Land Transport for Exports:

The Effects of Cost, Time, and Uncertainty in Sub-Saharan Africa

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ABSTRACT: The process of moving goods from the exporter's location to the port involves significant financial costs, as well as costs associated with lengthy and uncertain delivery times. We illustrate these costs by considering exports from landlocked countries in sub-Saharan Africa (SSA). Inland transport costs and time delays are a much larger share of total export costs and time for landlocked countries, and vary substantially between different geographic corridors. The experience of exporters shows that the sources of these costs are diverse, and include weak infrastructure, imperfect information, and corruption. An analysis of unit costs and costs of time for land transport of particular export commodities reveals a pattern of high costs for many agricultural products and low costs for metals and other high-value products, which frustrates the ability of SSA countries to participate in exports involving vertically integrated production processes. Uncertainty in a system including both land and maritime transport for exporting is illustrated by use of a simulation model. Relationships among uncertainty, infrastructure quality, and other features of logistics systems and export markets are highly non-linear, and can be potentially used to identify priorities for trade facilitation.

Introduction

       This paper is designed to examine several underexplored themes in the economics of trading costs. First, high transaction costs in trade are not simply analogous to high tariffs, which arise from a single policy instrument and can be reduced by a single action. High transaction costs are associated with interactions among multiple layers of transport, infrastructure, policy, and geography, often involving several countries. This means that trade facilitation efforts targeted at a single point in the process can be easily frustrated. As has been observed, and Macchi note, "infrastructure projects in Sub-Saharan Africa have not had the expected impact on the reduction of transport prices."(Raballand and Macchi, 2008b) Second, the available metrics for transaction costs in international trade, while useful for international comparisons, are not well designed for assessing the impact of high transaction costs from the point of view of an exporter in a particular location exporting a particular good. Third, the role of uncertainty in costs and time is sufficiently large that it ought to be treated, along with financial costs and time costs, as an independent dimension in assessing the level of transaction costs experienced by exporters and importers.

       We address each of these themes by focusing on the part of the exporting to process that involves moving goods from the exporter's physical location (ex-farm, ex-factory) to the port. The movement-to-port process involves transaction costs comparable in magnitude to other stages of the process, such as port procedures and shipping, tariffs and customs procedures, and wholesale-retail markups in the importing country. Though these themes apply broadly to developing economies, we use the landlocked economies of sub-Saharan Africa (SSA) as a context in which they are most visible.

It has been noted with increasing frequency that costs and time associated with importing and exporting in SSA are particularly high by global standards. Cross-regional analysis of the World Bank Doing Business data indicate that on average SSA countries generally have the largest time, cost, and documentation requirements compared to other geographic regions of the world.[1] These additional costs both reduce the volume of SSA trade and affect the ability of countries in the region to diversify, particularly hampering entry into markets that involve importing-to-export, such as electronics and apparel. It is also generally recognized that landlocked countries experience substantially larger trading costs and times compared to coastal countries.

The gravity modeling literature is replete with estimates that dramatize the effects of landlocked status on trade. To cite only a few examples, Limão and Venables (2001) find that the cost of shipping a container from the port of Baltimore is $3,450 higher for shipping to a landlocked country, relative to a baseline cost of $4,620 for a non-landlocked destination. Raballand (2003) estimates that landlocked status reduces trade of central Asian countries by 80 percent. Djankov, Freund, and Pham (2006) note that the time to export is highest for landlocked countries, often amounting to many weeks, and estimate that an additional day's delay is associated with a 7 percent decline in exports of time-sensitive agricultural goods relative to time-insensitive agricultural goods.

Although it is increasingly and generally accepted that increased costs and time delays raise costs to SSA producers, and therefore hamper SSA participation in global trade, the role of uncertainty is less often acknowledged and quantitatively assessed. In their paper assessing the costs of travel time uncertainty and benefits of time information, Ettema and Timmermans (2006) observe that although research has provided insight into the effect of reduced congestion

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[1] Other databases confirm this general finding. For example, the Logistics Performance Index cross-regional and cross-income level analyses show SSA and low-income countries in general ranking very low in various logistics performance indicators.

in decreasing travel time, the practice of focusing on travel time "overlooks a second source of user benefits: the reduction of travel time uncertainty." The role of uncertainty is, nevertheless, receiving increased attention. For example, Raballand and Marteau state that "delays increase costs and the uncertainty of delivery—and that's as big a problem as a lengthy transport process." (World Bank, 2008a) Similarly, Arvis, Raballand, and Marteau (2007) comment that "transportation costs only explain one part of the real impact of being landlocked. Delays and even more importantly low degree of reliability and predictability of services create massive disincentives to invest and higher total logistics costs," and, therefore, "are even more important in constraining their trading and thereby growth prospects."

The pathologies of high cost, time, and uncertainty in exporting extend beyond SSA, as well as beyond the set of countries that are landlocked in the strict sense. Indeed, the issues raised in this paper may apply to most of the developing world. Large regions of coastal countries are remote from the port. Exporting from northern Ghana may be more difficult than exporting from the capital of Burkina Faso, even though Ghana has a port and Burkina Faso does not. Exporting from the middle of the Congo River basin is as difficult as from anywhere in the world. Although Brazil, China, and India have extensive coastlines, the interiors of these countries face movement-to-port barriers comparable to those of landlocked countries. Moreover, even the port locations in developing countries are subject to time and cost disadvantages such that they are essentially as remote from world markets as inland locations in countries with better logistics.

The first section of this paper outlines some stylized facts regarding trading costs for SSA from the widely used Doing Business Trading Across Borders data, focusing on differences between landlocked and coastal countries in general and along four principal trading corridors. The costs and time associated with movement to port are shown to vary widely across sub-

regions in SSA. That is, they are corridor-specific. Second, we illustrate some of the realities

underlying high costs on the ground with a series of illustrative examples. Third, we combine

various data to obtain a fuller picture of the costs associated with movement to port. These costs

vary across products and corridors in a manner that demonstrates the bias of the logistics system

toward exports of high-value primary commodities and against basic agricultural products and

goods requiring several steps in the supply chain.

Finally, we focus on the interacting roles of uncertainty in road and ship transport using a

simplified simulation model of the movement to port implemented using numerical methods.

The results demonstrate the existence of substantial non-linearities in the benefits of addressing

different components of the logistics system, such as physical infrastructure, port district

conditions, information, and corruption. The returns to each of these depend to a great extent on

the status of the rest of the system. We find evidence both for low-level poverty traps in which

returns to certain improvements are low, and for increasing returns to other investments under

the right conditions. These results suggest that it may be possible to develop general principles

for prioritizing of trade facilitation activities to maximize social return on investment, as well as

structures for data collection useful in refining and focusing future analysis.

Cost and Time: Stylized Facts

The World Bank Doing Business – Trading Across Borders[2] indicators provide data on

import and export costs and time, which allow us to present some stylized facts about the

importance of land transport costs and time in SSA and the additional effects of being

landlocked. Figure 1a reflects the relatively strong association of costs and time to trade for SSA

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[2] The Doing Business data on costs and time are collected for a standardized logistics environment. Included among the assumptions that a domestically owned private company located in the country's largest city and exporting a significant share of its goods exports using a dry-cargo, 20-foot full container load that does not require special treatment for refrigeration, SPS or environmental safety standards other than accepted international standards, or hazardous or military items. See Djankov, Freund, and Pham (2006) for more details.

(R^2=0.60). Figure 3b further demonstrates the driving factor of inland transport costs and time in this association. The relationship between time and cost is even more strongly correlated (R^2=0.84) in figure 3b.

