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Road Network Upgrading and Overland Trade Expansion in Sub-Saharan Africa

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Abstract

Recent research suggests that isolation from regional and international markets has contributed significantly to poverty in many Sub-Saharan African countries. Numerous empirical studies identify poor transport infrastructure and border restrictions as significant deterrents to trade expansion. In

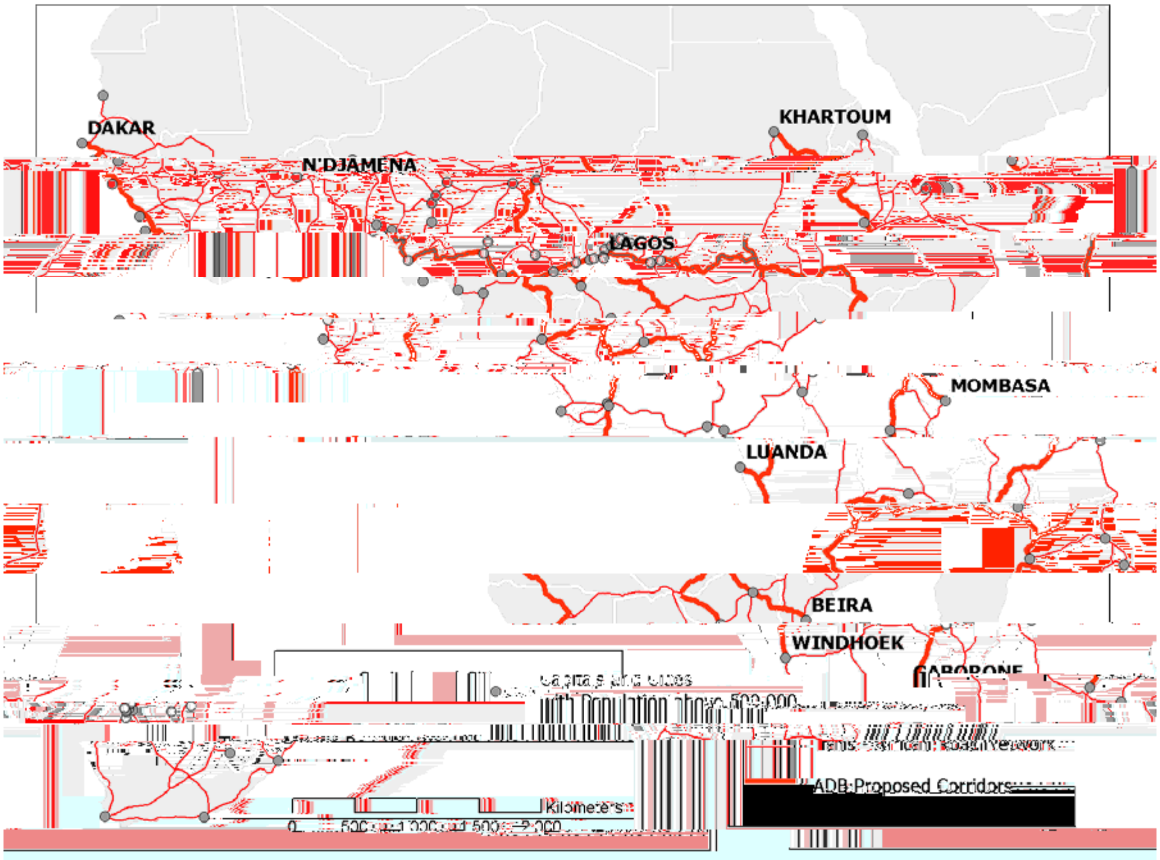
1. Introduction

This paper presents evidence on the trade-expansion potential of improvements in Sub-Saharan Africa's road network. The impetus for our work is well-summarized by the following description of a trucker's journey in Cameroon:

> *"The plan was to carry 1,600 crates of Guinness and other drinks from the factory in Douala where they were brewed to Bertoua, a small town in Cameroon's south-eastern rainforest. According to a rather optimistic schedule, it should have taken 20 hours, including an overnight rest. It took four days. When the truck arrived, it was carrying only two-thirds of its original load. …we were stopped at road-blocks 47 times. … Our road was rendered impassable by rain three times, causing delays of up to four hours. The Cameroonian government has tried to grapple with the problem of rain eroding roads by erecting a series of barriers … that stop heavy trucks from passing while it is pouring. … Early on the second evening … we met a [locked] rain barrier in the middle of the forest. It was dark, and the man with the key was not there. ,,, he returned shortly before midnight. The hold-up was irritating, but in the end made no difference. Early the next morning, a driver coming in the opposite direction told us that the bridge ahead had collapsed, so we had to turn back.* (The Economist (2002))[1]

In this case, the driver did not even face a long wait at a border station. According to the African Development Bank (ADB, 2003), In thioad-Tc Td- Tw - 0 Ttp-ays of up to5Tfcd1d ns((0 T13 hauling produce to market is too expensive, evidence and spatial network analysis techniques to explore the relationship between road transport quality and overland trade in Sub-Saharan Africa.

Figure 1: The ADB's Proposed Highway Corridors (in bold) in Sub-Saharan Africa



We employ the conventional gravity model, which has provided a robust fit to the data in many recent studies of trade flows between cities, countries and regions. In this model, the volume of trade between two areas is directly proportional to their economic activity levels, and inversely proportional to the cost of transporting goods between them. In Africa, the cost of overland transport is greatly magnified by bad roads, difficult border crossings, and harassment of truckers at road blocks. Our modeling exercise estimates the trade growth that would result from removal of these difficulties, as well as the associated costs.

The remainder of the paper is organized as follows. Section 2 reviews the theoretical and empirical literature on gravity models, highlighting evidence on overland trade flows in developing countries. In Section 3, we use computer mapping to identify a network of primary roads connecting all 42 mainland Sub-Saharan capitals, along with 41 other cities with populations over 500,000.[3] Section 4 estimates a gravity model for Sub-Saharan Africa, using inter-country trade data, road transport quality indicators, actual road distances, and estimates of economic scale for trading partners. We use the results to estimate current trade flows in the inter-city network, and to simulate the impact of a major improvement in road network quality. We explore the implications of our results for trade expansion at the regional, country and city levels. In Section 5 we estimate the costs of network improvement, using a World Bank database of upgrading and maintenance costs for hundreds of African road projects. Section 6 considers the environmental implications of network upgrading, and suggests ways in which new data on African biodiversity could be integrated into network planning. Drawing on our empirical results, Section 7 considers the establishment of a consortium to finance, administer and maintain the network. The consortium would join participating states and donor institutions in a long-term collaboration for road improvement, relaxation of trade restrictions, and overland trade expansion in Sub-Saharan Africa. Section 7 also estimates the cost of operating the network-wide consortium for 15 years. Section 8 concludes the paper by summarizing our benefit and cost estimates, as well as offering some thoughts on the feasibility of continental-scale upgrading.

