic	89.42	122.22	138.75
Slovenia	88.93	98.85	102.63
Tajikistan	126.67	148.98	110.46
Turkmenistan	132.47	150.45	116.59
Ukraine	59.34	91.26	95.13
Uzbekistan	46.29	40.07	64.15
World	*35.30*	*41.32*	*44.87*
Low income	*31.84*	*33.30*	*37.79*
Lower middle income	*36.84*	*44.96*	*57.51*
Upper middle income	*47.86*	*58.85*	*67.04*
High income	*34.25*	*39.64*	*41.51*

Table 2: Delays at export and import (days) and cost to export and import (USD). (Source: World Bank, 2005 & 2006.)

	2005		2006			
Country *or Region*	**Export Time**	**Import Time**	**Export Time**	**Import Time**	**Export Cost**	**Import Cost**
Albania	37	38	34	34	818	820
Armenia	34	37	34	37	1,600	1,750
Azerbaijan	69	79	69	79	2,275	2,575
Bulgaria	26	24	26	25	1,233	1,201
Bosnia and Herzegovina	32	43	22	25	1,150	1,150
Belarus	33	37	33	36	1,472	1,472
Czech Republic	20	22	20	22	713	833
Estonia	12	14	3	5	640	640
Georgia	54	52	13	15	1,370	1,370
Croatia	35	37	26	18	1,250	1,250
Hungary	23	24	23	24	922	1,137
Kazakhstan	93	87	93	87	2,780	2,880
Kyrgyz Republic	NA	127	NA	127	NA	3,032
Lithuania	6	17	6	17	704	782
Latvia	18	21	11	12	965	965
Moldova	33	35	33	35	1,185	1,285
Macedonia, FYR	32	35	32	35	1,070	1,070
Poland	19	26	19	26	2,260	2,260
Romania	27	28	14	14	1,300	1,200
Russia	29	35	39	38	2,237	2,237
Serbia and Montenegro	32	44	11	12	1,240	1,440
Slovak Republic	20	21	20	21	1,015	1,050
Slovenia	20	24	20	24	1,070	1,107
Tajikistan	NA	NA	72	44	4,300	3,550
Turkmenistan	NA	NA	NA	NA	NA	NA
Ukraine	34	46	33	46	1,009	1,025
Uzbekistan	NA	139	44	139	2,550	3,970
Europe & Central Asia	*31.6*	*43*	*29.2*	*37.1*	*1,450.20*	*1,589.30*

	2005		2006			
Country *or Region*	Export Time	Import Time	Export Time	Import Time	Export Cost	Import Cost
East Asia & Pacific	*25.8*	*28.6*	*23.9*	*25.9*	*884.8*	*1,037.10*
Latin America & Caribbean	*30.3*	*37*	*22.2*	*27.9*	*1,067.50*	*1,225.50*
Middle East & North Africa	*33.6*	*41.9*	*27.1*	*35.4*	*923.9*	*1,182.80*
OECD	*12.6*	*14*	*10.5*	*12.2*	*811*	*882.6*
South Asia	*33.7*	*46.5*	*34.4*	*41.5*	*1,236.00*	*1,494.90*
Sub-Saharan Africa	*48.6*	*60.5*	*40*	*51.5*	*1,561.10*	*1,946.90*

Table 3: Overall Trade Restrictiveness Index for ECA countries (% ad valorem equivalent). So

Kee et al. (2006).

Country or *Region*	**OTRI - Tariffs**	**OTRI - Tariffs & NTBs**
Albania	10.9	11.4
Belarus	9.1	15.9
Czech Republic	4.0	5.0
Estonia	1.1	2.3
Hungary	6.1	11.3
Kazakhstan	5.4	14.0
Kyrgyz Republic	6.9	7.4
Lithuania	2.0	5.0
Latvia	3.0	9.8
Moldova	4.7	7.4
Poland	10.8	15.2
Romania	11.9	15.8
Russia	10.4	22.6
Slovenia	9.8	18.2
Ukraine	9.3	21.6
ECA Average	*7.0*	*12.2*
OECD Average	*5.6*	*11.4*

Table 4: Market Access Overall Trade Restrictiveness Index for ECA countries (% ad valorem equivalent). Source: Kee et al. (2006).