Geographic location, however, plays an important role in the cost and time associated with exporting. Figures 2a and 2b show that median average total export costs in SSA for landlocked countries (LL) are 92 percent larger than for coastal countries (CC), and the average total export time for landlocked countries is 56 percent more than that for coastal countries. These disparities are even larger when examining the inland transport cost component of total trade costs. Figures 2a and 2b also indicate that the inland trasport cost for the median landlocked country in SSA exceeds that of the median coastal country by 328 percent. Similarly, inland transport time for the median landlocked country exceeds that of the median coastal country by 337 percent.

Not all landlocked countries experience the same level of constraints, however. The relative burden of being landlocked is also affected by regional location, as landlocked countries depend largely on transport corridors and the land transport (hard and soft[3]) infrastructure of neighboring countries (see map below[4]). As illustrated on the map, the main transport networks and corridors (as well as ports) are regionally based. The regional groupings of the countries in the analysis discussed below are based on these regional networks/corridors as cost and time are, in part, driven by features of these networks/corridors. The four regions are Western (spanning from the coastal countries of Senegal to Nigeria), Central (from Cameroon to DROC), Southern (from Angola around South Africa to Mozambique), and Eastern (from Tanzania to Kenya); these regions include the landlocked countries that make use of their respective

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[3] Soft infrastructure includes transport-related regulations, customs requirements, (legal and illegal) road blocks, and (formal and informal) facilitation payments.
[4] Map sourced from USITC (2009).

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networks/corridors to access coastal ports.[5] In figures 3a and 3b we further categorize the data

and present inland transport costs and time to export by region and geographic status. From these

representations, it is evident that, regardless of region, landlocked countries fare worse than

almost all coastal countries. In addition, costs and time to export improve for landlocked

countries as one moves from Central Africa to East Africa to Southern Africa to West Africa,

reflecting not only the quality and level of integration of transport infrastructure in these regions,

but also the number of ports, port countries, and routes available to landlocked countries in each

region. Whereas the Central and Eastern regions have one and two ports of entry available to

landlocked countries, respectively, the Southern and Western regions have four and five ports of

entry, respectively.[6] The landlocked countries in Central Africa (Chad and the Central African

Republic) experience, by far, the most costly and lengthiest time to export. Notably, despite

being a coastal country, Angola fares worse in terms of time required to export than most

countries that are better integrated into South Africa's infrastructure network.

Table 1 data not only reflect the regional differences in the cost and time to export from

SSA, but also the levels of discrepancy between landlocked and coastal countries by region.

Overall, SSA inland transport and handling costs are approximately 4.5 times larger for

landlocked countries than for coastal countries, and represent a larger percent of total costs and

time to export. For the Central African region, however, these costs are 7 to 7.5 times larger for

landlocked countries. Additionally, although the Western African region may have an overall

lower average cost and time for exporting than the Southern African region, the discrepancy

between landlocked and coastal countries is smaller (2 to 3 times versus 3 to 4 times) for the

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[5] Due to lack of Doing Business data for Djibouti (a major port for the region) and Somalia, we do not include a Northeastern region. Also, as this map reflects, there are alternate outlets available to Zambia (primarily through the Southern region or Eastern region). For the purpose of this analysis, Zambia is grouped in the Southern region.
[6] Central (Douala); Eastern (Mombasa, Dar es Salaam); Southern (Durban, Walvis Bay, Mozambique, Dar es Salaam); Western (Abidjan, Tema, Lome, Cotonou, Dakar). See Arvis, Raballand, and Marteau, "The Cost of Being Landlocked," appendix 1.

Southern African region. This result could possibly reflect the shorter distances and larger

number of port countries in the Western African region, but better regional transportation

integration in the Southern African region.

Map of Land Transport Routes and Major Ports in SSA
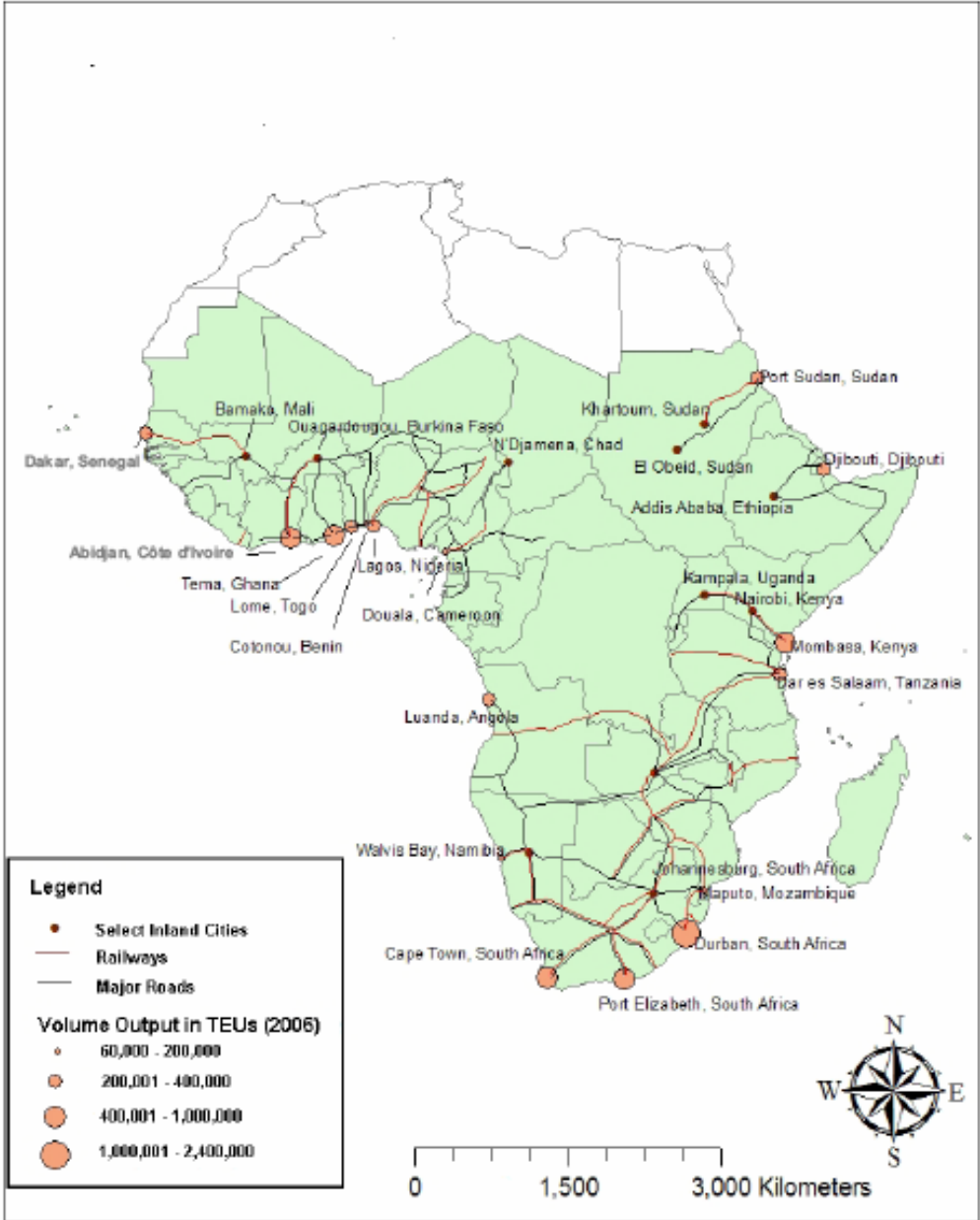
Note: TEU refers to a twenty-foot equivalent unit, the cargo capacity of a standard shipping container 20 feet long and eight feet wide.