[3] Our analysis excludes Madagascar, Sao Tome and Principe, the Comoros, and other island states that are considered part of Sub-Saharan African.

heterogeneous goods.[4] Recent empirical studies have fitted a variety of augmented gravity models to international trade data. Frankel (1997) tests for the effects of a common border, per capita GDP, a common language, and membership in regional trading arrangements, as well as economic scale and distance. Rose (2000) augments Frankel's model by introducing colonial ties, exchange rate volatility and a common currency. Soloaga and Winters (2001) provide a further control for effective distance, by introducing a measure of generalized remoteness from all potential trade partners. Carillo and Li (2002) include the effects of a common border and trade association membership in a gravity-model analysis of Latin American trade. In an econometric analysis of trade links among seven of eight West African Economic and Monetary Union (WAEMU) countries[5] and other states, Coulibaly and Fontagné (2004) augment distance with measures of transport infrastructure quality: percent of roads that are paved and quality of border-station customs services.[6]

Most of the cited econometric studies employ a log-transformation of the gravity model:

$$(2) \quad \log T_{ij} = k_0 + \alpha_i \log E_i + \alpha_i \log M_j + \beta \log q_{ij} + \gamma \log d_{ij} + \varepsilon_{ij}$$

Estimation techniques vary with the cross-sectional and time series properties of the data.

quality.[7] Although the two studies fit gravity models to very different data sets, Table 1 shows that their core results are qualitatively similar: Exporter GDP elasticities between 1.0 and 2.0; importer elasticities around 1.0; and road distance elasticities between -1.0 and -1.7. In addition, the Coulibaly / Fontagné results suggest a road quality elasticity near 1.5.

Table 1: Recent Gravity Model Estimates for Africa and Latin America[a]

[a] t-statistics in parentheses
[b] Coulibaly and Fotagné (2004), Table 5, Column 6, p. 29
[c] Carrillo and Li (2002), Table 5, Columns 1-5, p. 27

3. Mapping the Trans-African Road Network

To assess the potential for overland trade expansion, we analyze a road system that includes the Trans African Highway corridors proposed by the African Development Bank (ADB, 2003).[8] Using a computerized map and spatial network analysis software, we configure a distance-minimizing network of existing primary roads that connects all mainland capitals and cities above 500,000 population.[9] Figure 2 displays the network, along with the 83 connected cities.[10] Since the network covers all major cities, it has more connections in countries with large populations. Nigeria has 18 cities in the

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[7] Coulibaly and Fontagné use two-stage least squares to allow for the potential endogeneity of road quality. Their model is fitted to the UN Statistics Division's COMTRADE data for the period 1996-1998.

[8] The ADB's corridors include North African countries, while our analysis is limited to Sub-Saharan Africa.

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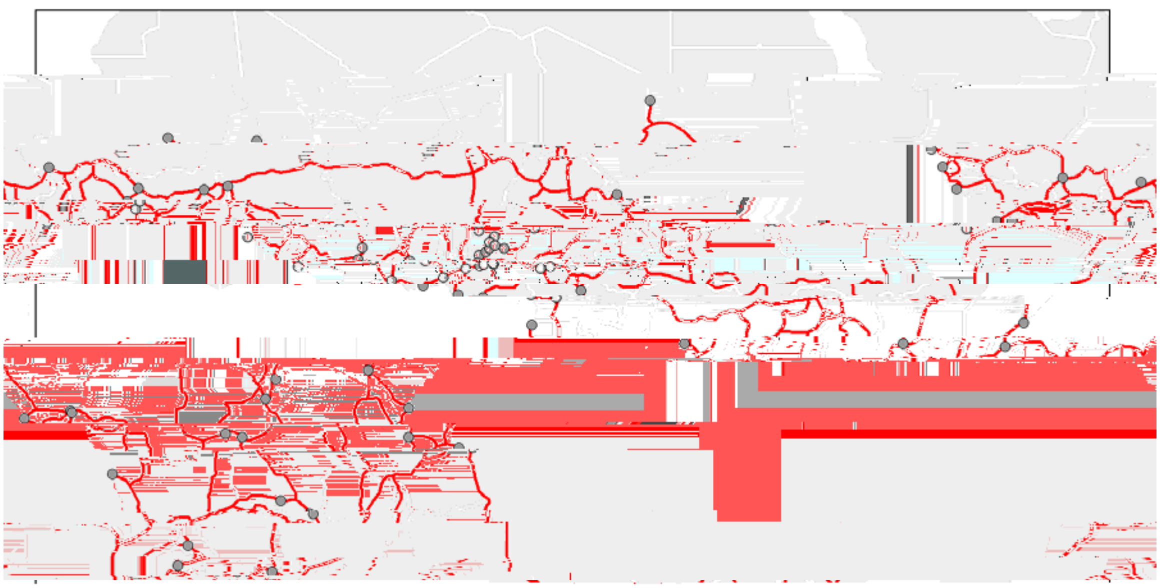
network, South Africa has 9, and the Democratic Republic of Congo has 6. The complete network contains 885 road segments, joining 3,403 paired combinations of cities. Our index of country road quality is determined by the following equation:

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

where

Q_j = Road quality index for country j
P_j = Percent of roads that are paved in country j
G_j = GDP per capita in country j (an index of capacity to maintain roads)
C_j = The World Bank's Country Policy and Institutional Capacity (CPIA) index for transparency, accountability and corruption in country j (a proxy for delays and costs inflicted on truckers).[11]

Figure 2: Trans-African Network, Based on Existing Primary Roads



[11] Data definitions are as follows:
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We believe that a mildly increasing-returns function ($\alpha_1 = 0.8$; $\alpha_2 = 0.2$; $\alpha_3 = 0.2$) provides a reasonable approximation to road transport quality differentials in Sub-Saharan Africa.[12,13] Table 2 presents index values by country, normalized to 100 for the highest-quality road transport (in South Africa). Estimated road quality for Botswana (87.5) is over 20 times the quality for the Democratic Republic of the Congo (3.8). We believe that this does not overstate the existing differential in average road speed, vehicle depreciation on bad roads, harassment of truckers, payments at road blocks, and frontier difficulties.[14]

trade data, road transport quality indicators, actual road distances, and estimates of economic scale for trading partners.