Country or *Region*	**MA-OTRI - Tariffs**	**MA-OTRI - Tariffs & NTBs**
Albania	11.3	16.7
Belarus	9.8	15.4
Czech	6.2	10.7
Estonia	9.3	15.3
Hungary	7.6	13.3
Kazakhstan	5.7	15.3
Kyrgyzstan	11.8	19.2
Latvia	10.8	20.0
Lithuania	14.5	23.0
Moldova	17.1	25.9
Poland	8.2	13.8
Romania	8.8	15.7
Russia	4.3	12.2
Slovenia	8.0	13.9
Ukraine	7.1	15.2
ECA Average	*9.4*	*16.4*
OECD Average	*7.0*	*13.1*

Table 5: Breakdown of cities included in the ECA road netw

Country	No. of Cities > 300 000
ALB	1
ARM	1
AZE	2
BGR	3
BIH	1
BLR	5
CZE	3
EST	1
GEO	1
HRV	1
HUN	1
KAZ	7
KGZ	1
LTU	2
LVA	1
MDA	1
MKD	1
POL	10
ROM	6
RUS	63
SRB	1
SVK	1
SVN	1
TJK	1
TKM	1
UKR	18
UZB	3

Table 6: Comparison of percentage paved roads data. (Sources: World Road Statistics, World Development Indicators, CIA World Fact Book online).

Country	WRS	*Year*	WDI	*Year*	CIA	*Year*	Preferred
Albania	39	*2002*	39	*2002*	39	*2002*	39
Armenia	100	*2003*	97	*1998*	100	*2003*	97
Azerbaijan	49	*2004*	47	*2003*	47	*2003*	47
Belarus	87	*2004*	100	*2003*	100	*2003*	87
Bosnia and Herzegovina	52	*1999*	52	*1999*	52	*2005*	52
Bulgaria	99	*2004*	92	*2002*	92	*2003*	92
Croatia	NA	*NA*	85	*1999*	85	*2004*	85
Czech Republic	100	*2003*	100	*2002*	100	*2003*	100
Estonia	24	*2004*	23	*2003*	23	*2003*	23
Georgia	39	*2004*	39	*2003*	39	*2003*	39
Hungary	44	*2003*	44	*2002*	44	*2005*	44
Kazakhstan	93	*2004*	96	*2003*	96	*2003*	96
Kyrgyz Republic	91	*1999*	90	*2004*	91	*1999*	90
Latvia	100	*2004*	100	*2003*	100	*2003*	100
Lithuania	28	*2004*	27	*2003*	89	*2003*	89
Macedonia, FYR	64	*1999*	64	*1999*	64	*1999*	64
Moldova	86	*2004*	86	*2003*	86	*2003*	86
Poland	70	*2003*	70	*2003*	70	*2003*	70
Romania	30	*2004*	50	*2002*	30	*2003*	30
Russian Federation	NA	*2001*	67	*1999*	85	*2004*	85
Serbia and Montenegro	96	*2004*	62	*2002*	62	*2002*	62
Slovak Republic	87	*2004*	87	*2003*	87	*2003*	87
Slovenia	100	*2004*	100	*2003*	100	*2003*	100
Tajikistan	NA	*NA*	83	*1995*	NA	*2000*	83
Turkmenistan	81	*1999*	81	*1999*	81	*1999*	81
Ukraine	97	*2004*	97	*2003*	97	*2003*	97
Uzbekistan	87	*1999*	87	*1999*	87	*1999*	87

Table 7: Calculation of the Road Quality Index for Europe and Central Asia.