Figure 1a

Total Cost and Time to Trade

$R^2 = 0.6027$

Labeled points: Chad, Angola, Eritrea, CAR, Rwanda

Legend:
- Landlocked countries
- Coastal countries

Y-axis: Days
X-axis: $0 to $12,000

Figure 1b

Inland Transport Cost and Time to Trade

$R^2 = 0.8352$

Labeled points: Chad, Burundi, CAR, Rwanda

Legend:
- Landlocked countries
- Coastal countries

Y-axis: Days
X-axis: $0 to $9,000

Figure 2a

Export Trade and Inland Transport Costs [Coastal (CC) vs Landlocked (LL) Countries] in SSA

Figure 2b

Export Trade and Inland Transport Time [Coastal (CC) vs Landlocked (LL) Countries] in SSA

Figure 3a

Inland Transport Cost to Export by Region and Geographic Status

Legend:
- ● Landlocked countries
- ◆ Coastal countries

Central
- Chad ● 4000
- Central African Rep ● 3900
- DROC ◆ 1100
- ROC ◆ 850
- Eq Guinea ◆ 359
- Gabon ◆ 300
- Cameroon ◆ 242

Eastern
- Uganda ● 2500
- Rwanda ● 2300
- Burundi ● 1600
- Kenya ◆ 900
- Tanzania ◆ 200

Southern
- Zambia ● 2100
- Botswana, Zimbabwe ● 2000
- Swaziland ● 1486
- Malawi ● 1000
- Lesotho ● 900
- South Africa, Namibia ◆ 800 to 814
- Angola, Madagascar ◆ 500
- Mozambique ◆ 300
- Mauritius ◆ 100

Western
- Niger ● 1869
- Burkina Faso ● 1200
- Mali ● 817
- Cote d'Ivoire ◆ 700
- Liberia, Mauritania, Ghana ◆ 400 to 455
- Guinea-Bissau, Guinea, Togo / Senegal, Sierra Leone, Benin ◆ 232 to 320
- Gambia, Nigeria ◆ 145 to 180

