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Road Infrastructure in Europe and Central Asia: Does Network Quality Affect Trade?

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Abstract: We present a new database of minimum distance road routes connecting 138 cities in 27 countries across Europe and Central Asia. We use it to show that improved road network quality is robustly associated with higher intraregional trade flows. Gravity model simulations suggest that an ambitious but feasible road upgrade could increase trade by 50% over baseline, exceeding the expected gains from tariff reductions or trade facilitation programs of comparable scope. Cross-country spillovers due to overland transit are important: total intraregional trade could be increased by 30% by upgrading roads in just three countries—Albania, Hungary and Romania.

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

JEL Codes: F13; F15; H54.

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1 Introduction

In this paper, we show that better roads are strongly associated with larger trade flows within the Eastern Europe and Central Asia region (ECA). Simulation results demonstrate that the benefits for ECA from upgrading its road network may well be greater than from tariff reforms or customs streamlining programs of comparable ambition. This is the case even when the up front costs of road improvement are netted out. We also find evidence of the need for regional coordination of road network upgrades. This is due to large cross-country spillovers stemming from transit effects. Our results indicate that road investments in Albania, Hungary and Romania are likely to have particularly large trade payoffs for the region as a whole.

We focus on road transport because of its particular importance in the ECA region (Molnar and Ojala 2003; ADB 2006; Cadot et al. 2006). Part of this importance comes from the fact that eleven of the 27 countries that we study are landlocked. The available empirical evidence suggests that being landlocked adds significantly to the cost of trading internationally (Raballand 2003; Cadot et al. 2006). Exporting firms rely not only on the quality of infrastructure provided by their home governments, but also on that of neighboring countries through which goods must transit. Because of this, the relationship between road quality and trade may not be entirely linear: for example, upgrades in important transit countries or resolution of regional bottlenecks could have impacts well beyond the individual countries concerned. Our results provide strong support for this view.

An important aspect of our paper is its comparative outlook. We are primarily interested in identifying the intraregional trade benefits that can come from improved roads. We also want, however, to compare them with what is available from different policy approaches, such as tariff reductions or more streamlined customs procedures (largely an issue of “trade facilitation” as reflected in World Trade Organization disciplines). The relative costs and benefits of these options are of direct interest to policymakers. At the same time, there is mounting empirical evidence that in the current environment of historically low tariff levels, “traditional” trade policy accounts for an increasingly small proportion of overall trade costs (Anderson and Van Wincoop 2004). This analysis suggests that the impact of policy reform in the areas of trade-related infrastructure and trade facilitation might be correspondingly greater. Our results support this conclusion, which is not surprising considering the current state of trade policy in Europe and Central Asia (relatively low traditional barriers, but high transport and transaction costs—see Tables 2-4). Moreover, initiatives to reduce trade costs in these ways are more attractive when tariff reforms are dependent upon on a complex, uncertain, and slow multilateral process.

Against this background, the empirical literature has produced a number of model-based evaluations of the sensitivity of trade flows to infrastructure and trade facilitation. Studies of general scope such as Bougheas et al. (1999), Wilson et al. (2005) and Francois and Manchin (2006) use the gravity model to show that improvements along those dimensions are associated with increased trade flows. Another strand of the trade facilitation literature has emphasized the importance of time delays (Djankov et al. 2006; Nordås et al. 2006). Meanwhile, the results in Limão and Venables (2001) demonstrate that infrastructure plays an important role in determining transport costs, and thereby impacts trade flows. Nordås and Piermartini (2004) and Cadot et al. (2006) arrive at similar conclusions. In particular, the latter paper shows that the infrastructure of neighboring countries is important for landlocked Central Asian economies, due to transit effects.

Two recent papers deal more specifically with road infrastructure. The first of them, Coulibaly and Fontagné (2006), focuses on West Africa. The authors find that a composite measure of road quality in the importing and exporting countries has a positive and statistically significant effect on trade. Transit effects are also 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 taking 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 benefits of a road upgrade are very substantial: around $250bn over 15 years. The trade benefits far outweigh the costs, which include an initial investment of the order of $20bn and yearly maintenance of $1bn.

Our paper builds on and extends this literature in five main ways. In terms of substance, our analysis incorporates a new ECA road distance database similar to the one used by Buys et al. (2006) in the SSA context (Section 2). It allows us to identify road transit routes in detail, and to construct bilateral road quality indicators based on actual distances traveled in the exporting, importing and transit countries (Section 3). Secondly, our data and gravity model (Sections 4-5) allow us to simulate the trade impacts of road upgrades in different countries, taking account of cross-border spillovers due to overland transit. Thirdly, our model includes policy variables covering applied tariffs and trade facilitation, in addition to road network quality. This enables a comparison of the relative impacts of different reform scenarios (Section 6). On the methodological front, we use the "theoretical" gravity model specification due to Anderson and Van Wincoop (2003, 2004). Fixed effects are used to take account of unobservable country- and sector-specific factors, including multilateral resistance. Finally, to ensure that our results are robust to the presence of zero trade flows in the dataset, we use a variation on the Poisson Pseudo-Maximum Likelihood approach of Santos Silva and Tenreyro (2006), in addition to standard OLS.

2 Mapping Road Networks in Europe and Central Asia

As defined in this paper, the ECA region covers 27 countries stretching 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 (Table 1 and Figure 1). Anecdotal evidence suggests that the road network in this area is extensive, but of variable quality. This observation is particularly true in those countries where the post-Communist transition has been long and difficult. (See Molnar and Ojala 2003; ADB 2006; and Cadot et al. 2006 for further details.)

Computerized maps and spatial analysis software make it possible to develop a detailed picture of road transport routes in the ECA region, as Buys et al. (2006) have done for SSA. We construct minimum-distance routes connecting 138 cities, i.e. all regional cities with a year 2000 population of over 300 000 people. In all, we have 9453 inter-city routes along 2411 individual arcs (Figure 1). For each route, we are able to identify the exact road distance traveled in each of the sample countries. For instance, the minimum distance route from Prague to Moscow includes 128.6km of road travel in the Czech Republic, 723.6km in Poland, 547.2km in Belarus and finally 454.4km in Russia.

We will be analyzing international trade data in the remainder of this paper. We need, therefore, to aggregate our intercity road distance data to the country 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 cities for which we have data in those two countries. This is the same approach as in Buys et al. (2006).[1]

As a check on the reliability of our international distance measure, we compare it with the CEPII distance database (Mayer and Zignago 2006). The most commonly used CEPII measure expresses the distance between two countries as the great circle distance between their respective largest cities. Over the full sample, we find a correlation coefficient ρ equal to 0.93. However, at long distances (greater than 3000km) the relationship between the two series is substantially weaker (ρ = 0.66). Visual evidence (Figure 2) suggests that the CEPII measure is systematically lower than ours over long bilateral distances. We take this as indicating that while the great circle approximation is reasonable for short overland distances, it loses much of its relevance as those distances grow. A detailed mapping is therefore particularly important for long international routes, such as those we are dealing with in the ECA context.