Country Name	% Paved	Source	Year	GDP/cap	CPIA	Quality	Quality Index
Albania	39	WDI	2002	4301	3	124.45	32.45
Armenia	97	WDI	2003	3408	3.5	253.94	66.21
Azerbaijan	47	WDI	2003	3414	3	137.96	35.97
Belarus	87	WRS	2004	5748	2.5	241.61	63.00
Bosnia and Herzegovina	52	WDI	1999	6030	3	167.61	43.70
Bulgaria	92	WDI	2002	7079	4	289.36	75.45
Croatia	85	WDI	1999	11021	4	296.75	77.37
Czech Republic	100	WDI	2002	17040	4	368.73	96.14
Estonia	23	WDI	2003	12297	4	106.60	27.79
Georgia	39	WDI	2003	2459	2.5	107.30	27.98
Hungary	44	WDI	2002	14575	4.5	189.73	49.47
Kazakhstan	96	WDI	2003	6208	2.5	265.46	69.21
Kyrgyz Republic	90	WDI	2004	1664	3	200.93	52.39
Latvia	100	WDI	2003	10025	4	331.61	86.46
Lithuania	89	CIA	2005	11174	4	308.72	80.49
Macedonia, FYR	64	WDI	1999	5914	3	197.13	51.40
Moldova	86	WDI	2003	1491	3	189.55	49.42
Poland	70	WDI	2003	11287	4	255.27	66.56
Romania	30	WRS	2004	7235	3.5	115.45	30.10
Russian Federation	85	CIA	2004	8524	3	266.13	69.39
Serbia and Montenegro	62	WDI	2002	4400	3	181.15	47.23
Slovak Republic	87	WDI	2003	12665	4	310.85	81.05
Slovenia	100	WDI	2003	18441	4.5	383.53	100.00
Tajikistan	83	WDI	1995	1030	2.5	164.97	43.01
Turkmenistan	81	WDI	1999	3668	1	173.65	45.28
Ukraine	97	WDI	2003	5211	3	268.06	69.89
Uzbekistan	87	WDI	1999	1631	1	156.35	40.77

Table 8: Main sources of minimum paved road percentages across 702 international (country-pair) routes.

Country	No. of Routes	Percentage of Total Routes	Percentage Paved Rank
Albania	130	18.52	24
Hungary	108	15.38	23
Romania	220	31.34	26

Table 9: Main sources of minimum road quality indices across 702 international (country-pair) routes.

Country	No. of Routes	Percentage of Total Routes	Quality Index Rank
Georgia	142	20.23	26
Romania	184	26.21	25
Uzbekistan	96	13.68	22

Table 10: Variables and sources.

Variable	Description	Year	Source
$Border_{ij}$	Dummy variable equal to 1 if countries i and j share a common land border	NA	Mayer & Zignago (2006)
$Colony_{ij}$	Dummy variable equal to 1 if countries i and j have ever had a colonial link	NA	Mayer & Zignago (2006)
$Comlang\_Ethno_{ij}$	Dummy variable equal to 1 if the same language is spoken by at least 9% of the populations of countries i and j	NA	Mayer & Zignago (2006)
$Dist\_Cepii_{ij}$	Great circle distance between countries i and j	NA	Mayer & Zignago (2006)
$Distance\_Mean_{ij}$ or $Dist_{ij}$	Distance between countries i and j calculated as the mean of road distances between city pairs in those countries	NA	Own calculations
$Docs_{ij}$	Sum of number of export documents in origin country and number of import documents in final destination country	2005	World Bank (2006)
EU	Dummy variable equal to 1 if both countries belong to the set {Czech Republic, Estonia, Hungary, Lithuania, Latvia, Poland, Slovakia, Slovenia}	NA	Own calculations
$Paved\_Ave_{ij}$	Average of quality index in origin country i, destination country j and all transit countries (based on road routing), weighted by distance traveled in each country as a fraction of total distance between i and j.	2003	Own calculations
$Paved\_Min_{ij}$	Minimum of quality index in origin country i, destination country j and all transit countries (based on road routing)	2003	Own calculations
Q_Ave_{ij}	Average of quality index in origin country i, destination country j and all transit countries (based on road routing), weighted by distance traveled in each country as a fraction of total distance between i and j.	2003	Own calculations
Q_Min_{ij}	Minimum of quality index in origin country i, destination country j and all transit countries (based on road routing)	2003	Own calculations
$Tariff_{ij}$	1+Simple average tariff applied by country j to imports from country i	2003	WITS – UNCTAD TRAINS
$Tariffw_{ij}$	1+Trade weighted average tariff applied by country j to imports from country i	2003	WITS – UNCTAD TRAINS
Trade_k	Merchandise imports in BEC sector k (aggregated from HS-1996) into destination country from origin country, in US dollars	2003	WITS – UN Comtrade