Y-axis: $0, $500, $1,000, $1,500, $2,000, $2,500, $3,000, $3,500, $4,000, $4,500

Source and Notes: World Bank Doing Business, Trading Across Borders Data, 2009; Export values; WB data does not include Djibouti and Somalia. Also excludes small island nations (Cape Verde, Comoros, Sao Tome & Principe, and Seychelles) and northeastern countries (Ethiopia, Eritrea, and Sudan).
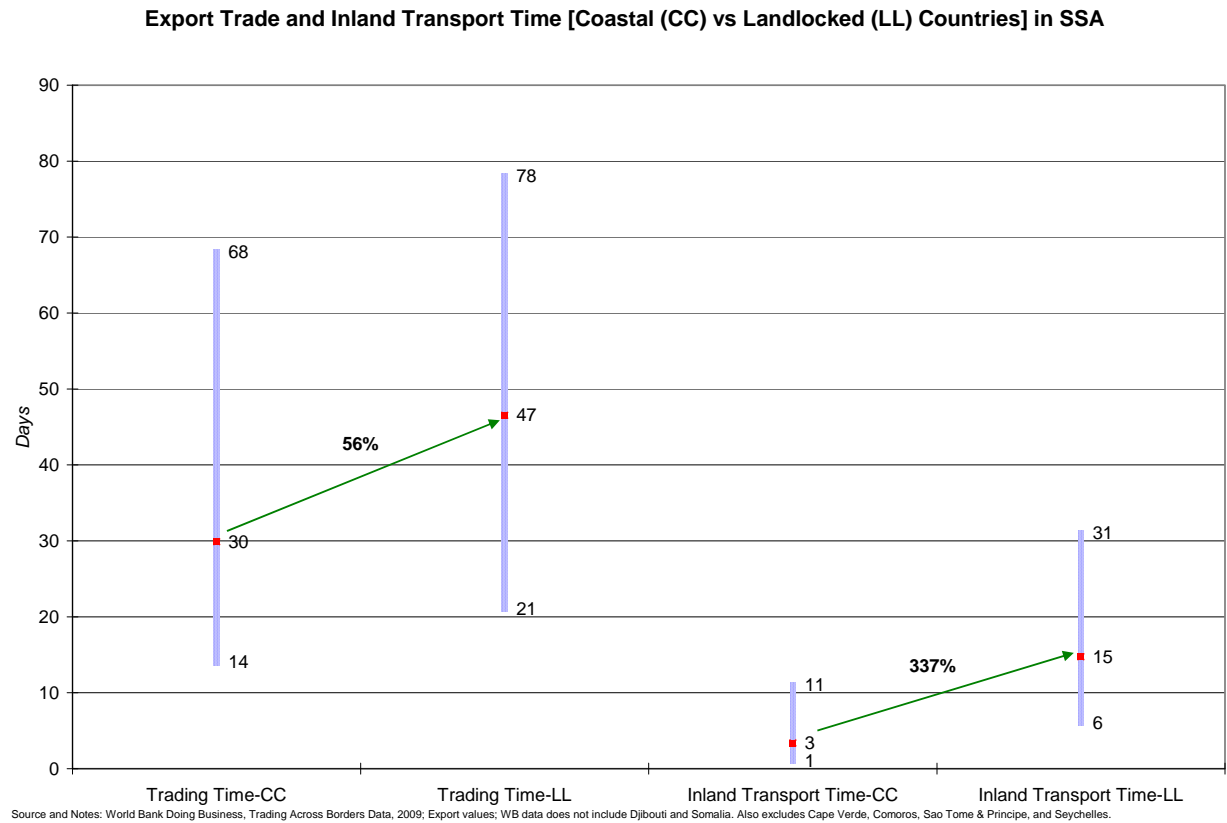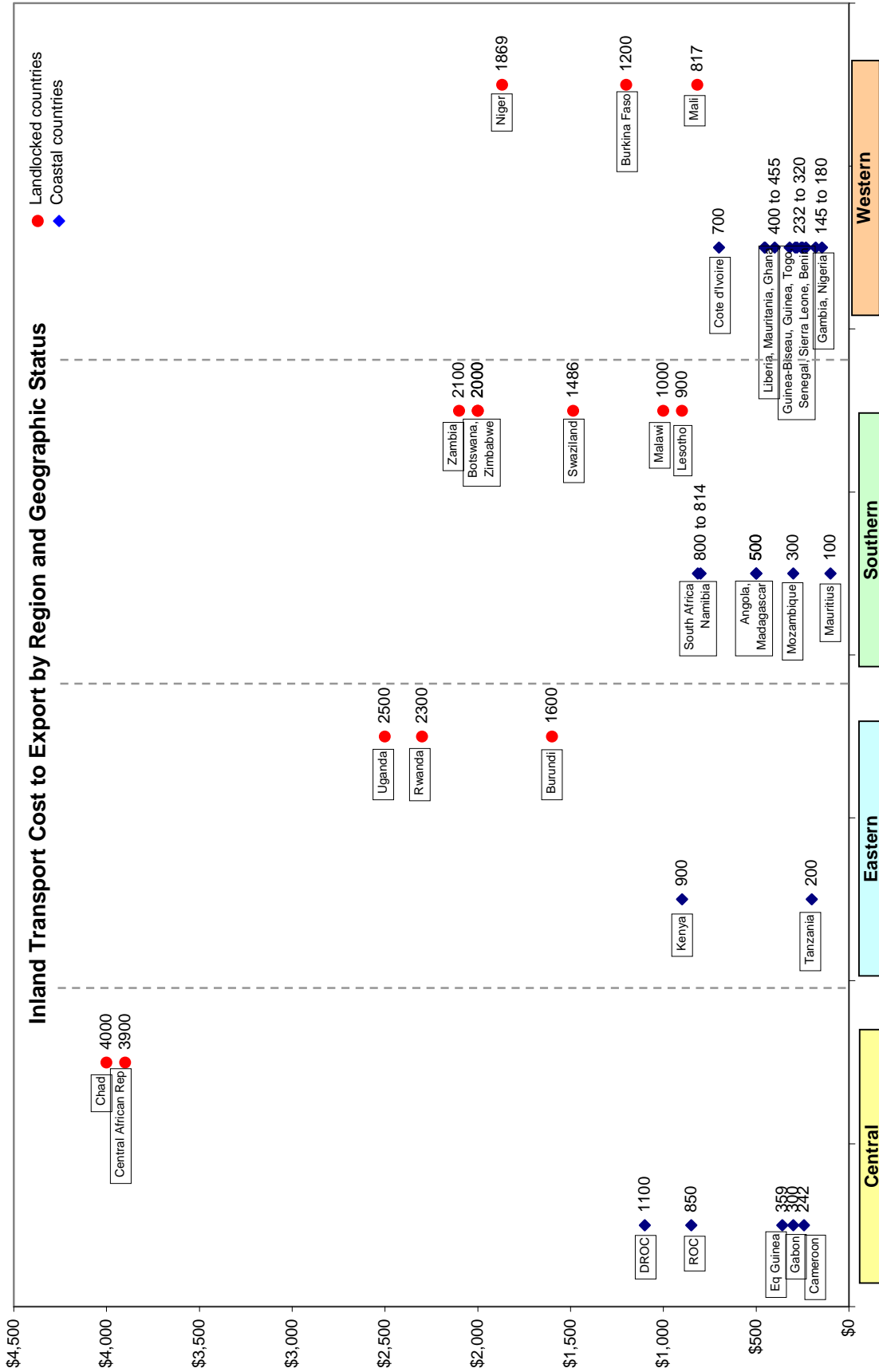
Figure 3b
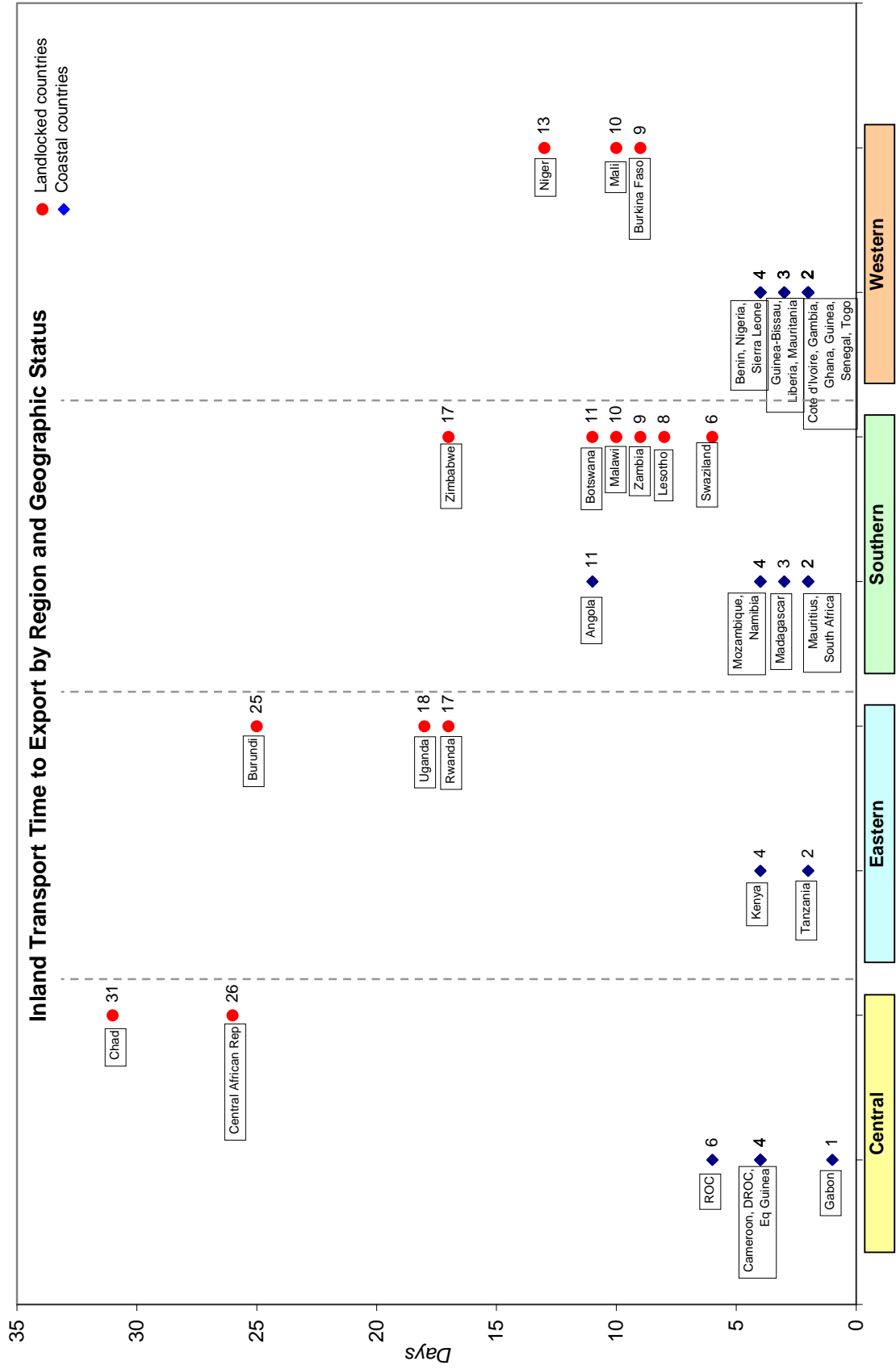

Inland Transport Time to Export by Region and Geographic Status

Source and Notes: World Bank Doing Business, Trading Across Borders Data, 2009; Export values; WB data does not include Djibouti and Somalia. Also excludes small island nations (Cape Verde, Comoros, Sao Tome & Principe, and Seychelles) and northeastern countries (Ethiopia, Eritrea, and Sudan).

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Table 1. Costs and Time to Export: Comparison by region and geographic status