One potential drawback with our approach—which might also explain part of the difference between our measures and CEPII's—stems from the considerable cross-country variation that our network map displays in terms of detail. The minimum population threshold that we have chosen results in 16 out of 27 countries being represented by a single city, while the largest country (Russia) is represented by 63 cities (Table 5). At first glance, it seems plausible that Russia might therefore exert an undue influence on our results. However, even with Russia excluded from the sample, the pattern identified above with respect to the CEPII distance measure still stands (full sample ρ = 0.94; for distances greater than 3000km, ρ = 0.62). Further, we find below that exclusion of Russia from the estimation sample in fact has little bearing on

[1] Weighting average distances by city population, or using the median rather than the mean, does not change our results.

the estimated coefficients. We are therefore confident that our population criterion, while necessarily arbitrary, strikes an acceptable balance between detail and tractability.

3 Measuring the Quality of Road Networks

The literature cited above generally uses the percent of paved roads in a country as a proxy for road quality (Limão and Venables, 2001; Coulibaly and Fontagné, 2006; and Cadot et al., 2006). Buys et al. (2006), by contrast, also include GDP per capita and a corruption indicator.[2] Such an approach is valuable insofar as it highlights the fact that upgrading road quality is not just about bitumen, but also requires maintenance capacity and the ability to control unofficial payments. However, aggregating all three dimensions into a single composite indicator makes it difficult to relate regression coefficients to specific policy actions. In particular, the relative importance of each dimension in relation to the others is determined by the researcher's priors, and not by the data themselves. The desire to map our results directly to policy space motivates our decision to limit our consideration of "quality" to the percent paved roads criterion.

In constructing a road quality measure, we compare data from different sources to resolve (usually minor) disagreements amongst them. We have, however, found instances of apparently spurious time-series variation in percent paved roads data. Such instances appear to be related to definitional changes that can significantly alter the apparent percent of paved roads, even though no physical changes have in fact taken place. Table 6 provides our consolidation of the available data for ECA. In arriving at our preferred measures, we have been guided by expert opinion from

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[2] The Buys et al. (2006) indicator Q_j combines the percent of paved roads (P_j), per capita GDP (G_j) and the World Bank's Country Policy and Institutional Capacity Index (C_j) such that $Q_j = P_j^{\alpha_1} G_j^{\alpha_2} C_j^{\alpha_3}$. Imposing slightly increasing returns, the alpha parameters are set to α_1=0.8, α_2=0.2 and α_3=0.2.

the World Bank. As a result we believe that our measures represent a reasonable approximation of the reality on the ground. To limit the risk of spurious time-series variation, we use a single base year only (2003).

One important advantage of our road distance mapping approach is that it enables us to produce detailed measures of bilateral road quality that take full account of transit effects. We can consider road quality in third countries, not just the exporter and importer (cf. Nordås and Piermartini 2004). We can also use actual transit distances to weight road quality in each country along the route, rather than using an approximation such as a count of the number of border crossings (cf. Coulibaly and Fontagné 2006).

As in Buys et al. (2006), we construct two measures of road quality. The first is a distance weighted average (*paved_ave*). We construct it using the percent of paved roads in the exporting and importing countries, as well as in all transit countries along the set of minimum distance routes used to calculate international distances as set out above. The paved roads data are weighted in each case by the proportion of the total distance traveled in each country. Our second measure (*paved_min*) is calculated using the same information, but taking the minimum percent of paved roads observed across the exporting, importing and transit countries. The purpose of this measure is to help identify bottlenecks and assess the potential for cross-country infrastructure spillovers. An incidental benefit of our approach is that our quality measures are unlikely to suffer unduly from endogeneity to bilateral trade flows, since they depend also on policy decisions by countries not involved in a given bilateral relationship.

Interestingly, we find strong geographical concentration (65%) of *paved_min* scores in just three countries: Albania, Hungary and Romania. To the extent that *paved_min* is found to be a significant determinant of bilateral trade, this finding suggests that improved road quality in those three countries is likely to impact a substantial number of third-country trade flows. Given their geography and current income levels, this would perhaps not be a surprising result. But it could be an important one in terms of regional investment initiatives, given that Hungary is an EU Member State and that Romania will accede on 1 January 2007.

4 Model Description and Data

As noted at the outset, our primary interest is in assessing the impact of road quality on intraregional trade. We would also like to compare that impact to what can be had through tariff reductions and improved trade facilitation. To do that, we will use a standard tool of empirical international trade, namely the gravity model. Our specification is based on the micro-founded gravity model due to Anderson and Van Wincoop (2003, 2004):

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

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.

As is well known, the most important innovation of this model is its inclusion of the "resistance" or "remoteness" terms P_{j}^{k} and Π_{i}^{k}. Inward resistance P_{j}^{k} captures the fact that j's imports from i depend on trade costs across all suppliers. Outward resistance Π_i^k, by contrast, captures the dependence of exports from i to j on trade costs across all importers.

In applied work with (1), bilateral trade costs t_{ij}^k need to be specified in terms of observables. We postulate:

$$t_{ij}^k = d_{ij}^{\rho} \tau_{ji}^{\theta} \prod_{m=1}^{M} \left(b_m^{z_{ij}^{k,m}} \right)$$
$$\Leftrightarrow \log\left(t_{ij}^k\right) = \rho \log\left(d_{ij}\right) + \sum_{m=1}^{M} \log\left(b_m\right) z_{ij}^{k,m} \qquad (2)$$

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 our baseline gravity model:

$$\log\left(X_{ij}^k\right) = \log\left(E_j^k\right) + \log\left(Y_i^k\right) - \log\left(Y^k\right) + \left(1-\sigma_k\right)\left[\rho \log\left(d_{ij}\right) + \sum_{m=1}^{M} \log\left(b_m\right) z_{ij}^{k,m}\right] - \ldots$$
$$\ldots - \left(1-\sigma_k\right)\log\left(P_j^k\right) - \left(1-\sigma_k\right)\log\left(\Pi_i^k\right) + \varepsilon_{ij}^k \qquad (3)$$

The resistance terms P_j^k and Π_i^k are not directly observable. We will account for them using fixed effects. In a panel data context, Baldwin and Taglioni (2006) have recently shown that proper specification of the fixed effects version of (3) has given rise to considerable confusion in the applied literature. When estimating over a single year, (3) should, strictly speaking, include fixed effects in the exporter-sector, importer-sector and sector dimensions. In addition, given that the elasticity of substitution σ_k varies across sectors, it is necessary to allow the reduced form coefficients in the trade cost function to do likewise. A strict derivation therefore suggests the following estimable form for (3):

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

Depending on the size of the dataset, it may prove difficult to identify all coefficients in (4) due in particular to lack of variation in the exporter-sector or importer-sector dimensions. We therefore propose a simplification in which trade cost elasticities are assumed to be constant across sectors, and country-sector fixed effects are taken to be subsumed by country fixed effects. The resulting estimation equation (5) uses fewer degrees of freedom than (4), but can be expected to provide a reasonable approximation in cases where cross-sectoral variation is not too strong.