Table 11: Regression results using OLS with origin, destination and sector fixed effects. Road network quality proxied by percent paved roads.

Variable	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
ldist	-2.08*** *0.15*	-2.09*** *0.15*	-2.07*** *0.15*	-1.89*** *0.13*	-2.19*** *0.14*	-2.06*** *0.14*
lpaved_ave	0.18 *0.44*	0.20 *0.44*	0.35 *0.45*	0.53 *0.43*	0.56 *0.41*	
lpaved_min	0.56*** *0.21*	0.55*** *0.21*	0.50** *0.21*	0.49** *0.20*		0.59*** *0.21*
ltariff	-4.72*** *0.91*				-4.76*** *0.91*	-4.73*** *0.91*
ltariffw		-3.72*** *0.73*				
ldocs	-3.06 *2.47*	-3.12 *2.44*	-3.21 *2.18*		-2.39 *2.48*	-3.19 *2.47*
border	0.24 *0.17*	0.23 *0.17*	0.22 *0.18*	0.28* *0.17*	0.24 *0.17*	0.25 *0.17*
colony	0.29 *0.31*	0.31 *0.30*	0.31 *0.30*	0.27 *0.27*	0.32 *0.33*	0.28 *0.31*
comlang_ethno	1.01*** *0.33*	1.01*** *0.34*	0.98*** *0.34*	1.10*** *0.30*	1.09*** *0.34*	0.99*** *0.32*
_cons	24.60*** *7.54*	24.71*** *7.43*	26.75*** *5.80*	18.67*** *2.24*	26.59*** *8.29*	25.47*** *7.30*
Observations	2440	2440	2937	3382	2440	2440
R2	0.62	0.62	0.61	0.58	0.62	0.62
Model F	58.99***	58.93***	75.78***	70.21***	58.19***	59.30***

Table 12: Regression results using OLS with origin, destination and sector fixed effects. Road network quality proxied by Buys et al. (2006) quality index.

Variable	Model 7	Model 8	Model 9	Model 10	Model 11	Model 12
ldist	-2.17*** *0.15*	-2.18*** *0.15*	-2.15*** *0.15*	-1.96*** *0.13*	-2.18*** *0.13*	-2.14*** *0.15*
lq_ave	0.53 *0.50*	0.57 *0.50*	0.74 *0.50*	1.07** *0.48*	0.57 *0.49*	
lq_min	0.08 *0.29*	0.07 *0.30*	0.04 *0.30*	0.22 *0.28*		0.18 *0.29*
ltariff	-4.73*** *0.91*				-4.73*** *0.91*	-4.77*** *0.92*
ltariffw		-3.75*** *0.72*				
ldocs	-2.64 *2.44*	-2.70 *2.40*	-2.69 *2.15*		-2.57 *2.46*	-2.85 *2.44*
border	0.25 *0.17*	0.24 *0.17*	0.24 *0.18*	0.28* *0.17*	0.26 *0.17*	0.26 *0.17*
colony	0.29 *0.33*	0.31 *0.32*	0.30 *0.32*	0.27 *0.27*	0.29 *0.33*	0.31 *0.33*
comlang_ethno	1.08*** *0.34*	1.08*** *0.34*	1.06*** *0.35*	1.18*** *0.31*	1.08*** *0.34*	1.03*** *0.33*
_cons	27.19*** *8.22*	27.19*** *8.10*	25.93*** *5.81*	18.65*** *2.33*	27.15*** *8.24*	29.41*** *8.06*
Observations	2440	2440	2937	3382	2440	2440
R2	0.62	0.61	0.61	0.58	0.62	0.61
Model F	58.37***	58.16***	76.27***	70.45***	58.53***	58.80***

Table 13: Regression results using Poisson PML with origin, destination and sector fixed effects. Road network quality proxied by percent paved roads.