Region	Nature of Export Procedure	Cost ($) or Time (days)	Average Value		Percent of Total Cost		Region Discrepancy
			Coastal Countries [CC]	Landlocked Countries [LL]	Coastal Countries [CC]	Landlocked Countries [LL]	[LL] / [CC]
SSA	Customs clearance & tech control	Cost	276.3	185.4	19%	6%	0.67
	Customs clearance & tech control	Time	4.5	3.6	16%	8%	0.80
	Documents preparation	Cost	346.2	328.4	24%	12%	0.95
	Documents preparation	Time	15.7	23.4	54%	50%	1.49
	Inland transportation & handling	Cost	437.0	1,976.6	30%	69%	4.52
	Inland transportation & handling	Time	3.4	15.0	12%	32%	4.46
	Ports & terminal handling	Cost	374.0	362.7	26%	13%	0.97
	Ports & terminal handling	Time	5.4	4.6	19%	10%	0.85
	Total	Cost	1,433.6	2,853.1	100%	100%	1.99
	Total	Time	28.9	46.6	100%	100%	1.61
Central	Customs clearance & tech control	Cost	308.6	366.0	16%	7%	1.19
	Customs clearance & tech control	Time	6.6	3.0	19%	4%	0.45
	Documents preparation	Cost	544.6	561.0	29%	11%	1.03
	Documents preparation	Time	20.6	33.0	60%	49%	1.60
	Inland transportation & handling	Cost	570.2	3,950.0	30%	75%	6.93
	Inland transportation & handling	Time	3.8	28.5	11%	42%	7.50
	Ports & terminal handling	Cost	466.2	367.0	25%	7%	0.79
	Ports & terminal handling	Time	3.6	3.0	10%	4%	0.83
	Total	Cost	1,889.6	5,244.0	100%	100%	2.78
	Total	Time	34.6	67.5	100%	100%	1.95
Eastern	Customs clearance & tech control	Cost	210.0	73.3	13%	3%	0.35
	Customs clearance & tech control	Time	5.0	4.0	19%	9%	0.80
	Documents preparation	Cost	560.0	280.0	34%	10%	0.50
	Documents preparation	Time	13.5	13.3	51%	31%	0.99
	Inland transportation & handling	Cost	550.0	2,133.3	33%	75%	3.88
	Inland transportation & handling	Time	3.0	20.0	11%	47%	6.67
	Ports & terminal handling	Cost	338.5	350.7	20%	12%	1.04
	Ports & terminal handling	Time	5.0	5.3	19%	13%	1.07
	Total	Cost	1,658.5	2,837.3	100%	100%	1.71
	Total	Time	26.5	42.7	100%	100%	1.61

Southern	Customs clearance & tech control	Cost	310.5	114.8	22%	5%	0.37
	Customs clearance & tech control	Time	4.0	3.7	12%	9%	0.92
	Documents preparation	Cost	308.8	261.5	22%	12%	0.85
	Documents preparation	Time	16.3	23.2	51%	56%	1.42
	Inland transportation & handling	Cost	502.3	1,581.0	35%	72%	3.15
	Inland transportation & handling	Time	4.3	10.2	13%	25%	2.35
	Ports & terminal handling	Cost	309.2	251.7	22%	11%	0.81
	Ports & terminal handling	Time	7.5	4.2	23%	10%	0.56
	Total	Cost	1,430.8	2,209.0	100%	100%	1.54
	Total	Time	32.2	41.2	100%	100%	1.28
Western	Customs clearance & tech control	Cost	256.8	318.0	21%	12%	1.24
	Customs clearance & tech control	Time	3.8	3.3	15%	7%	0.89
	Documents preparation	Cost	246.6	355.7	20%	14%	1.44
	Documents preparation	Time	13.7	27.7	54%	58%	2.02
	Inland transportation & handling	Cost	330.1	1,295.3	27%	51%	3.92
	Inland transportation & handling	Time	2.8	10.7	11%	23%	3.88
	Ports & terminal handling	Cost	374.0	594.0	31%	23%	1.59
	Ports & terminal handling	Time	5.1	5.7	20%	12%	1.11
	Total	Cost	1,207.4	2,563.0	100%	100%	2.12
	Total	Time	25.3	47.3	100%	100%	1.87

Source and notes: World Bank Doing Business, Trading Across Borders Data, 2009, export values. Doing Business data does not include Djibouti and Somalia. Data in this analysis also exclude small island nations (Cape Verde, Comoros, Sao Tome & Principe, and Seychelles) and the northeastern countries (Ethiopia, Eritrea, and Sudan).

Cost, Time, and Uncertainty: Illustrative Examples[7]

In general, inland transport in SSA is characterized by high costs, long times, and high levels of uncertainty. Although geographic features, such as low road density, contribute to costs, time, and uncertainty, other factors include regulation, market structure, administrative barriers, and corruption. Below are some summaries and illustrative examples that detail the particular problems experienced by SSA exporters. These anecdotes complement the stylized facts above, providing a comprehensive view of costs, time, and uncertainty of exporting from SSA.

High Costs and Time of Land Transport

In a review of numerous studies, Raballand and Macchi broadly summarize that transport prices are high in Africa compared to other regions, and highlight one study that finds that "transport prices for most African landlocked countries range from 15 to 20 percent of import costs, which is three to four times higher than in most developed countries." (Raballand and Macchi, 2008a) Portugal-Perez and Wilson conclude that "transport prices in Africa are more expensive and provided at a lower quality, as measured by the LPI [Logistics Performance Index]. Moreover, an inverse relationship between transport quality and transport price as the greater the LPI, the better the transport quality. The Central African region is an extreme case of high prices associated with low quality." (Portugal-Perez and Wilson, 2008) Anecdotal information also supports the negative cost effects associated with the relatively high costs of inland transport. A USITC report states that "Rwandan coffee is transported over 1,500 km on

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[7] Much of the anecdotal information in this section is sourced from USITC, *Sub-Saharan Africa: Effects of Infrastructure Conditions*, 2009 (forthcoming).

roads of variable quality via Uganda to the port in Mombasa, Kenya, or alternately by road and rail to Dar es Salaam, Tanzania. Transport costs may represent up to 40 percent of total costs of Rwandan coffee exports. One apparel producer near Nairobi, Kenya, estimated that improvements in all aspects of the transport process, including ports, roads, and customs procedures, could lower total costs by 10–40 percent and improve the firm's competitiveness." (USITC, 2009) Additionally, shea butter producers in West Africa incur additional transport costs associated with poorly maintained roads and rainy seasons as high vehicle repair costs raise rental rates and increase overall transport prices. (USITC, 2009) Another report notes that in Uganda, "transport costs add the equivalent of an 80 per cent tax on clothing exports." (Commission for Africa, 2005)

In addition to the high cost of land transport, the time associated with land transport is also extremely long for landlocked SSA countries. Although the poor quality of land transport infrastructure is an important factor, administrative hurdles at border crossings also substantially compound delays. A study assessing the determinants of transport prices and costs, reports that an important component in delays is waiting for administrative procedures. It cites, for example, that along a corridor "in East Africa, truckers usually lose up to four hours in reduced speed because of road conditions along some segments but spend, on average, more than one day at the border-crossing between Kenya and Uganda." (Raballand and Macchi, 2008) In some West African corridors, road blocks may occur every 30 kilometers or less; and in 2003, the border delay between South Africa and Zimbabwe (Beit Bridge) reached 6 days. (Arvis, Raballand, and Marteau, 2007) The Regional Trade Facilitation Programme cites the motivation for the Zambia-Zimbabwe one-stop-border-post: "The border post at Chirundu on the Zambezi

River is one of the busiest inland border crossings in the whole of southern and eastern Africa with an average of 270 trucks a day carrying goods between Zambia, DR Congo, Tanzania and Malawi and the countries south. Private vehicles must weave their way, for several kilometres on both sides of the border, in and out of queues of trucks which have to wait an average of 4 days to clear Customs. With an average of 581 travellers a day passing through Immigration, the scale of the traffic congestion becomes clear."[8] A 2009 USITC report relates that, because of administrative procedures at borders, trucks can lose more time at borders than in transit (e.g., 6 times more time at the Uganda-Kenya border post), and can spend days at border crossings (e.g., an average of two days at the Uganda-Kenya border post in Malaba, one day at the Uganda–Rwanda border post in Gotuma, and up to 2weeks at the Central African Republic-Cameroon border). (USITC, 2009)

Due to poor road and rail infrastructure conditions, susceptibility of such infrastructure to destruction by weather or civil unrest, and other delays on land transport, the shortest and most direct route is not necessarily the most economically feasible route. Anecdotal examples illustrate the burden felt by traders in SSA. For example, "Burundi's most direct route to the coast is through neighboring Tanzania, but infrastructure along this route is so poor that the primary Burundian transit route to Mombasa is via Rwanda, Uganda, and Kenya, an additional 600 km. Due to bridges washing out in Togo, many freight shipments from northern Togo must travel to Tema, Ghana, via Ouagadougou, Burkina Faso, a detour of an estimated 1,750 km that contributes to overuse of and damages to Burkinabé roads." (USITC, 2009) In addition, "Although large quantities of shea butter are produced in western Burkina Faso and more direct routes to the ports of

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[8] "OSBP: Zambia – Zimbabwe," http://www.rtfp.org/zam_zim.php (accessed April 6, 2009).