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

Our data and sources are set out in detail in Table 8. For bilateral trade, we use the value of 2003 imports by BEC 1-digit sector, taken from the WITS database. 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 measures of average and minimum road quality. Our tariff variable is drawn from effective applied tariffs as recorded in the WITS-TRAINS database.[3] For trade facilitation, we use data

[3] We use the simple average tariff when aggregating to the BEC 1-digit level. Use of the trade weighted average does not affect our results.

from the 2006 Doing Business Report (World Bank, 2006) on the number of documents required to export and import (*docs*), summing across the exporting and importing countries.[4] We prefer this measure to the more commonly used indicator of time to export and import (Djankov et al. 2006; Nordås et al. 2006) because it does not suffer from endogeneity to trade flows in the same way: while an unexpectedly large trade flow this year might lead to congestion and thereby increase trading time, the same is not true for the number of documents required by customs authorities.[5] Another appealing feature of our measure is that it bears a close relationship to the core interpretation given to the term "trade facilitation" at the WTO level, which emphasizes the streamlining of trade-related administrative procedures and formalities (Wilson 2005).

5 Estimation Results

We use (5) as our baseline gravity model for estimation purposes. We first estimate using standard OLS. Next, we present the results of a number of alternative estimation methods drawn from the recent literature.[6] In all cases, we gauge robustness by considering three different specifications of (5). Model 1 is our preferred specification, and takes the exact form of (5) above. Model 2 drops *paved_min* and uses *paved_ave* only, while Model 3 does the opposite. Finally, we briefly discuss some additional robustness checks.

The first three columns of Table 9 contain our OLS estimates. The dependent variable is *log(trade)*, with zero or missing observations simply dropped from the dataset; this is an issue we

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

[5] Our argument is indirectly supported by the results of Djankov et al. (2006), who instrument for trading time using two related variables, namely the number of signatures required to export and import. Their model is overidentified and does not reject the relevant restriction, which suggests that the proposed instruments are valid.

[6] All calculations were performed using Stata 9.2SE.

return to below. Models 1, 2 and 3 all perform well, with R^2 of around 62%. All estimated coefficients carry the expected signs and have economically reasonable magnitudes. Except in the case of *paved_ave*, coefficient estimates are quite stable across specifications. The distance elasticity is greater than 2 in absolute value in all three models, which is stronger than the central tendency of the gravity literature (around 0.9 according to the meta-analysis of Disdier and Head 2005). We put the difference down to three factors. Firstly, we use overland distances and not the more common great circle measures. Secondly, our data are disaggregated at the sectoral level, whereas many gravity models use total trade. Thirdly, our sample covers just one geographic region, in which it is conceivable that road distance plays a particularly important role, for the reasons set out above.

Only distance, *paved_min*, tariffs and common language are statistically significant at conventional levels. A 1% improvement in *paved_min* is associated with a 0.6% increase in trade, while a 1% cut in applied tariffs increases trade by 3.5% (evaluated at the approximate sample mean of 8%). Even though the estimated coefficients for *paved_ave* and *docs* are not statistically significant, we still regard them as economically significant: a 1% improvement in average road quality is associated with a 0.2% to 0.6% increase in trade, while a similar percentage reduction in the number of export and import documents is associated with a 2.4% to 3.2% increase in trade. Based on OLS estimates, we tentatively conclude that improved road quality, lower tariffs and better trade facilitation are all associated with stronger bilateral trade flows.

To be sure that this result holds, we need to deal more carefully with the issue of zero or missing trade flows. In our case, around 1500 observations (nearly one-third of the potential dataset) fall into that category. Unfortunately, we are also missing data for applied tariffs and trade facilitation. This means that in terms of our effective sample, i.e. the number of observations for which data are available across all variables, the zero problem in fact only affects 159 observations. Although this is just 6% or so of the effective sample, we still believe it is important to ensure that our results are robust in this sense.

Our approach to this problem follows Santos Silva and Tenreyro (2006).[7] First, we express (5) in non-linear form (i.e., prior to taking logarithms):

$$X0_{ij}^{k} = \exp\begin{bmatrix} c + \delta_i + \delta_j + \delta_k + \beta_1 \log(dist_{ij}) + \beta_2 \log(paved\_ave) + \beta_3 \log(paved\_\min) + \ldots \\ \ldots + \beta_4 \log(1 + tariff) + \beta_5 \log(docs) + \beta_6 border + \beta_7 colony + \beta_8 language \end{bmatrix} + \omega_{ij}^{k} \quad (6)$$

The notation $X0_{ij}^{k}$ is designed to emphasize the fact that the trade flow data include zeros. The essential difference between (5) and (6) relates to the error term, which we have relabeled ω_{ij}^{k} in (6). Equation (5) assumes that the error is additive in a log-linear specification, or alternately that $\exp(\varepsilon_{ij}^{k})$ is multiplicative in the original non-linear specification. On the other hand, equation (6) more naturally assumes that the error is additive in the original non-linear specification. If (6) represents the "true" model, then the OLS estimator derived by log-linearization will generally be inconsistent (see Santos Silva and Tenreyro 2006 for details).