Variable	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
ldist	-1.32***	-1.34***	-1.10***	-1.04***	-1.36***	-1.40***
	0.18	*0.18*	*0.19*	*0.16*	*0.18*	*0.17*
lpaved_ave	1.37***	1.38**	1.84***	1.79***	1.50***	
	0.52	*0.54*	*0.70*	*0.66*	*0.52*	
lpaved_min	0.20	0.23	0.47**	0.57**		0.33*
	0.19	*0.19*	*0.20*	*0.23*		*0.19*
ltariff	-6.71***				-6.97***	-6.44***
	2.08				*2.08*	*2.10*
ltariffw		-4.77**				
		2.01				
ldocs	2.40	2.04	0.78		2.41	2.15
	3.41	*3.45*	*3.85*		*3.26*	*3.38*
border	0.19	0.18	0.22	0.26*	0.17	0.20
	0.14	*0.15*	*0.17*	*0.16*	*0.15*	*0.16*
colony	-0.09	-0.04	0.09	-0.11	-0.09	-0.24
	0.23	*0.23*	*0.24*	*0.26*	*0.23*	*0.21*
comlang	0.90***	0.91***	1.37***	1.55***	0.93***	0.58**
	0.22	*0.23*	*0.25*	*0.29*	*0.22*	*0.25*
_cons	3.34	4.31	9.28	12.19***	9.71	9.81
	9.68	*9.95*	*14.02*	*3.43*	*7.67*	*9.45*
Obs.	2559	2559	3864	4914	2559	2559
Model Chi2	16491.58***	19052.58***	22548.4***	18989.39***	17830.7***	17733.07***

Table 14: Regression results using Poisson PML with origin, destination and sector fixed effects. Road network quality proxied by Buys et al. (2006) quality index.

Variable	Model 7	Model 8	Model 9	Model 10	Model 11	Model 12
ldist	-1.22***	-1.24***	-0.93***	-0.93***	-1.27***	-1.40***
	0.20	*0.20*	*0.21*	*0.17*	*0.19*	*0.17*
lq_ave	1.79***	1.86***	2.58***	2.74***	1.88***	
	0.61	*0.62*	*0.77*	*0.69*	*0.61*	
lq_min	0.24	0.28	0.68***	0.77***		0.38
	0.24	*0.24*	*0.25*	*0.27*		*0.25*
ltariff	-6.56***				-6.78***	-6.52***
	2.09				*2.09*	*2.09*
ltariffw		-4.73**				
		1.99				
ldocs	1.78	1.38	-0.14		1.89	1.96
	3.31	*3.31*	*3.56*		*3.20*	*3.31*
border	0.24*	0.23	0.30*	0.30**	0.22	0.21
	0.14	*0.14*	*0.15*	*0.14*	*0.14*	*0.16*
colony	-0.19	-0.14	-0.04	-0.26	-0.20	-0.24
	0.21	*0.21*	*0.21*	*0.24*	*0.21*	*0.21*
comlang	0.96***	0.98***	1.46***	1.67***	0.97***	0.59**
	0.21	*0.22*	*0.22*	*0.28*	*0.21*	*0.25*
_cons	8.67	9.37	11.86	8.06**	9.13	16.10**
	7.68	*7.87*	*11.46*	*3.66*	*7.36*	*7.65*
Obs.	2559	2559	3864	4914	2559	2559
Model Chi2	17375.34***	20347.11***	22004.65***	17985.38***	18113.92***	18609.34***

Table 15: Regression results using Negative Binomial PML with origin, destination and sector fixed effects. Road network quality proxied by percent paved roads.