Abidjan, Côte d'Ivoire, and Tema are available, western Burkinabé shea exporters often ship products through Ouagadougou to the northeast to reach Tema because of poor road conditions along the more direct routes. According to one shipper, this detour, which adds approximately 1,500 km to a trip originally only 1,300 km, avoids the nearly impassable roads in northwestern Ghana. Similarly, Togolese shea exporters generally ship from the port in Lome, Togo, the closest port. However, because of a recently collapsed bridge along the primary corridor to the port, and poor road conditions rendering an alternative route impassable, many Togolese exporters must transport shea via Ouagadougou in the north and export through Tema rather than through Lome. This diversion adds an estimated 1,750 km to a trip that would otherwise be 650 km." (USITC, 2009)

Uncertainty of Land Transport

Ad-hoc administrative hurdles, unpredictable and ever-changing road and rail conditions, and corruption and other informal payment demands contribute to a high level of uncertainty with regard to land transport. A 2009 USITC report mentions that "trucks in Ghana traveling from Paga (on the northern border with Burkina Faso) to Tema (on the Gulf of Guinea) take two to four days under normal conditions, but an estimated 10–20 percent of trucks are delayed by a week or more; moreover, if a truck breaks down on this route, it can take up to three weeks to procure a mechanic from Kumasi in south-central Ghana." (USITC, 2009) According to Arvis et al., although the transit time is approximately 8 days along the Central corridor (Dar es Salaam to Kampala), it can also exceed 15 days; and, whereas the total travel time between Mombassa and Kigali was 25

days in 2005, the standard deviation was 10.5. (Arvis, Raballand, and Marteau, 2007) In assessing the role of infrastructure on the leather industry, the 2009 USITC report comments that of the hides and skins that reach the leather factories, 20 percent of them, on average, are rejected because of poor quality stemming, in part, from poor land transport, although rejection rates can reach 80 percent. (USITC, 2009) This uncertainty means that the time and costs of transport can not be predictably factored into the cost of doing business; from a business or investment perspective, a long, but certain, transport time may be preferable to a (potentially) shorter, but unpredictable, transport time.

Where uncertainty increases the negative effects of poor land transport on trade costs and time, the interaction of uncertainty among multiple modes of transport further compounds these effects. For example, Marteau comments that "uncertainty in ports is extremely high, and it affects the whole system." (World Bank, 2008b) Additionally, the USITC summarizes some of the effects of the interaction of uncertain land and maritime transport, reporting that "a lack of resources to repair washed-out bridges, delays due to roadblocks and checkpoints, and occasional hijackings also contribute to highly unpredictable truck arrival times at the port. If warehouse capacity at the port is insufficient, trucks may serve as ad hoc warehouses until the ship arrives, exposing goods to the risk of theft, and drivers may need to be compensated for food and lodging in the port city while awaiting the ship. Further, delays may lead to spoilage of perishable goods. Conversely, trucks may also arrive too late and miss the ship, as arrival times for container lines are uncertain, in part because of accumulated delays at previous port calls. Moreover, fewer containers may be loaded onto the ship than were contracted for, requiring some of the goods to be left behind on the dock. Ships that are loaded but

unable to leave the port on schedule because of logistical inefficiencies may incur port charges for demurrage, another unpredictable event. If perishable produce arrives at import markets in a spoiled state, exporters may receive no compensation, and claims may be filed against shipping lines for the losses incurred by the importer." (USITC, 2009)

This uncertainty leads to numerous costs such as scheduling costs, information costs, suboptimal inventory levels, supply chain redundancy, and reduced orders. A study of landlocked countries notes that "Operators need to hedge in view of the unreliable service delivery - either through increasing inventories or through switching towards alternative but more expensive transport modes;" and that anecdotal evidence indicated that companies in landlocked developing countries frequently maintain three months or more of inventory to compensate for delays and uncertainty, and safety stocks can reach one year of expected sales. (Arvis, Raballand, and Marteau, 2007) A beer factory in Cameroon, for example, keeps 40 days of inventory to cope with poor road conditions and a beer distributor stockpiles five months of inventory at the beginning of each rainy season.(*The Economist*, 2002) An apparel producer in Nairobi also notes that poor road conditions can result in additional costs incurred from cancelled orders, discounts to apparel buyers, or penalties incurred by the producer. (USITC, 2009) Although difficult to quantify, the cost of uncertainty can be very large. In their simulation of the cost of travel time uncertainty (for a developed economy—Netherlands), Ettama and Timmermans' conclude that the "cost reduction is not caused by travel time savings,... but by reduced scheduling costs. The largest gain is brought about by a reduction in early

schedule delay, implying that travellers profit from not having to keep a large safety margin." (Ettema and Timmermans, 2006)

This increased cost, time, and uncertainty can substantially reduce SSA producers' ability to export, or even participate in global trade of many industries. The USITC reports that an examination of SSA country export profiles reveals that whereas one might expect SSA countries to participate more in industries that have a low production cost share of electricity (e.g., electronics, machinery, and motor vehicles), "these industries are often characterized by global supply chains that rely on efficient and timely multi-modal transportation networks. However, SSA's weak transport infrastructure increases the cost and time associated with importing needed production inputs and exporting final products, effectively increasing economic distance between SSA and the rest of the world." The report also adds that speed to market is increasingly important for the global apparel industry, and, due in part to poor land transport, SSA apparel firms' response to "an inefficient transportation infrastructure has been to produce low- to mid-range, commodity-type apparel products, for which speed to market is relatively less important." (USITC, 2009)

Effects at Country and Product Level

Ideally, we would like to compare the cost increases associated with moving from the farm or factory to the port with the revenues actually obtained by the exporter, and to know how much is added to the ex-farm or ex-factory price not only by the truck movement, but by paperwork costs and ship loading costs. Such information would enable us to decompose the f.o.b. price of exports into its various components, which

would allow us in turn to assess the potential gains to export producers associated with lower exporting costs. It would also allow us to compare the relative importance of movement-to-port costs and costs in other parts of the supply chain, such as maritime transport costs, offloading, customs formalities in importing countries, import duties, and wholesaling and retailing.[9] For added insight, one might like to add the implicit costs associated with time delays, as have been estimated by Hummels (2001, 2007).

As this information is not all in one place , we have gathered together available information on monetary and time costs associated with exporting from a variety of sources, linking them together with the help of some assumptions, in order to produce a picture of what these costs look like from the standpoint of the exporter. These data are explained below and include (1) transit time and cost survey data, (2) SSA export data, (3) Doing Business Trading Across Borders data, and (4) tariff equivalent of time estimates. This exercise focuses on four land transport corridors in SSA linking seven landlocked countries with their respective exit ports. These countries (Burkina Faso and Niger on the Western corridor, Chad and Central African Republic on the Central corridor, Rwanda and Uganda on the Eastern corridor, and Zambia on the Southern corridor) are those for which Teravaninthorn and Raballand (2009, Table 4.1; hereinafter TR) supply an estimate of transit times and transport prices per ton along the land transport corridor, derived from a survey of truckers.[10] These estimates apply to import

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[9] For analytical frameworks relating movement-to-port to other supply chain costs, see Deardorff and Stern (1998), pp. 105-106, and Ferrantino (2006), pp. 66-67.