The first order conditions for estimation of (6) by weighted nonlinear least squares are identical to those for maximum likelihood estimation using the Poisson model for count data (Gourieroux et al. 1984; Davidson and MacKinnon 2004). Estimated coefficients from Poisson can still be

[7] The most common alternative is the Heckman sample selection model (e.g., Francois and Manchin 2006; Helpman et al. 2006). However, reliance only on the non-linearity of the inverse Mills ratio for identification implies a strong distributional assumption that may often be rejected in practice (Davidson and MacKinnon 2004, 488-489). At the same time, overidentification via variable exclusion has tended to rely on unconvincing assumptions.

interpreted as elasticities, as under log-linearized OLS. Expressing (6) in matrix form as $\mathrm{Y} = \mathrm{XB} + \mathrm{w}$ (dropping subscripts), the first order conditions for Poisson take the form:

$$\sum \left(\left(Y - e^{XB} \right) X \right) = 0 \tag{7}$$

Continuing with the above notation, the weights applied in terms of nonlinear least squares estimation can be seen to be $e^{-\frac{XB}{2}}$.[8]

Although the Poisson estimator can still be consistent under alternative distributional assumptions (i.e., it is a pseudo-maximum likelihood estimator), we also apply a Negative Binomial estimator (NB2 in the terminology of Cameron and Trivedi 2001) that allows for overdispersion in the data and may therefore provide a better fit in this case. First order conditions for maximum likelihood estimation of the NB2 model are again equivalent to weighted nonlinear least squares estimation of (6), though with different weights from Poisson:

$$\sum \left(\frac{\left(Y - e^{XB} \right)}{1 + \alpha e^{XB}} X \right) = 0 \tag{8}$$

The NB2 model puts less weight on large observations than does Poisson, the difference between the two depending on the size of the NB2 overdispersion parameter α (estimated from the data). In the limiting case of no overdispersion (i.e., α = 0), the NB2 model collapses to Poisson and both estimation methods therefore apply the same weighting system.[9]

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[8] The first order conditions for unweighted nonlinear least squares estimation of (6) take the form $\sum \left(\left(Y - e^{XB} \right) X e^{XB} \right) = 0$.

[9] Cravino et al. (2006) and Soloaga et al. (2006) also use the Negative Binomial model to estimate gravity models of foreign investment and trade flows respectively. In their Monte Carlo simulations, Santos Silva and Tenreyro (2006) consider the closely related Gamma model, which has first order conditions equivalent to weighted nonlinear least

Columns 4-6 of Table 9 report estimates using the Poisson model, and columns 7-9 show results for the NB2 model. The overdispersion parameter α is estimated in all three NB2 models to be 3.0. A likelihood ratio test of the (unrestricted) NB2 model against the (restricted) Poisson strongly rejects the null for all three specifications (χ^2 = 9.3e10 for models 1 and 2, χ^2 = 9.5e10 for model 3, prob. = 0.00). We conclude that the NB2 model is to be preferred over Poisson, and our discussion of results will therefore focus on the former.

As for the OLS case presented above, we find that coefficient estimates (except for colonization) have the expected signs and economically sensible magnitudes.[10] The coefficient on distance has fallen somewhat in absolute value—an effect also noted by Santos Silva and Tenreyro (2006)—and all policy variables are now significant at the 10% level. The coeffcients on tariffs and export/import documents are respectively a little weaker and stronger than those obtained with OLS. While *paved_min* enters with almost the same elasticity as under OLS, *paved_ave* is considerably stronger. In general, coefficient estimates are quite stable across specifications, although *paved_ave* and *docs* exhibit some variance according to the presence or absence of other variables. In terms of magnitude, we find that 1% improvements in *paved_ave* and *paved_min* are associated with trade increases of 0.8% and 0.6% respectively. By comparison, 1% reductions in tariffs and export/import documents are associated with trade increases of 3.0% and 4.0% respectively (evaluated at the sample mean for tariffs).

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squares with weights e^{-XB} (Gourieroux et al. 1984). The effect is similar to NB2, in the sense that it downweights large observations compared with Poisson.

[10] An additional reason for preferring NB2 estimates to Poisson is that the latter suggests that *docs* has a positive but statistically insignificant impact on trade flows. This is highly counterintuitive, and against the existing evidence using closely related variables (e.g., Djankov et al. 2006).

In Table 10, we present the results of additional robustness checks using our preferred NB2 model.[11] Exclusion of Russia from the sample (column 2) makes no significant difference to our results. Bootstrapping (column 1) results in larger standard errors than using asymptotic results. Our variables *paved_ave* and *docs* are no longer statistically significant at the 10% level, but the other variables of interest remain significant. Specifying fixed effects in line with (4), i.e. by importer-sector, exporter-sector and sector, but imposing constant slope coefficients across sectors, results in a lower (and statistically insignificant) coefficient on *paved_ave*, but does not result in large changes in the other parameters (column 4). Finally, adding country-pair random effects to (5) to account for possible omission of bilateral trade determinants (cf. Carrère 2006) leads to *paved_ave* and *docs* entering with unexpected signs, although both estimated coefficients are statistically insignificant (column 3).[12] *Paved_min* remains significant at the 5% level, although its magnitude is reduced to 0.25. Overall, we conclude that our main findings are robust, in particular the importance of road infrastructure bottlenecks as captured by *paved_min*.

Finally, we present results disaggregated by BEC sectors 1-6 (Table 11).[13] As expected, coefficient estimates vary considerably across sectors. This is due to two factors. Firstly, it follows from (3) that the reduced form parameters in (4), (5) and (6) will vary to the extent that the elasticity of substitution varies across sectors. Secondly, trade flows in different sectors may themselves be more or less sensitive to particular factors, due to certain product characteristics such as unit value, perishability and bulk.

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[11] An appendix (available on request) provides additional specification and robustness checks.

[12] This model converged extremely slowly under BFGS optimization, and required the default tolerances to be relaxed slightly. Combined with the unexpected signs referred to in the text, this suggests that great caution should be exercised in interpreting these results.

[13] Estimates obtained in this way are equivalent to pooled estimates of (4). We exclude BEC sector 7 (other goods), since the products it groups together are too heterogeneous to allow the drawing of meaningful conclusions.

In terms of our road quality variables, Table 11 shows that the impact of *paved_min* is uniformly positive across sectors and is of comparable magnitude to our core elasticity estimate of 0.6 (Table 9 column 7). *Paved_ave*, on the other hand, displays much greater variation, and is not significant in most cases. Taking results for the two coefficients together, we conclude that trade flows in food, fuel, capital goods and transport equipment are particularly sensitive to road network quality, whereas industrial supplies and consumer goods are less so. Industrial supplies and capital goods are particularly sensitive to tariffs, while improved trade facilitation seems to be relatively important for food, transport equipment and consumer goods.

In sum, the above results disclose strong and consistent evidence to the effect that road network quality affects intraregional trade in ECA. We find that both the average and minimum levels of quality across transit countries are important, but our result is clearest in terms of the latter. We interpret this as suggesting that bottleneck effects and, by corollary, cross-country spillovers are important factors in determining intraregional trade. These results withstand numerous robustness checks, as well as estimation by individual sector (subject to cross-sectoral differences in the estimated elasticities of most variables).