Variable	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
ldist	-1.74***	-1.76***	-2.10***	-1.98***	-1.86***	-1.68***
	0.17	*0.17*	*0.21*	*0.18*	*0.16*	*0.18*
lpaved_ave	0.79*	0.79*	1.00**	1.08**	1.21***	
	0.40	*0.41*	*0.47*	*0.46*	*0.38*	
lpaved_min	0.60***	0.61***	0.84***	0.89***		0.74***
	0.20	*0.21*	*0.23*	*0.23*		*0.20*
ltariff	-4.03***				-3.96***	-4.05***
	0.78				*0.79*	*0.78*
ltariffw		-2.47***				
		0.70				
ldocs	-4.03*	-3.64*	-0.96		-3.12	-4.79**
	2.21	*2.19*	*2.29*		*2.30*	*2.23*
border	0.01	-0.02	-0.10	-0.19	0.02	0.04
	0.15	*0.15*	*0.20*	*0.23*	*0.15*	*0.15*
colony	-0.14	-0.13	-0.28	-0.37	-0.09	-0.14
	0.23	*0.23*	*0.29*	*0.30*	*0.25*	*0.24*
comlang	1.09***	1.08***	1.55***	1.73***	1.17***	0.98***
	0.25	*0.26*	*0.34*	*0.36*	*0.25*	*0.25*
_cons	26.48***	25.27***	28.28***	18.61***	26.72***	30.91***
	6.75	*6.70*	*8.57*	*2.32*	*5.92*	*6.64*
Obs.	2559	2559	3864	4914	2559	2559
Model Chi2	3761.55***	3796.71***	3087.89***	3558.61***	3574.03***	3677.03***

Table 16: Regression results using Negative Binomial PML with origin, destination and sector fixed effects. Road network quality proxied by Buys et al. (2006) quality index.

Variable	Model 7	Model 8	Model 9	Model 10	Model 11	Model 12
ldist	-1.81*** *0.17*	-1.83*** *0.18*	-2.17*** *0.21*	-2.09*** *0.18*	-1.82*** *0.16*	-1.74*** *0.18*
lq_ave	1.29*** *0.49*	1.31*** *0.50*	1.22* *0.63*	1.85*** *0.66*	1.34*** *0.48*	
lq_min	0.08 *0.28*	0.09 *0.29*	0.35 *0.35*	0.37 *0.38*		0.35 *0.27*
ltariff	-3.93*** *0.79*				-3.93*** *0.79*	-3.96*** *0.80*
ltariffw		-2.38*** *0.71*				
ldocs	-3.49 *2.27*	-3.10 *2.25*	-0.36 *2.34*		-3.42 *2.29*	-4.21* *2.30*
border	0.06 *0.15*	0.02 *0.15*	-0.10 *0.20*	-0.22 *0.24*	0.06 *0.15*	0.06 *0.15*
colony	-0.15 *0.26*	-0.14 *0.26*	-0.23 *0.31*	-0.33 *0.31*	-0.15 *0.26*	-0.07 *0.27*
comlang	1.15*** *0.26*	1.16*** *0.26*	1.67*** *0.35*	1.92*** *0.37*	1.16*** *0.25*	1.02*** *0.25*
_cons	26.97*** *6.02*	26.04*** *5.98*	30.85*** *8.32*	19.02*** *3.05*	26.94*** *6.04*	32.49*** *5.82*
Obs.	2559	2559	3864	4914	2559	2559
Model Chi2	3620.45***	3599.94***	3033.17***	3381.13***	3593.32***	3468.80***

Table 17: Regression results using a dummy variable for EU accession.