[10] An alternate estimate of transport prices, based on price in dollars per kilometer, can be derived from Table 4.2 in TR (2009). Because we wish to compare transport prices with the unit values of exported goods, we use dollars per ton. We also use the full ranges of both time and price for all countries. For Zambia, information is reported for both Lusaka, in the south, and Ndola, in the north, for a connection to the port in Durban. We have not attempted to locate products geographically within Zambia. Copper, for example, is in the north, implying higher costs and transit times to Durban. However, Zambian goods may also use alternate routes through Dar es Salaam, Tanzania, or Maputo, Mozambique, if these are cheaper.

movements. There are reportedly some discounts for exporters, who may take advantage

of backloads on the greater volume of trucking used for imports. We ignore these

discounts for the present purpose, believing that they may not be large on average. We

also use prices rather than costs for trucking services, being mindful of the point raised by

TR that markups on some African trucking routes are substantial due to the exercise of

market power.

To obtain unit values for exported goods, we use import data for the European

Union as reported to GTIS, averaging annual values for 2006-2008. The European Union

is the primary market for six of our seven exporters, and the primary market for non-oil

exports from Chad. We consider all exports at the HS-6 level from these countries

exceeding $1 million annually, except for goods classified in HS 27 (mineral fuels),

which may be transported by different methods, and HS 71 (gems and jewelry), which

are likely to have very high unit values. These prices are measured on a c.i.f. basis (cost,

insurance, freight). Since all of the relevant goods are measured in metric tons, we are

able to impute a value for trucking costs relative to c.i.f. prices. Lacking a direct measure

of shipping costs (insurance and freight), we do not attempt to compare these to f.o.b.

prices.

We use the Doing Business Trading Across Borders data, described above, for

two purposes. The first is to obtain an estimate of costs associated with the movement to

port other than trucking costs. The Doing Business indicators break out export-related

costs into four categories: inland transport, port costs (e.g. loading of ships), customs and

related costs, and document preparation. Since we are using the TR estimates to obtain

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We are indebted to Gael Raballand for several communications on a variety of points relating to use of the truck survey data.

inland transport costs per ton, we use the Doing Business estimates to obtain the ratio of the other three cost components to inland transport costs. This allows us to obtain an estimate of total monetary costs of exporting that can be compared with the value of the product. As already noted, the largest share of costs for the countries in question, as reported by Doing Business, is inland transport costs, so the adjustment from trucking prices to total monetary costs of exporting is modest in magnitude.

The second use of the Doing Business data is to cross-check the TR estimates. This is feasible for the estimate of time for inland transport.[11] For the countries in the Western and Southern corridors, inland transport times for export reported by Doing Business are fairly consistent with road transit times for import reported by TR. However, along the Eastern and Southern corridors, the Doing Business estimates are substantially higher than the TR estimates.[12] This discrepancy suggests that our estimates of the economic value of time to trade along these corridors may be biased downward, and also raises the issue of how much difference it makes to consider trucks vs. shipping containers as the standard unit for this type of analysis on the cost side.

The estimates of the tariff equivalent of time are taken from Hummels (2007), which are generated at the HS-4 level using the procedure described in Hummels (2001).

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[11] We do not attempt to compare the cost estimates of TR and Doing Business, since the basis for comparison is not clear; for example, the number of trucks it takes to fill a shipping container, and the number of tons a shipping container holds, may vary from commodity to commodity and from shipment to shipment. It is also possible that Doing Business may have done their measurements along different corridors than TR. In addition to the possible corridor choices for Zambia noted above, there are many choices in West Africa. For example, Burkina Faso's exports often leave through Abidjan, Côte d'Ivoire, and Tema, Ghana, while TM's estimates consider a corridor linking Burkina Faso to Lomé, Togo.

[12] These are as follows, in days:

	Doing Business		TR
	Export	Import	Import
Central African Republic	26	26	8 to 10
Chad	31	38	12 to 15
Rwanda	17	18	8 to 10
Uganda	18	13	5 to 6

These estimates are based on the premium traders are willing to pay for faster air travel as opposed to slower ship travel for trade with the United States.

The results of these calculations are presented in Table 2 and summarized in Table 3 below. Two main points emerge from the analysis. First, for the countries and commodities in question, the implied costs of time to export in general exceed the price of trucking. For the 41 country/commodity pairs we consider, the median (and interquartile range) for the cost of time are 8.2 percent and (4.6 percent, 13.5 percent) compared to 3.4 percent and (2.0 percent, 5.9 percent) for the price of trucking services. Second, for certain commodities the costs are significantly higher. Evaluated at the mean travel time, the implied time costs of exporting peas and beans from Zambia, or cotton from Burkina Faso, are on the order of 60-70 percent ad valorem, while the time costs of exporting cotton from Chad are nearly 170 percent ad valorem. Similarly, evaluated at the mean travel time, the financial costs of exporting various varieties of wood from the Central African Republic are on the order of 31-38 percent of the c.i.f. price. Evaluated relative to the exporters' revenues prior to loading the wood on the truck, these costs amount to 46-61 percent ad valorem on the assumption of zero maritime shipping costs, and something higher than that using a positive value for maritime shipping costs.

These results may be usefully compared with the widely cited calculation of Anderson and van Wincoop (2004) for trade costs applying to developed-country trade. Their calculation yields a 170 percent ad valorem markup from the producer's location in the exporting country to the retail level in the importing country. These costs, which may include an element of rent, are broken down into a 21 percent transport cost markup, including freight costs and time value of goods in transit, a 44 percent markup for border-

related variables, and a 55 percent markup for wholesaling and retailing (1.70 =

1.21*1.44*1.55 – 1). The transport costs are derived from observed U.S. freight costs,

which typically do not include inland transport to port,[13] while the costs of time are based

on Hummels (2001). A cursory examination of Table 2 shows that for many of the

product-country pairs we consider, the sum of estimated total monetary costs of export

and time savings associated with inland transport is well in excess of 21 percent ad

valorem. Note also that this total does not include time costs associated with export

procedures other than inland transport, or time and costs associated with water transport.

One can further see that the impact of time and trucking prices reflects an

interaction between the location and the type of goods. As we expect, all goods on the

Central corridor leading from Chad and the Central African Republic to Cameroon are

expensive both financially and time-wise. Cotton, which has attracted a great deal of

attention in the Doha Round, is disadvantaged because of the high time cost associated

with it, which creates difficulties for its use as an input into the apparel supply chain.

Similarly, many fruits and vegetables have a high cost associated with them. On the other

hand, goods with high unit values, such as specialty metals and spices, face relatively low

land transport costs in terms of either money or time. Commodities such as coffee and tea

are in an intermediate position, with significant but not extreme costs of both types

associated with land transport. The analysis of time and pecuniary costs of transport may

explain to a significant extent why the visible comparative advantage of SSA is strongly

concentrated in primary commodities, and why, for example, it is virtually infeasible to

maintain anything like an electronics supply chain in, or including, the region.

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[13] This observation is not absolute, since the particular nature of the import charges listed as "insurance and freight" depends in part on the nature of the contract drawn up between the exporter and importer. We are grateful to Mike Craig of U.S. Customs and Border Protection for clarifying this point.