6 Policy Simulations

For the remainder of this paper, we will concentrate on the NB2 results reported in column 7 of Table 9. Under this specification, 1% improvements in *paved_ave* and *paved_min* are associated with trade increases of 0.8% and 0.6% respectively. By comparison, 1% reductions in tariffs and export/import documents are associated with 3.0% and 4.0% trade increases respectively (evaluated at the sample mean for tariffs).

The above policy elasticities should be considered with caution. The marginal impact of tariff reductions and trade facilitation would appear to be much stronger than for improved roads, since the estimated elasticities are greater in absolute value. Analysis of the standardized coefficients corresponding to the OLS estimates in column 1 tells a similar story: one standard deviation reductions in tariffs and export/import documents are associated with 0.1% and 0.2% increases in trade respectively, while similar innovations in *paved_ave* and *paved_min* are associated with 0.01% and 0.07% changes in trade. However, it would be unwise to draw policy conclusions from such an analysis. As is clear from the way the two paved roads variables are constructed, the relationship between bilateral road quality and the percent of paved roads in any given country is a complex one. It depends on overland transit routes, and on the quality of road infrastructure in transit countries. More important than the results from simply shocking either aggregate variable, is to trace through the impact of a change in individual country indices, allowing for transit effects.

We deal with these difficulties through simulations (cf. Wilson et al. 2005). We define four counterfactuals in terms of particular changes to national policies. Following this, we use our gravity model elasticities to estimate the resulting change in intraregional trade flows. We are conscious of the limits of this approach, in particular to the extent that it assumes parameter constancy across policy shifts and treats each policy change in isolation from the others. Our simulation results should therefore be taken as indicative of the orders of magnitude involved only. Given the scope of this research, 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.

We therefore identify two initial policy simulations:

I. Road networks in all ECA countries are upgraded to the regional mean level of quality, namely 74.52% of paved roads; and

II. Road networks in Albania, Hungary and Romania only are upgraded as in I.

The motivation for these simulations is that raising each country's level of road network quality to the currently prevailing regional average represents an ambitious but feasible scenario. Concretely, this means that under Simulation I, 13 out of 27 ECA countries receive an upgrade, while under Simulation II it is limited to only the three countries identified above as connected with 65% of minimum quality routes in the region.

We conduct the simulations as follows. First, we set up the policy shock by recalculating both weighted average and minimum quality measures for all inter-country routes, in exactly the same way as described in Section 3. The only difference is that country scores below the regional average are increased to that level before recalculation. Next, we calculate the resulting percentage changes in *paved_ave* and *paved_min*. Using our trade data and our estimated elasticities (0.79 and 0.60 respectively), we then map these policy shocks to changes in bilateral trade values. Finally, we sum estimated bilateral trade impacts across countries to give the estimated overall increase in intraregional trade.

Results in Table 12 show that the potential trade gains from an ambitious but feasible program of road upgrades are large in absolute terms. It does not seem unreasonable to consider positive impacts of the order of 50% of baseline trade, or just over US$55 billion based on total intra-regional trade in 2003. These figures are based exclusively on the projected increase in intra-regional trade. They do not include any flow-on effects to extra-regional trade. We therefore consider that our results lie towards the lower bound of 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 intra-regional trade benefits equal to over 50% of those projected from the region-wide program in Simulation I. That cross-country infrastructure spillovers are important is demonstrated by Figures 3 and 4, which show the distribution of export and import changes by country for both simulations. 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.

To provide a comparative context for the above results, we also conduct simulations designed to assess the projected trade impacts of policy changes affecting applied tariffs and trade facilitation (export/import documents):

III. Applied tariffs in all ECA countries are cut such that no tariff above the regional mean of 8% ad valorem is applied; and

IV. The numbers of documents required to export and import are reduced to their regional means, namely 8 and 12 respectively.

We regard these counterfactuals as representing ambitious but feasible reform programs in terms of tariffs and trade facilitation. On a substantive level (if not a formal one), we consider them to be comparable in scope to the road network upgrade analyzed above.

Results for both simulations are again reported in Table 12. It is notable 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%—nearly an order of magnitude smaller than the trade increases that flow from an infrastructure upgrade.[14] The impact of trade facilitation measures is, however, considerably stronger than for a tariff reduction, of the order of 20% of baseline trade. It is still small relative to the gains from a road upgrade, even if it is focused on just three countries.

6.1 The Cost Dimension

The policy simulations discussed here 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, we also need information on costs. This is particularly true when one of the options—an infrastructure upgrade—has much higher direct costs than do the others.[15]

Our purpose here is not to provide a detailed cost breakdown of the type that would be required before undertaking a specific road upgrade project. Our analysis has taken place at a higher level of generality, and in particular has not considered the state of individual road arcs. For that reason, our assessment of the costs will focus on producing a general estimate only (cf. the more detailed approach of Buys et al. 2006).

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[14] Since we do not have data on quantitative restrictions and other measures that might restrain trade following a tariff cut, we would argue that this estimate is, if anything, on the high side.

[15] 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.

The World Bank's ROad Costs Knowledge System (ROCKS) provides the starting point for our analysis.[16] 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 includes partial and full widening and/or reconstruction work, along with improvements to the road surface. The types of work that we are considering lie towards the high end of the full range of unit costs in ROCKS (excluding those relating to entirely new construction projects).

Table 13 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.[17] 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. We take the length of road to be upgraded in each country as the total length of arcs passing through that

[16] ROCKS can be downloaded from http://www.worldbank.org/transport/roads/rd_tools/rocks_main.htm.

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

country as per our computerized map. 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 14. 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 up front 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 12 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 billion for a region wide program, and $30 billion for a three country program, without allowing for any amortization of the cost of the upgraded road network over its expected lifespan.[18]

7 Conclusions and Directions for Further Research

In this paper, we have built on and extended recent work by Buys et al. (2006) to show that an ambitious but feasible road upgrade program in ECA has great potential to boost intra-regional trade—by as much as 50%. Moreover, it is possible for the region to reap a large proportion of the overall gains by focusing attention on just three countries which are important transit corridors but exhibit significant limitations in terms of infrastructure quality: Albania, Hungary and Romania. Such a concentrated program of road upgrading would come at significantly

[18] Even using the extreme upper tail of ROCKS unit costs results in net benefits of around $35 billion and $27 billion for the 13 and 3 country programs respectively.

reduced cost (perhaps 40%) compared with attaining the same level of road quality on a region-wide basis, yet would bring around 60% of the total expected trade benefits.