Table 2: Road Transport Quality Indices for Sub-Saharan Countries

Country	Road Transport Quality Index		Country	Road Transport Quality Index
South Africa	100.0		Cameroon	18.4
Botswana	87.5		Mauritania	16.6
Zimbabwe	50.0		Mali	16.5
The Gambia	41.6		Kenya	16.3
Sudan	40.4		Angola	15.8
Togo	37.0			

Table 3: Overland Trip, Johannesburg – Lagos (Network Minimum Distance Route)

Country	Distance (km)	Road Quality
South Africa	313.6	100.0
Botswana	842.0	87.5
Namibia	1056.2	25.9
Angola	1875.8	15.8
Congo DR	582.3	3.8
Congo Rep.	389.7	13.6
Gabon	820.0	19.2
Cameroon	829.8	18.4
Nigeria	805.3	32.3
Total	7514.7	30.1

Even though South Africa and Nigeria have the two largest economies in Sub-Saharan Africa, overland shipments between them seem almost nonexistent.[17] For this reason, we believe that minimum road link quality (for D.R. of Congo, in this case), provides a better index than average link quality. However, we also report econometric results for average link quality.

Table 4 provides suggestive evidence on the effect of bad roads on overland transport. Using 2004 IMFDOT data, we calculate total import and export flows between Chad and Central African Republic, two landlocked north-central African states, and two sets of countries: their neighboring states (each other, as well as Niger, Nigeria, Cameroon, Congo, Democratic Republic of Congo and Sudan), and five central-southern African landlocked (CSAL) states: Rwanda, Burundi, Malawi, Zambia and Zimbabwe. These states are separated from Chad and Central African Republic by only one country: Democratic Republic of Congo, which has extremely low road quality. For contrast, we also present total trade flows for the CSAL countries in Table 4. Together, trade flows

[17] After an extensive search, we can find no evidence of regular overland trade between Nigeria (or, for that matter, West Africa) and South Africa.

between Chad and CAR and their neighboring present results for minimum link quality in the other columns of Table (5), but average link quality retains a large elasticity and high significance in the same specifications.

We obtain very strong results for exporter GDP, importer GDP and road network distance. The GDP elasticities are both in the upper range for the previous studies summarized in Table 1, and both have very high significance levels. Road distance is also highly significant, with the expected sign and elasticities that are somewhat larger than previous estimates for West Africa and Latin America.[19]

Columns (3) and (4) augment the gravity model with controls for six regional trade agreements that are identified in Table 5 and Appendix Table A7. Three of these agreements – WAEMU (West Africa), CEMAC (Central Africa) and EAC (East Africa) – are among contiguous states with very long-standing monetary and trade relationships.[20] The other three – ECOWAS, SADC and COMESA – are broader and looser aggregates that overlap somewhat with the first three agreements.[21] Our results suggest that the close-knit agreements have had a major impact on trade, ceteris paribus. The highly-significant dummy-variable results for WAEMU and CEMAC, in the range 2.3 – 3.4, suggest trade volumes 10-30 times higher than expected volumes without the

Table 5: Gravity Model Regressions for Sub-Saharan Africa: Paired Trading Countries

Dependent Variable: Log Trade Value ($US)

	(1)	(2)	(3)	(4)	(5)
Log Exporter GDP	1.563	1.656	1.710	1.706	1.709
	(12.38)**	(13.54)**	(13.92)**	(13.97)**	(14.04)**
Log Importer GDP	1.295	1.386	1.434	1.433	1.435
	(10.26)**	(11.23)**	(11.62)**	(11.64)**	(11.69)**
Log Avg. Road Quality	1.984				
	(4.78)**				
Log Min. Road Quality		1.872	2.067	1.991	1.932
		(7.79)**	(7.99)**	(8.07)**	(8.09)**
Log Road Distance	-3.836	-2.531	-2.308	-2.048	-2.096
	(18.66)**	(9.60)**	(7.46)**	(7.26)**	(7.55)**
Trade Agreement Member					2.742
[WAEMU,CEMAC,EAC]					(4.63)**
WAEMU			2.532	2.353	
			(3.08)**	(3.28)**	
CEMAC			2.887	3.400	
			(2.82)**	(3.41)**	
EAC			3.324	3.471	
			(1.62)	(1.70)	
ECOWAS			-0.766		
			(1.18)		
SADC			0.235		
			(0.36)		
COMESA			-1.495		
			(3.02)**		
Constant	-32.284	-44.482	-48.982	-51.153	-50.776
	(7.28)**	(9.44)**	(9.79)**	(10.45)**	(10.44)**
Observations	1128	1128	1128	1128	1128
R-squared	0.36	0.38	0.39	0.39	0.39

Absolute value of t statistics in parentheses
* significant at 5%; ** significant at 1%

Regional Trade Agreements (Country Membership in Appendix Table A7)

WAEMU = West African Economic and Monetary Union R8**5 at 1% 9og M TwCrj-( )928317( )-35 TD( )Tj marginally significant.[22] In contrast, none of the broader, more recent agreements has a positive, significant elasticity, and two – for ECOWAS and COMESA – have perverse signs.[23] For our baseline impact simulations, we use the results in column (5), which control for membership in the three strongest trade agreements.