	Model 13			Model 14		
Variable	OLS	Poisson	Neg. Binomial	OLS	Poisson	Neg. Binomial
ldist	-2.03***	-1.27***	-1.62***	-2.13***	-1.21***	-1.71***
	0.15	*0.17*	*0.17*	*0.15*	*0.19*	*0.18*
lpaved_ave	0.12	1.32**	0.62			
	0.44	*0.52*	*0.40*			
lpaved_min	0.57***	0.20	0.60***			
	0.21	*0.19*	*0.20*			
lq_ave				0.45	1.74***	1.02**
				0.51	*0.64*	*0.50*
lq_min				0.06	0.24	0.05
				0.30	*0.24*	*0.28*
ltariff	-4.66***	-6.68***	-4.03***	-4.68***	-6.56***	-3.94***
	0.92	*2.09*	*0.78*	*0.92*	*2.09*	*0.79*
ldocs	-2.92	2.58	-3.70*	-2.49	1.87	-3.20
	2.46	*3.42*	*2.17*	*2.43*	*3.32*	*2.24*
border	0.26	0.22	0.05	0.27	0.25*	0.09
	0.17	*0.14*	*0.15*	*0.17*	*0.14*	*0.15*
colony	0.30	-0.12	-0.10	0.31	-0.21	-0.09
	0.31	*0.24*	*0.25*	*0.34*	*0.22*	*0.28*
comlang	0.98***	0.88***	1.05***	1.05***	0.95***	1.11***
	0.33	*0.22*	*0.25*	*0.34*	*0.21*	*0.26*
eu	0.27	0.16	0.55**	0.23	0.07	0.50**
	0.23	*0.19*	*0.23*	*0.24*	*0.20*	*0.24*
_cons	24.09***	5.35	25.25***	26.82***	6.33	26.69***
	7.49	*8.22*	*5.71*	*8.16*	*9.04*	*6.87*
Obs.	2440	2559	2559	2440	2559	2559
Model F/Chi2	59.01***	16035.04***	3885.77***	58.59***	17336.16***	3730.64***

Table 18: Simulation results (increase in aggregate intra-regional trade) using estimated coefficients from Model 1 (Negative Binomial PML).

	Shock to Mean		Shock to Median	
	US$bn	% of baseline	US$bn	% of baseline
Simulation I (region wide road upgrade)	56.71	50.4	74.66	66.32
Simulation II (3 country road upgrade)	34.99	31.07	38.38	34.09
Simulation III (tariff reduction)	6.19	6.38	8.23	8.49
Simulation IV (trade facilitation)	19.02	17.56	35.89	33.15

Note: Implied baselines are slightly different across simulations due to rounding and variations in effective sample size.

Table 19: Simulation results (increase in aggregate intra-regional trade) using estimated coefficients from Model 7 (Negative Binomial PML).

	Shock to Mean		Shock to Median	
	US$bn	% of baseline	US$bn	% of baseline
Simulation I (region wide road upgrade)	9.83	8.73	6.64	5.90
Simulation II (3 country road upgrade)	4.73	4.20	4.07	3.61
Simulation III (tariff reduction)	6.04	6.23	8.03	8.28
Simulation IV (trade facilitation)	16.47	15.21	31.08	28.71

Note: Implied baselines are slightly different across simulations due to rounding and variations in effective sample size.

Table 20: Estimated costs (US$ per km) of road reconstruction and development work. Source: ROCKS.

	Eastern Europe	Former USSR	Combined	Western Europe	World
Observations	82	8	90	2	205
Average	266686	295560	269253	359172	280691
Median	227031	283737	234153	359172	211445
Minimum	36762	128935	36762	306353	8219
Maximum	666219	464811	666219	411991	2678092
Std Deviation	147025	118359	144373	74698	276780

Table 21: Estimated costs (US$ million) of upgrading principal national roads (km). (Simulation II based on countries identified using minimum percentage paved roads criterion.)