The results we have presented suggest a number of considerations for policy 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 greater intraregional trade benefits than comparable actions affecting either tariffs or customs procedures. In any case, the combined impact of upgrading road network quality and improving trade facilitation appears likely to produce gains well in excess of those that could be expected from comparable tariff reductions. This result aligns well with the recent literature on trade facilitation using CGE models, which suggests that the expected gains from such measures may indeed be of greater quantitative significance than those from liberalization of "traditional" trade policy measures (e.g., Francois et al. 2005). 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 is that once transit is taken into account, infrastructure projects can have important intraregional spillovers. This dynamic does not generally operate in the same way for traditional trade policy measures, such as tariff cuts. Spillovers therefore need to be taken into account when assessing costs and benefits of various options for trade facilitation and development assistance strategies. They may support an argument for regional coordination and shared funding responsibilities for infrastructure projects (see Schiff and 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. Future allocation of EU funding could benefit from taking account of potential trade impacts not only on a national level, but also through those countries' regional links.

A final policy message to highlight given our results is that the trade benefits from infrastructure upgrades can be obtained by countries acting unilaterally, or through regional cooperation. As is the case for many policy measures under the broad heading of trade facilitation, it is not necessary to wait for multilateral 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.

Our 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. It will also be important to take account of possible trade creation or diversion effects. 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 available data have not allowed us to pay detailed attention to the state of upkeep of 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 detailed work needed as part of a concrete upgrade program. There is thus considerable scope for additional work on specific cost-benefit analyses to be undertaken in this area.

References

Anderson, James E. and Eric Van Wincoop, 2003, "Gravity with Gravitas: A Solution to the Border Puzzle", *The American Economic Review*, 93(1), 170-192.

Anderson, James E. and Eric Van Wincoop, 2004, "Trade Costs", *Journal of Economic Literature*, 42(3), 691-751.

Asian Development Bank (ADB), 2006, *Central Asia: Increasing Gains from Trade Through Regional Cooperation in Trade Policy, Transport and Customs Transit*, Manila: ADB.

Baldwin, Richard E. and Daria Taglioni, 2006, "Gravity for Dummies and Dummies for Gravity Equations", Working Paper No. 12516, NBER.

Bougheas, Spiros, Panicos O. Demetriades and Edgar L. W. Morgenroth, 1999, "Infrastructure, Transport Costs and Trade", *Journal of International Economics*, 47, 169-189.

Buys, Piet; Uwe Diechmann and David Wheeler, 2006, "Road Network Upgrading and Overland Trade Expansion in Sub-Saharan Africa", The World Bank, mimeo.

Cadot, Olivier, Céline Carrère and Christopher Grigoriou, 2006, "Landlockedness, Infrastructure and Trade in Central Asia", Mimeo.

Cameron, A. Colin and Pravin K. Trivedi, 2001, "Essentials of Count Data Regression" in Badi H. Baltagi (ed.), *A Companion to Theoretical Econometrics*, Malden, Ma.: Blackwell.

Carrère, Céline, 2006, "Revisiting the Effects of Regional Trade Agreements on Trade Flows with Proper Specification of the Gravity Model", *European Economic Review*, 50, 223-247.

Coulibaly, Souleymane and Lionel Fontagné, 2006, "South-South Trade: Geography Matters", *Journal of African Economies*, 15(2), 313-341.

Cravino, Javier, Daniel Lederman and Marcelo Olarreaga, 2006, "Substitution Between Foreign Capital in China, India, the Rest of the World and Latin America: Much Ado About Nothing?", The World Bank, mimeo.

Davidson, Russell and James G. MacKinnon, 2004, *Econometric Theory and Methods*, New York, N.Y.: Oxford University Press.

Disdier, Anne-Celia, and Keith Head, 2005, "The Puzzling Persistence of the Distance Effect on Bilateral Trade", Mimeo.

Djankov, Simeon, Caroline Freund and Cong S. Pham, 2006, "Trading on Time", Policy Research Working Paper No. 3909, The World Bank.

Francois, Joseph, Hans van Meijl and Frank van Tongeren, 2005, "Trade Liberalization in the Doha Development Round", *Economic Policy*, April, 349-391.

Francois, Joseph and Miriam Manchin, 2006, "Institutional Quality, Infrastructure and the Propensity to Export", Mimeo.

Helpman, Elhanan, Marc Melitz and Yona Rubinstein, 2006, "Trading Partners and Trading Volumes", Mimeo.

Limão, Nuno and Anthony Venables, 2001, "Infrastructure, Geographical Disadvantage, Transport Costs and Trade", *World Bank Economic Review*, 15, 451-479.

Mayer, Thierry and Soledad Zignago, 2006, "Notes on CEPII's Distance Measures", CEPII, Mimeo.

Molnar, Eva and Lauri Ojala, 2003, "Transport and Trade Facilitation Issues in the CIS 7, Kazakhstan and Turkmenistan", Paper prepared for the Lucerne Conference of the CIS-7 Initiative, 20th to 22nd January 2003, Mimeo.

Nordås, Hildegunn K. and Roberta Piermartini, 2004, "Infrastructure and Trade", Staff Working Paper No. ERSD-2004-04, WTO.

Nordås, Hildegunn K., Enrico Pinali and Massimo Geloso Grosso, 2006, "Logistics and Time as a Trade Barrier", Working Paper No. TD/TC/WP(2006)3/FINAL, OECD.

Raballand, Gael, 2003, "Determinants of the Negative Impact of Being Landlocked on Trade: An Empirical Investigation Through the Central Asian Case", *Comparative Economic Studies*, 45, 520-536.

Santos Silva, J.M.C. and Silvana Tenreyro, 2006, "The Log of Gravity", *Review of Economics and Statistics*, 88(4), 641-658.

Soloaga, Isidro, John S. Wilson and Alejandro Mejia, 2006, "Moving Forward Faster: Trade Facilitation Reform and Mexican Competitiveness", Policy Research Working Paper No. 3953, The World Bank.

Wilson, John S., Catherine L. Mann and Tsunehiro Otsuki, 2005, "Assessing the Benefits of Trade Facilitation: A Global Perspective", *The World Economy*, 28(6), 841-871.

World Bank, 2006, *Doing Business in 2006: Creating Jobs*, Washington, D.C.: World Bank.

World Bank, 2007, *Doing Business in 2007: How to Reform*, Washington, D.C.: World Bank.

Tables

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*
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*

Country *or Region*	2005 Export Time	Import Time	2006 Export Time	Import Time	Export Cost	Import Cost
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). Source: 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*

a. The OTRI represents the uniform tariff required in each country to achieve an equivalent level of total imports as under current policy settings.

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*

a. The MA-OTRI 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.

Table 5: Breakdown of cities included in the ECA road network.

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: 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 8: 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)
$Paved\_Ave_{ij}$	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
$Tariff_{ij}$	1+Simple 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
Trade0_k	Trade_k with zeros inserted for missing bilateral trade flows	2003	WITS – UN Comtrade and own calculations

Table 9: Regression results for equation (5) using BEC 1-digit data (2003).