4.3 Calibration of the Inter-City Gravity Model

For each city pair in the network, gravity model estimation of trade flows requires four pieces of information: the economic scales of the two cities, the network distance between them, and the quality of the connecting roads. To proxy economic scale, we multiply the population of each city by national GDP per capita at purchasing power parity for 2001 (the most recent year for which comprehensive Sub-Saharan income data are available). We calculate inter-city distances in the network using our spatial network analysis model (see Figure 2), and index inter-city road quality using the minimum quality for transit countries. Then we use the parameter estimates from column (5), Table 5 to estimate trade volumes for 3,403 city pairs:[24]

$$(4) \quad \hat{T}_{ij} = K \frac{A_{ij}^{2.74} E_i^{1.71} M_j^{1.44} q_{ij}^{1.93}}{d_{ij}^{2.10}}$$

where T_{ij} = Trade volume between exporter i and importer j
K = A valuation constant
A_{ij} = Membership in WAEMU, CEMAC or EAC (1=exporter and importer both members of the same agreement)
E_i = Exporter economic scale
M_j = Importer economic scale
q_{ij} = Quality index for the road joining cities i and j
d_{ij} = Road distance between cities i and j

[22] Formally, rejection of zero effect with only 90% confidence.
[23] The negative, significant result for COMESA appears in the reported regression, which is based on minimum inter-city road quality. The result is still negative, but insignificant, in the corresponding regression that is based on average inter-city road quality.
[24] This involves 6,806 calculations, since each city plays two roles (exporter, importer) in each pair. Two sets of calculations are necessary because parameter estimates for importers and exporters are not identical. We exclude 6 countries from the analysis because data for trade and other variables are missing: Botswana, Lesotho, Namibia, Swaziland, Somalia and Liberia.

Arbitrarily setting K=1, we use equation (4) to compute pre-upgrade trade flows as index numbers. We add all index numbers for cities in different count

Gravity Model Simulation

For each city pair, we use equation (4) to predict trade before and after road network upgrading. We compute ex-ante values for city-to-city trade, aggregate to country-to-country totals, and standardize to intercountry value totals from the IMFDOT data. To compute ex-post values, we upgrade minimum road link quality to 45 (intermediate between Zimbabwe and The Gambia) for all city pairs, re-compute intercity and intercountry index values, and standardize to the projected intercountry value totals from our econometric analysis of the IMFDOT data.

Our comparative results for the current and upgraded networks provide estimates of trade expansion for 77 cities, 36 countries, and 5 regions (West, Central, East, Southern and South Africa[28]). Table 7 displays regional values for current trade, estimated values after network upgrading, and changes.[29] Total within-region trade grows by $11.1 billion, with large gains in West Africa ($4.5 billion), Central Africa ($1.2 billion), and East Africa ($5.4 billion). Total cross-region trade grows by $8.6 billion, with $1.6 billion attributable to expanded trade among West, Central and East Africa, $5.3 billion to trade expansion between South Africa and West, Central and East Africa; $224 million to expanded trade between Southern Africa and West, Central and East Africa; and $1.4 billion to trade growth between Southern Africa and South Africa.

[28] Data problems prevent inclusion of cities in

Appendix Table A2 provides an impact assessment at the country level, sorted regionally by percent change. Current trade summarizes IMFDOT data for 2000-03; upgraded trade reflects the change attributable to road network improvement. In West and Central Africa, predicted trade growth is very rapid in several coastal states near Nigeria (Benin (436%), Togo (294%), Ghana (223%), Cameroon (264%)), as well as countries that have been largely isolated by bad roads (e.g. Chad (507%), Central African Rebublic (445%), Sudan (1,027%). The model predicts similar overland trade growth for Angola, Congo and Democratic Republic of Congo. However, their predicted growth rates in Table A2 are smaller because current export values are inflated by bulk minerals whose enclave production and export (by rail or ship) does not depend on road quality. In Southern Africa, road upgrading induces substantial trade expansion for Mozambique (168%) because of its prox 0. 2keWPd growth on for Mozam

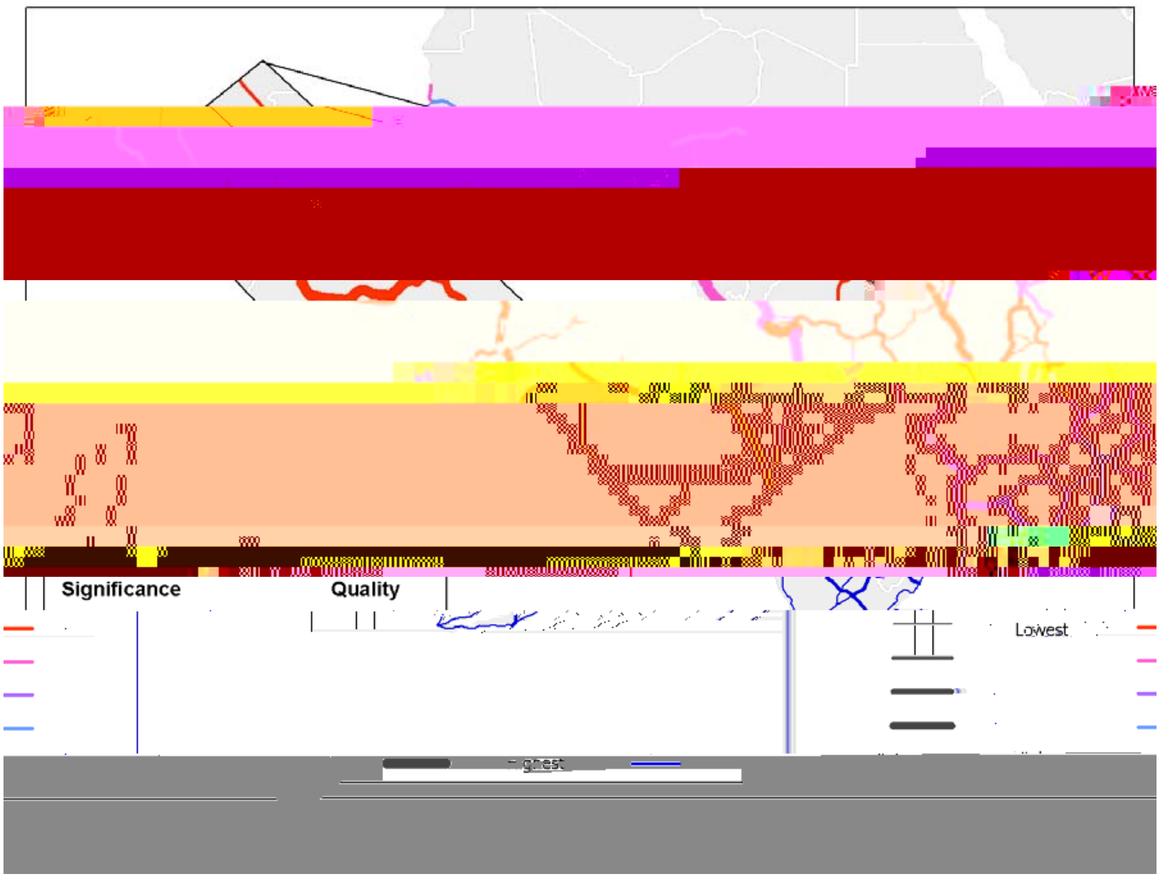
West Africa to East, Southern and South Africa are divided between two corridors with low road transport quality indices (RQI see Table 2). The first passes through Cameroon (RQI 18.4), Gabon (19.2) , Congo (Rep.) (13.6), Congo (D.R.) (3.8) and Angola (15.8). The second passes through the four countries with the lowest road quality indices in Africa: Chad (1.8), Congo D.R. (3.8), Central African Republic (4.4) and Tanzania (6.2). The result for this route is a low-level equilibrium trap. Interregional traffic is negligible because the roads in these countries are so poor. At the same time, poverty in the areas traversed by the roads is increased by their isolation. Under these conditions, our results suggest that network upgrading, including simultaneous improvement of road links in all four countries, would promote a very large expansion of local and interregional trade. Local improvements in one or two countries will not overcome the low-level trap, because risk-averse shippers will continue to judge the weakest link in assessing the profitability of interregional shipments.