Country	Road Length	Simulation I Low Cost	Simulation I Mean Cost	Simulation I High Cost	Simulation II Low Cost	Simulation II Mean Cost	Simulation II High Cost
Albania	375	14	101	250	14	101	250
Armenia	328	0	0	0	0	0	0
Azerbaijan	989	36	266	659	0	0	0
Bosnia and Herzegovina	1880	69	506	1252	0	0	0
Bulgaria	3628	0	0	0	0	0	0
Belarus	5673	0	0	0	0	0	0
Croatia	2679	0	0	0	0	0	0
Czech Republic	3397	0	0	0	0	0	0
Estonia	1059	39	285	706	0	0	0
Georgia	1246	46	335	830	0	0	0
Hungary	4100	151	1104	2732	151	1104	2732
Kazakhstan	13006	0	0	0	0	0	0
Kyrgyzstan	1685	62	454	1122	0	0	0
Latvia	1847	0	0	0	0	0	0
Lithuania	2331	0	0	0	0	0	0
Macedonia	910	0	0	0	0	0	0
Moldova	1075	40	289	716	0	0	0
Poland	12818	0	0	0	0	0	0
Romania	7664	282	2064	5106	282	2064	5106
Russia	41438	0	0	0	0	0	0
Serbia and Montenegro	3834	141	1032	2554	0	0	0
Slovakia	2655	0	0	0	0	0	0
Slovenia	1016	0	0	0	0	0	0
Tajikistan	1713	63	461	1141	0	0	0
Turkmenistan	1310	48	353	873	0	0	0
Ukraine	14071	0	0	0	0	0	0
Uzbekistan	2986	110	804	1989	0	0	0
Total	*135713*	*1100*	*8055*	*19930*	*446*	*3269*	*8088*

Figure 1: Network of major roads in Europe and Central Asia.

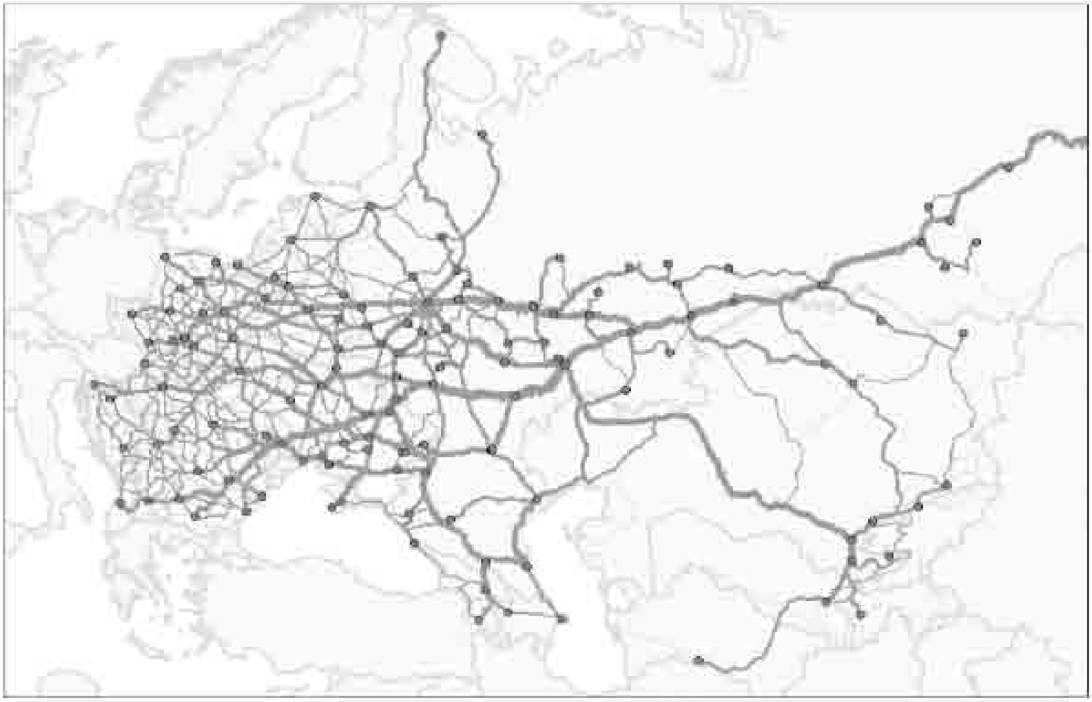

Figure 2: Scatter plot of mean road distance against great circle distance.