	OLS			Poisson			NB2		
Variable	**Model 1**	**Model 2**	**Model 3**	**Model 1**	**Model 2**	**Model 3**	**Model 1**	**Model 2**	**Model 3**
ldist	-2.08***	-2.19***	-2.06***	-1.32***	-1.36***	-1.40***	-1.74***	-1.86***	-1.68***
	0.15	*0.14*	*0.14*	*0.18*	*0.18*	*0.17*	*0.17*	*0.16*	*0.18*
lpaved_ave	0.18	0.56		1.37***	1.50***		0.79*	1.21***	
	0.44	*0.41*		*0.52*	*0.52*		*0.40*	*0.38*	
lpaved_min	0.56***		0.59***	0.20		0.33*	0.60***		0.74***
	0.21		*0.21*	*0.19*		*0.19*	*0.20*		*0.20*
ltariff	-4.72***	-4.76***	-4.73***	-6.71***	-6.97***	-6.44***	-4.03***	-3.96***	-4.05***
	0.91	*0.91*	*0.91*	*2.08*	*2.08*	*2.10*	*0.78*	*0.79*	*0.78*
ldocs	-3.06	-2.39	-3.19	2.40	2.41	2.15	-4.03*	-3.12	-4.79**
	2.47	*2.48*	*2.47*	*3.41*	*3.26*	*3.38*	*2.21*	*2.30*	*2.23*
border	0.24	0.24	0.25	0.19	0.17	0.20	0.01	0.02	0.04
	0.17	*0.17*	*0.17*	*0.14*	*0.15*	*0.16*	*0.15*	*0.15*	*0.15*
colony	0.29	0.32	0.28	-0.09	-0.09	-0.24	-0.14	-0.09	-0.14
	0.31	*0.33*	*0.31*	*0.23*	*0.23*	*0.21*	*0.23*	*0.25*	*0.24*
comlang_ethno	1.01***	1.09***	0.99***	0.90***	0.93***	0.58**	1.09***	1.17***	0.98***
	0.33	*0.34*	*0.32*	*0.22*	*0.22*	*0.25*	*0.25*	*0.25*	*0.25*
_cons	24.60***	26.59***	25.47***	3.34	9.71	9.81	26.48***	26.72***	30.91***
	7.54	*8.29*	*7.30*	*9.68*	*7.67*	*9.45*	*6.75*	*5.92*	*6.64*
Observations	2440	2440	2440	2559	2559	2559	2559	2559	2559
R^2/Pseudo R^2	0.62	0.62	0.62	0.78	0.78	0.78	0.03	0.03	0.03
Model F/χ^2	58.99***	58.19***	59.30***	16491.58***	17830.7***	17733.07***	3761.55***	3574.03***	3677.03***

a. Dependent variable is *log(trade)* in columns 1-3, and *trade0* in columns 4-9.

b. All models include fixed effects by exporter, importer and sector.

c. Robust standard errors (adjusted for clustering by country-pair) are in *italics*.

d. Statistical significance at the 10%, 5% and 1% levels is indicated by *, ** and *** respectively.

Table 10: Sensitivity analysis of regression results.

Variable	Bootstrap	Russia Excluded	Country-Pair REs	Country-Sector FEs
ldist	-1.74***	-1.84***	-1.10***	-2.49***
	0.19	*0.19*	*0.06*	*0.18*
lpaved_ave	0.79	0.81*	-0.19	0.34
	0.52	*0.45*	*0.22*	*0.39*
lpaved_min	0.60**	0.62**	0.25**	0.59***
	0.25	*0.27*	*0.11*	*0.19*
ltariff	-4.03***	-3.33***	-2.31***	-2.77***
	0.95	*0.84*	*0.39*	*0.76*
ldocs	-4.03	-3.93*	0.91	-3.51*
	3.03	*2.32*	*0.97*	*2*
border	0.01	-0.02	-0.33***	0
	0.19	*0.17*	*0.09*	*0.16*
colony	-0.14	-0.18	0.35***	0.14
	0.31	*0.57*	*0.13*	*0.26*
comlang_ethno	1.09***	1.15***	0.54***	1.08***
	0.32	*0.27*	*0.12*	*0.28*
_cons	36.11***	30.18***	0.75	32.91***
	10.23	*6.15*	*2.93*	*5.36*
Observations	2559	2290	2559	2559

a. All models are NB2. Dependent variable is *trade0*.

b. Models in columns 1-2 include fixed effects by exporter, importer and sector.

c. The model in column 3 includes fixed effects as in b, and random effects by country-pair.

d. The model in column 4 includes fixed effects by exporter-sector, importer-sector and sector.

e. Robust standard errors (adjusted for clustering by country-pair) are in *italics* in columns 2-4.

f. Bootstrapped standard errors (500 replications, allowing for clustering by country-pair) are in *italics* in column 1.

Table 11: Regression results for equation (4) by BEC 1-digit sector (2003).

Variable	Food & Beverages	Industrial Supplies	Fuels & Lubricants	Capital Goods	Transport Equipment	Consumer Goods
ldist	-2.50***	-2.23***	-4.92***	-2.01***	-2.81***	-2.45***
	0.23	*0.21*	*0.71*	*0.21*	*0.21*	*0.2*
lpaved_ave	1.29**	0.4	-2.09	-0.23	-0.41	-0.38
	0.62	*0.42*	*2.03*	*0.52*	*0.7*	*0.37*
lpaved_min	0.71**	0.44*	0.93	0.62**	0.70**	0.37
	0.32	*0.26*	*0.58*	*0.24*	*0.28*	*0.23*
ltariff	-2.19**	-6.04***	2.09	-9.61***	-2.83**	-1.44
	0.99	*1.99*	*8.46*	*3.39*	*1.29*	*1.23*
ldocs	-5.53*	2.29	5.63	-5.25*	-7.82*	-8.11***
	3.02	*2.3*	*10.44*	*3.06*	*4.11*	*2.79*
border	-0.48**	0.04	2.14***	-0.19	-0.74***	-0.40*
	0.21	*0.18*	*0.47*	*0.2*	*0.2*	*0.21*
colony	0.67**	-0.21	-0.35	0.37	0.59*	0.5
	0.32	*0.26*	*0.66*	*0.3*	*0.3*	*0.32*
comlang_ethno	1.59***	1.31***	-0.35	1.22***	0.93***	1.60***
	0.37	*0.27*	*0.8*	*0.3*	*0.29*	*0.35*
_cons	40.03***	20.82***	28.18	36.48***	54.98***	49.15***
	9.78	*6.24*	*37.93*	*8.02*	*14.45*	*7.21*
Observations	437	474	279	445	370	457
R^2/Pseudo R^2	0.04	0.04	0.04	0.05	0.04	0.05
Model F/χ^2	1516.44***	2397.91***		2324.02***	2621.91***	2726.26***

a. All models are NB2 and include fixed effects by exporter and importer. Dependent variable is *trade0*.

b. Robust standard errors (adjusted for clustering by country-pair) are in *italics*.

c. Statistical significance at the 10%, 5% and 1% levels is indicated by *, ** and *** respectively.