A useful illustration is provided by estimated traffic volume in the Democratic Republic of Congo and, more specifically, on the road from Kisangani, in the northeast D.R. of Congo, to Bangui, Central African Republic. At present, road conditions are so poor that estimated traffic is very small; cost-benefit analysis based on local traffic counts would probably not justify the use of scarce resources to upgrade this road.[31] From a continental perspective, however, the situation looks very different. Of the 3,403 city pairs in our analysis, minimum-distance routes for 655 pairs include the road from Bangui to Kisangani (see Figure 3). As the enlarged component of Figure 3 shows, this is part of a link between West and Southern Africa in our configuration of the network.

[31] Salopek (2005) characterizes the roads of the northeast Congo D.R. as follows: "What words can be uttered about these roads? Clogged with mud, strangled by bush, reduced in many cases to absurd footpaths … The roads are no longer roads." (p. 84)

After upgrading, the baseline gravity model estimates that goods traded via this route would expand from a current value of $US 15.9 million to $US 142 million: a 793% increase.

Figure 3: Road Network Links: Current Quality and Potential Significance (West - Southern Africa Link Enlarged)



Figures 4 and 5 extend the results from one route to the entire network. Figure 4 displays estimated traffic volumes before upgrading, while Figure 5 displays percent changes in volume after upgrading. In Figure 4, the highest volumes are along the main western corridor (from Senegal to South Africa) and within southern Africa. Upgrading generates a striking pattern of continental change (Figure 5), with high volume growth rates in the interior regions of West, Central and East Africa, as well as along the main arteries that connect these regions. These high percentage ch

Figure 4: Current Trade Estimates for the Network ($US Million)

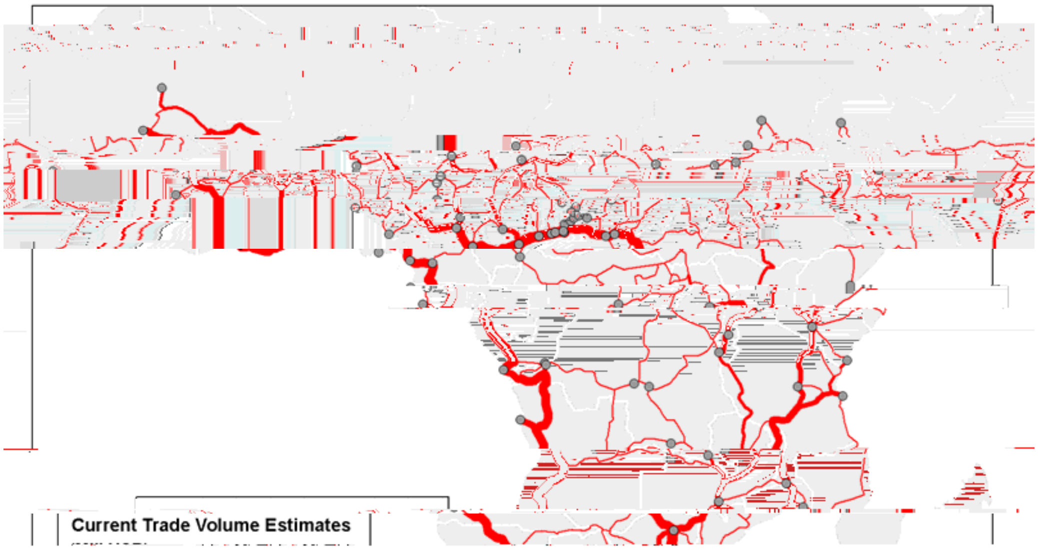
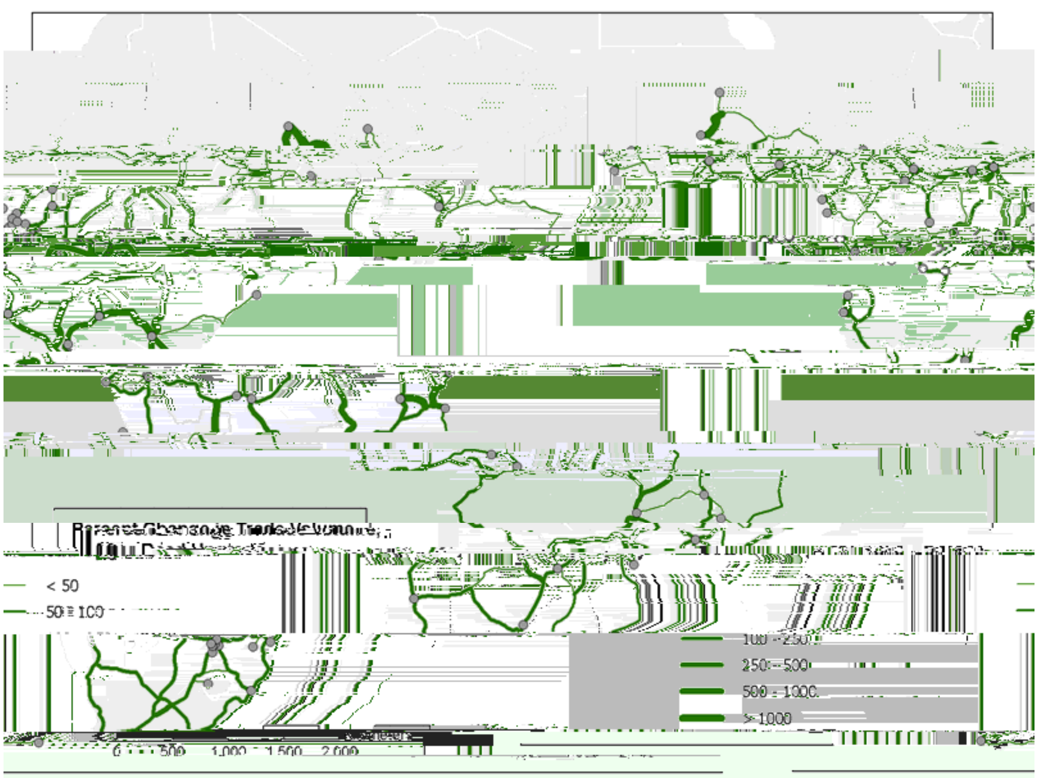


Figure 5: Percent Changes in Trade after Road Upgrading



Among all road links that form the Trans-African network, median traffic growth after upgrading is 182% at the median, 447% at the 75th percentile, and 1,295% at the

closer approximation, since they are primary roads connecting the major cities of each country with each other, and with the major cities of other countries. Not all World Bank projects have focused on primary roads, but it seems reasonable to assume that most of them have, in light of generally-poor road conditions and the scarcity of resources for and Institutional Assessments (CPIA). We employ the linear index in the reported regressions (Table 12); the log index gives the same (insignificant) result. We also introduce dummy variable controls for regions, to account for unobservable geographic factors, and for project types.

5.2 Cost Function Estimation: Results

Table 12 presents estimation results for the unit cost model. We discuss the results in column (2), which excludes governance because the latter is insignificant in column (1). The estimated parameter for rainfall has the expected sign, is highly significant, and indicates an important impact: Estimated unit costs rise about 1.4% for each 1% increase in rainfall intensity. The estimated elasticity for income per capita, our wage proxy, is also large and highly significant. Our results suggest that a 1% increase in income per capita increases road improvement costs by 0.75%. Percent paved is also highly significant, with a decrease of about 0.05 in the log of unit cost for every unit increase in percent paved. Given the strength of these results, we would expect significant inter-country differences in unit improvement costs, because Sub-Saharan countries exhibit wide variation in rainfall intensity, percent of roads paved and income per capita. As Table 11 shows, rainfall intensity varies 3-fold, percent paved over 60-fold, and income per capita about 20-fold in the countries connected by the network.

Our results indicate a pronounced cost effect in West Africa (significantly lower unit costs than the other regions), and the same wide dispersion of unit costs by work type that we have already observed in Table 8. The results suggest that, once we control for country characteristics, unit costs for upgrading projects are significantly different 8.t we control

Table 12: Determinants of Unit Costs for Road Upgrading and Maintenance

Dependent Variable: Log Road Project Unit Cost ($US/Km) from ROCKS

	(1)	(2)
Log Mean Rainfall	1.791 (2.44)*	1.355 (2.32)*
Percent Paved	-0.038 (2.28)*	-0.046 (4.58)**
Log Income Per Capita	0.709 (2.42)*	0.749 (2.67)**
Governance	0.309 (1.23)	
West Africa	-0.849 (1.32)	-0.730 (6.24)**
Central Africa	-0.339 (0.49)	
East Africa	0.139 (0.19)	
<u>Upgrading Categories</u>		
New 2-Lane Highway	2.057 (2.58)*	2.111 (2.66)**

pattern: Median maintenance costs vary from $5,900/km in West Africa to $18,200/km in Central Africa. We should stress that these variations are projected for the same project mix in each region.

Table 13: Regional Variations in Projected Unit Costs ($'000 US/km)

Upgrading				
Region	N	Min	Median	Max
West	16	70.2	135.0	309.0
Central	10	109.2	418.3	1,588.3
East	9	113.3	146.5	387.9
Southern	7	80.0	189.7	621.9
Total	42	70.2	167.7	1,588.3
Maintenance				
Region	N	Min	Median	Max
West	16	3.1	5.9	13.4
Central	10	4.8	18.2	69.1
East	9	4.9	6.4	16.9

being in poor condition.[35] For maintenance, our benchmark total annual cost estimate is $901 million, with standard error bounds at $683 million and $1.2 billion.

of the trans-African network generates trade flows that are far greater than the associated upgrade costs. We should stress that our benefit estimates are extremely conservative, since they do not include any inter-city trade expansion within countries (Nigeria alone has 18 cities in the network) or increased trade between Sub-Saharan countries and other parts of the world. Nor do they account for any induced growth from the expansion of inter-country trade. We conclude that the basic economics look very promising. In the next two sections, we turn our attention to the environmental and institutional implications of network upgrading.

6. Potential Environmental Impacts

Figure 4: Biodiversity in Road Network Corridors

full operation.[36] The agreement would ensure streamlined border procedures, finance and monitor needed repairs and maintenance, and implement measures to stop harassment of truckers for bribes at local road barriers. We should stress that donor support for this program would be strictly limited to the trans-African network links, which account for a modest part of primary and secondary road systems for most African countries. This limitation is necessary to preserve countries' incentive to use domestic resources for upgrading and maintaining their other roads. Existing national road funds would be well-spent on improving local access to the network on feeder roads, and the productivity of local funds would be greatly enhanced by the existence of the trans-African network.

and team size in a 90,000 km system,[38] annual vehicle and personnel costs for road monitoring (700 vehicles, 7,000 people) are approximately $US 400 million. Assuming 1,000 people for overhead support adds another $54 million. We estimate the annual cost of complementary airborne surveillance at about $56 million.[39] To summarize, the approximate annual cost for the requisite road and airborne monitoring system is about $500 million.

7.3 Working with Roadside Communities

A trans-African network cannot function properly if roadside communities constantly harass truckers for bribes. Under current conditions, local barricades are improvised "toll stations" for local police and other groups who have low wages (if any) and/or the power to extract payments from passing vehicles. Undoubtedly, these payments provide support for extended families in neighboring settlements, whose de facto local control will not change in the foreseeable future. Realistically, abutting settlements will only support barricade removal if they stand to gain from the change. For the trans-African network, the critical operational question is how to make barricade removal worth their while.