Table 12: Simulation results (increase in aggregate intra-regional trade) using estimated coefficients from Table 9 column 7.

	US$bn	% of baseline
Simulation I (region wide road upgrade)	56.71	50.4
Simulation II (3 country road upgrade)	34.99	31.07
Simulation III (tariff reduction)	6.19	6.38
Simulation IV (trade facilitation)	19.02	17.56

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

Table 13: 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 14: Estimated costs (US$ million) of upgrading principal national roads (km).

Country	Road Length	Simulation I			Simulation II		
		Low Cost	Mean Cost	High Cost	Low Cost	Mean Cost	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*

Figures

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

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

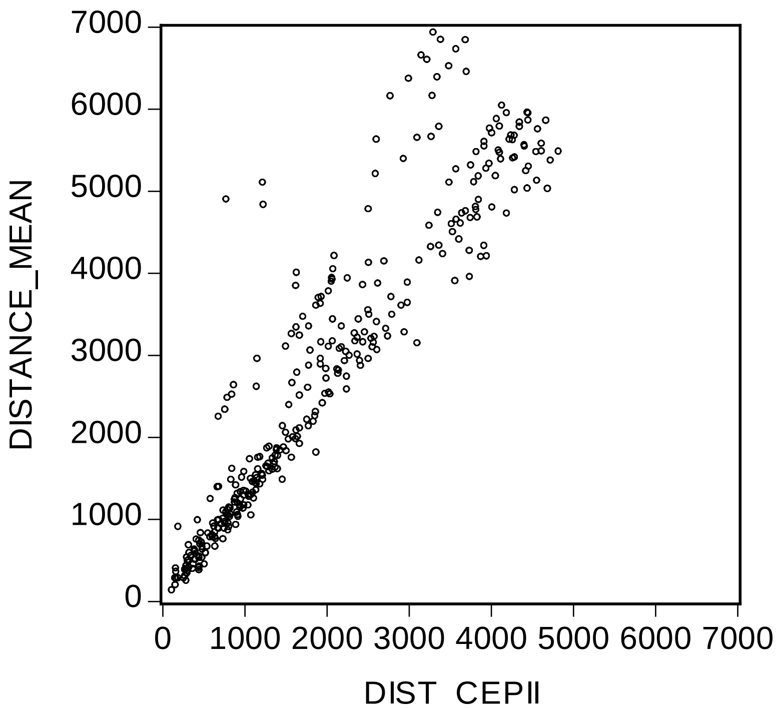

Figure 3: Simulation I, percent increase over baseline.

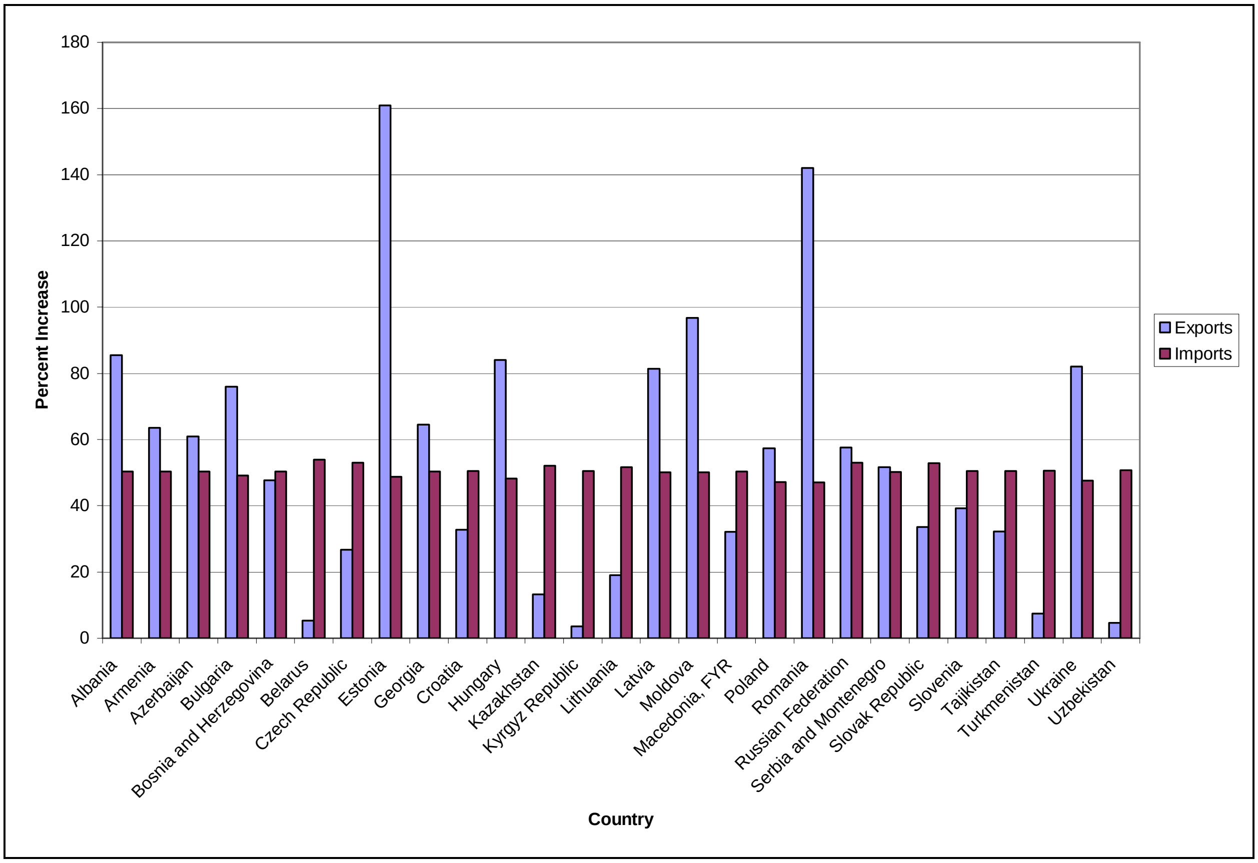

Figure 4: Simulation II, percent increase over baseline.