We believe that the requisite incentives would be provided by three factors. The first is employment and income generated by initial upgrading and continuous maintenance of the network, coupled with a clear prior understanding about barricade

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2.5 million person-years of employment and total labor income of $1.3 billion. Subsequent maintenance generates about 110,000 rural jobs, with an annual income flow of about $55 million. Comparison of employment generated with the abutting population range indicates a large local labor deficit during the upgrade, with consequent overflow benefits for more distant settlements. Assuming that 40% of the local population is employable on road construction,[42] annual maintenance demand can absorb between 4%

we find that approximately 67 million people, or 15% of SSA's total rural population, reside within the corridors.[43]

For abutting settlements, we believe that increased income and employment from construction, maintenance, and sales of goods and services would easily compensate for any loss of barricade-extracted payments. Since the network's road monitoring teams would circulate daily, villagers would be constantly reminded of the link between income growth and barricade-free passage. As insurance, however, it is also worth thinking about direct payment programs that are explicitly tied to the absence of barricades. As an added incentive for local support, such programs could provide village development funds, micro-credit, or cash transfers conditional on barricade-free road conditions.[44] They would probably work best if organized around regular payments in small increments, tied explicitly to monitored traffic flow.

We base our order-of-magnitude cost calculation for such a program on our estimate of abutting settlement numbers for the network, which we have explained in footnote 40. As we report in Appendix Table A6, the total number of settlements within 5 km of the continental network probably lies within the range 19,000 – 42,000. If we assume that 20% of settlement areas require additional compensation, at $20,000 per settlement annually, the total outlay is between $76 million and $168 million. To be conservative, we double the high-range estimate to $340 million. We believe that such costs would plummet once the abutting settlements perceived the full [illegible] network and brought pressure to bear on recalcitrant barrier-erectors. However, we include $340 million as a recurrent cost in our full accounting.

7.4 Network Benefits and Costs: A Summary Accounting.

We posit a 5-year period for network upgrading, followed by a 10-year period of network operation before a new upgrade would be needed. Our benchmark estimate for trade expansion is $19.7 billion annually, or $197 billion for the ten-year operational period. We assume that trade growth to full volume phases in continuously during the 5-year initial upgrade period, which adds $49.2 billion to total trade volume. The estimated cost of upgrading is $20.7 billion, with an annual maintenance cost of $900 million that would phase in during the first 5 years, and remain constant for the next 10 years. As we have previously noted, a significant percentage of these expenditures would generate jobs and income in high-poverty areas of rural Africa. Our estimate for the subcontinent is 8.4 million person-years of employment created by upgrading, and continuous employment of 365,000 people for maintenance. Conservative, order-of magnitude

To summarize, the balance sheet looks very good for network upgrading in Sub-Saharan Africa: total trade expansion between SSA countries over 15 years of $246 billion, weighed against total costs of $47 billion ($5.9 billion/year for the first five years and $1.8 billion/year thereafter) for multilateral and bilateral funding agencies supporting a trans-African consortium. Even though the monetary value of trade expansion is not a direct measure of welfare gain, we can assume that the direct and indirect benefits of greater trade will far exceed the costs—especially if upgrading and maintenance programs ensure that a large proportion of investments (i.e., costs) yields significant local employment and expenditure multipliers.[45]

Table 16: Trans-African Road Network: 15-Year Benefit and Cost Estimates ($US Billion)

	Upgrading (5 Years)	Operation (10 Years)
Trade Expansion	49.25	197.00
Cost Components		
Upgrading	20.70	
Maintenance	4.50	9.00
Admin, Monitoring	2.50	5.00
Settlement Programs	1.75	3.50
Total Trade Expansion	246.25	
Total Costs	46.95	

8. Summary and Conclusions

In this paper, we have estimated the benefits and costs of coordinated road network upgrading in Sub-Saharan Africa. Our simulated network uses minimum-distance routes over existing roads to connect 83 cities in mainland Sub-Saharan Africa: all 42 capital cities, as well as 41 other cities whose populations are 500,000 or greater. Using econometric estimates of gravity-model parameters for Sub-Saharan trade, we estimate

[45] See, for instance, Hertel and Winters (2005) for a recent discussion of the poverty reducing effects of increased trade.

trade flows in the network between 3,403 city pairs. The model incorporates economic scale for origin and destination cities (proxied by their estimated total incomes), the network road distance between them, and road quality in each transshipment country. We compute trade volumes for the current road network, and for an upgraded network with road quality comparable to current levels in The Gambia and Zimbabwe. Our results suggest that coordinated upgrading of the network would expand overland trade by about $250 billion over 15 years.

Using the World Bank's ROCKS database, we also estimate country-specific unit costs for upgrading and maintaining the 83-city road network. Our results indicate total between Sub-Saharan Africa and other regions has focused world attention and assistance on the region. Bilateral and multilateral development institutions have assigned Africa the highest priority, and donors appear willing to provide major resources for promising programs. Second, from a technical perspective, network upgrading can work because its goals are realistic. It seeks only to maintain basic quality standards in a limited network, rather than attempting improvement of all roads on the continent. Its operations and authority would be confined to the basic network of connector roads. It would avoid perverse financial incentives by leaving the greatest part of national road network improvement to budgetary support by national authorities. Third, all mainland Sub-Saharan countries should want to join the network, because their capitals and largest cities would be connected to it, and all would reap large gains from the expansion of trade. The potential gains should be sufficient for states to accept the desirability of streamlined border procedures and barricade-free roads. Fourth, we believe that large income increases from construction and service employment and expanded produce sales, coupled with direct compensation payments where needed, would provide sufficient incentives for road barricade removal. Fifth, and most important, we believe that coordinated road network upgrading is possible because Africa is ready for it. Governance is improving in many states, and a new, better-educated generation of leaders is ready to embrace the network's continental vision.

The final key to successful network upgrading would be willingness by donor countries to accept an unprecedented level of strategic coordination, as well as a 15-year commitment of approximately $47 billion. The donors would collectively provide long-term financial, technical and institutional support for the network. In return, our results suggest that network upgrading would offer an important economic opportunity for the subcontinent. If Sub-Saharan countries are ready to collaborate on this scale, then the donor countries should be prepared to follow their lead.

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Table A1
Trans-African Road Network Cities (*'s denote capital cities)

Region	Country	City	Region	Country	City
West	Benin	Cotonou*	South	South Africa	Soweto
	Benin	Porto Novo		South Africa	West Rand
	Burkina Faso	Ouagadougou*	Central	Angola	Luanda*
	Chad	N'Djamena*		Burundi	Bujumbura*
	Cote d'Ivoire	Abidjan*		Cameroon	Douala
	Cote d'Ivoire	Yamousoukro		Cameroon	Yaounde*
	Cote d'Ivoire	Bouake		Central African Republic	Bangui*
	Gambia, The	Banjul*		Congo	Brazzaville*
	Ghana	Accra*		Congo	Pointe-Noire
	Ghana	Kumasi		D.R. of Congo	Kinshasa*
	Guinea	Conakry*		D.R. of Congo	Kananga
	Guinea-Bissau	Bissau*		D.R. of Congo	Kisangani
	Liberia	Monrovia*		D.R. of Congo	Kolwezi
	Mali	Bamako*		D.R. of Congo	Lubumbashi
	Mauritania	Nouakchott*		D.R. of Congo	Mbuji-Mayi
	Niger	Niamey*		Equatorial Guinea	Bata
	Nigeria	Abeokuta		Gabon	Libreville*
	Nigeria	Abuja*		Rwanda	Kigali*
	Nigeria	Ado-Ekiti		Zambia	Lusaka*
	Nigeria	Enugu	East	Djibouti	Djibouti*
	Nigeria	Ibadan		Eritrea	Asmara*
	Nigeria	Ilesha		Ethiopia	Addis Ababa*
	Nigeria	Ilorin		Kenya	Mombasa
	Nigeria	Iwo		Kenya	Nairobi*
	Nigeria	Kaduna		Malawi	Blantyre-Limbe
	Nigeria	Kano		Malawi	Lilongwe*

Table A2
Country Trade Impacts of Network Upgrading
($US Million)[a]

Region	Country	Current	Upgraded	Change	% Change
West	Chad	20.5	124.5	104.0	507.3
	Benin	113.9	610.1	496.2	435.6
	Burkina Faso	105.6	499.2	393.6	372.7

* Current trade values are the averages of total exports and total imports for 2000-2003.

Table A3
City Trade Impacts of Network Upgrading
($US Million)

Region	Country	City	Current	Upgraded	Change	% Change

Region	Country	City	Current	Upgraded	Change	% Change

Table A4
Network Upgrade Costs by Country

Total Upgrade Cost ($US Million)	Upgrade Cost Per Km ($US '000)

Table A5
Network Maintenance Costs by Country

Region	Country	Total Cost ($US Million)			Cost Per Km ($US '000)			Network Length (Km)
		Baseline	Low (-1 SE)	High (+1 SE)	Baseline	Low (-1 SE)	High (+1 SE)	
West	Benin	3.9	3.4	4.4	4.2	3.7	4.8	931
West	Burkina Faso	9.3	7.8	11.2	5.9	4.9	7.1	1,590
West	Chad	16.2	13.5	19.5	7.8	6.5	9.4	2,071
West	Cote d'Ivoire	14.2	11.4	17.7	8.4	6.8	10.5	1,686
West	Gambia, The	0.6	0.4	0.9	5.9	4.1	8.4	105
West	Ghana	8.9	8.4	9.4	4.2	4	4.5	2,120
West	Guinea	29.1	20.1	42.1	10.6	7.4	15.4	2,733
West	Guinea-Bissau	4.9	3.3	7.3	10.9	7.3	16.2	450
West	Liberia	4.5	3.3	6	9.1	6.7	12.3	489
West	Mali	10.4	9.2	11.9	5	4.4	5.7	2,077
West	Mauritania	2.8	1.8	4.3	13.4	8.8	20.5	209
West	Niger	5.5	4.7	6.4	5.5	4.7	6.4	999
West	Nigeria	24.1	20.4	28.5	3.1	2.6	3.6	7,890
West	Senegal	10.4	8.1	13.5	5.3	4.1	6.9	1,964
West	Sierra Leone	4.2	3.2	5.5	6.8	5.2	9	609
West	Togo	2.2	1.9	2.4	3.1	2.8	3.4	703
Central	Angola	74.1	49	112.2	25.5	16.9	38.6	2,906
Central	Burundi	1.3	1	1.7	4.8	3.6	6.3	272

Table A6: Network Villages, Population and Construction Employment

Region	Country	Network Length (km)	Villages (Low)	Villages (High)	Village Pop. (Low)	Village Pop. (High)	Upgrade Person-Years	Maint. Person-Years	*Ann. Wage ($US)*
West	Benin	932	155	373	77,694	559,396	41,964	1,826	*749*
	Burkina Faso	1,590	589	589	750,197	750,197	95,712	4,165	*785*
	Chad	2,076	346	831	173,026	1,245,788	193,115	8,403	*675*
	Cote d'Ivoire	1,767	295	707	147,273	1,060,363	99,050	4,310	*1,156*
	Gambia, The	125	21	50	10,421	75,034	3,742	163	*1,331*
	Ghana	2,203	367	881	183,624	1,322,093	48,012	2,089	*1,493*
	Guinea	2,968	495	1,187	247,324	1,780,731	157,089	6,836	*1,490*
	Guinea-Bissau	450	75	180	37,459	269,704	66,264	2,883	*594*
	Liberia	624	104	249	51,962	374,123	67,655	2,944	*529*

Table A7: Trade Agreements in Sub-Saharan Africa

Country	WAEMU	CEMAC	EAC	ECOWAS	SADC	COMESA
Benin	X			X		
Burkina Faso	X			X		
Cote d'Ivoire	X			X		
Guinea-Bissau	X			X		
Mali	X			X		
Niger	X			X		
Senegal	X			X		
Togo	X			X		
Cameroon		X				
Central African Republic		X				
Chad		X				
Congo		X				
Equatorial Guinea		X				
Gabon		X				
Kenya			X			X
Tanzania			X		X	
Uganda			X			X
Gambia, The				X		
Ghana				X		
Guinea				X		
Liberia				X		
Nigeria				X		
Sierra Leone				X		
Angola					X	X
Botswana					X	
Dem.Rep. of Congo					X	X
Lesotho					X	
Malawi					X	X
Mozambique					X	
Namibia					X	
South Africa					X	
Swaziland					X	X
Zambia					X	X
Zimbabwe					X	X
Burundi						X
Djibouti						X
Eritrea						X
Ethiopia						X
Rwanda						X
Sudan						X
Mauritania						
Somalia						