Table 2

Country	Brief description	HS6	Estimated trucking prices as a percentage of CIF value			Estimated total monetary costs of export	Estimated time savings per day	
			Mean	Min	Max	Mean	Days	Mean tariff equivalent
Burkina Faso	Beans	70820	2.3%	2.0%	2.9%	4.1%	6 to 8	47.6%
Burkina Faso	Guavas, mangoes	80450	2.2%	1.7%	2.7%	3.8%	6 to 8	12.0%
Burkina Faso	Vegetable oil	151590	3.4%	2.4%	4.7%	6.1%	6 to 8	1.3%
Burkina Faso	Cotton	520100	4.4%	3.5%	5.2%	7.8%	6 to 8	66.3%
Cent. Afr. Rep.	Coffee	90111	12.5%	9.7%	20.2%	16.4%	8 to 10	8.4%
Cent. Afr. Rep.	Wood	440349	33.9%	29.9%	39.6%	44.5%	8 to 10	8.9%
Cent. Afr. Rep.	Wood	440399	37.9%	30.4%	48.6%	49.8%	8 to 10	8.9%
Cent. Afr. Rep.	Wood	440729	31.6%	29.8%	34.7%	41.5%	8 to 10	8.9%
Chad	Gum arabic	130120	11.6%	10.3%	13.1%	15.5%	12 to 15	3.8%
Chad	Cotton	520110	14.9%	12.9%	16.8%	20.0%	12 to 15	166.8%
Niger	Uranium	284410	1.5%	1.0%	2.2%	2.9%	12 to 15	0.0%
Rwanda	Coffee	90111	4.1%	3.4%	4.8%	5.8%	8 to 10	8.4%
Rwanda	Black tea	90240	3.9%	3.6%	4.1%	5.5%	8 to 10	4.6%
Rwanda	Tungsten ores	261110	0.2%	0.1%	0.6%	0.2%	8 to 10	3.0%
Uganda	Fish, fresh/chilled	30269	1.8%	1.7%	1.9%	2.3%	5 to 6	8.6%
Uganda	Fish, fresh/chilled	30379	2.3%	2.2%	2.4%	2.9%	5 to 6	5.3%
Uganda	Fresh fish fillets	30419	1.5%	1.4%	1.6%	1.9%	5 to 6	6.3%
Uganda	Frozen fish fillets	30429	1.9%	1.9%	2.0%	2.4%	5 to 6	6.3%
Uganda	Live plant cuttings	60201	0.7%	0.6%	0.7%	0.8%	5 to 6	0.0%
Uganda	Cut flowers	60311	2.1%	2.1%	2.1%	2.6%	5 to 6	4.7%
Uganda	Peppers	70960	3.6%	3.4%	3.7%	4.4%	5 to 6	13.5%
Uganda	Bananas/plantains	80305	4.0%	3.7%	4.4%	4.9%	5 to 6	13.1%
Uganda	Coffee	90110	4.5%	3.7%	5.3%	5.5%	5 to 6	5.0%
Uganda	Vanilla beans	90500	0.4%	0.3%	0.5%	0.5%	5 to 6	0.8%
Uganda	Sesame seeds	120740	6.7%	5.0%	8.4%	8.3%	5 to 6	14.6%
Uganda	Tobacco	240120	2.3%	2.1%	2.6%	2.9%	5 to 6	2.4%
Uganda	Cotton	520100	5.9%	5.1%	6.6%	7.2%	5 to 6	48.9%
Uganda	Cobalt	810520	0.2%	0.1%	0.3%	0.2%	5 to 6	1.0%
Zambia	Cut flowers	60319	2.7%	1.4%	5.4%	3.5%	8 to 10	7.9%
Zambia	Peas	70810	2.2%	1.5%	3.1%	2.8%	8 to 10	64.9%
Zambia	Beans	70820	2.8%	1.7%	4.1%	3.6%	8 to 10	64.9%
Zambia	Peppers	70960	2.0%	1.0%	3.8%	2.6%	8 to 10	23.0%
Zambia	Vegetables, misc.	70990	2.0%	1.2%	3.0%	2.6%	8 to 10	23.0%
Zambia	Coffee	90110	4.8%	3.0%	7.2%	6.1%	8 to 10	8.4%
Zambia	Cane sugar	170111	17.2%	11.1%	24.3%	21.8%	8 to 10	8.2%
Zambia	Tobacco	240120	2.8%	1.9%	3.7%	3.5%	8 to 10	3.9%
Zambia	Tobacco waste	240130	16.0%	10.7%	21.7%	20.3%	8 to 10	3.9%
Zambia	Cotton yarn	520532	4.1%	2.7%	5.6%	5.2%	8 to 10	7.9%
Zambia	Cotton yarn	520533	4.2%	2.8%	5.7%	5.3%	8 to 10	7.9%
Zambia	Copper cathodes	740311	1.8%	1.2%	2.6%	2.3%	8 to 10	1.6%
Zambia	Cobalt	810520	0.2%	0.1%	0.6%	0.3%	8 to 10	1.6%

Table 3

Time cost of trucking	10-170 percent	Beans, guavas, mangoes, peas, peppers (Burkina Faso, Zambia)	Cotton (Burkina Faso, Uganda) Peppers, bananas, sesame seeds (Uganda)	Gum arabic, cotton (Chad)
	5-10 percent	Fish and fish fillets (Uganda)	Coffee, tea (Rwanda/Uganda/Zambia) Cotton (Uganda, Zambia) Cotton yarn (Zambia)	Coffee, wood (CAR) Cane sugar (Zambia)
	0-5 percent	Uranium (Niger) Tungsten (Rwanda) Vanilla (Uganda) Tobacco (Zambia) Cobalt (Uganda, Zambia) Copper cathodes (Zambia)	Vegetable oil (Burkina Faso)	Tobacco waste (Zambia)
		0-2.5 percent	2.5-10 percent	10-40 percent
		Price of trucking		

Uncertainty: A Simulation Exercise

The inspiration for this simulation exercise comes in part from a field visit to a pineapple grower in central Ghana,[14] which illustrates widespread difficulties with logistic coordination of road transport and water transport. The decision to harvest and de-green pineapples must be made 9-10 days before they are loaded onto trucks, at which point they travel for three hours to the port of Tema. The farmer must make this decision taking into account both weather conditions and reports about congestion in Nigeria other West African ports where liners stop prior to Tema. The available information is always imperfect; moreover, there are cases of whole truckloads of output being lost in accidents

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[14] See USITC (2009).

on the farm's unpaved road linking to the local highway. Thus, the odds of trucks arriving too early or late are significant.

In order to focus on uncertainty, we explore some of the potential interactions between features of the logistics environment and performance of the exporter. We have constructed a simulation model in which the exporter makes a truck delivery by road in an attempt to meet a ship, which will carry the goods to their final destination. The simulation ignores all consideration of either the financial costs of road travel, or the Hummels-type cost associated with delay per se, to focus on the costs associated with uncertainty and failure to coordinate.[15]

In the simulation, travel time on the road is uncertain, as is the arrival time of the ship. There are penalties for being either too early or too late. Goods in trucks that arrive too early may be subject to spoilage (if perishable), theft, or additional warehousing fees. A time delay between truck arrival and ship arrival may also provide additional opportunities for port employees to demand "speed payments" to get the goods alongside the ship. Penalties for arriving too late may be imposed by the importer in the form of demanding discounts or cash penalties, or in the form of rejection of goods, or additional spoilage of perishable goods or warehousing fees while waiting for the next ship. In general we expect that penalties for being late are greater than penalties for being early. Differences between types of goods and importing markets may be associated with different levels of the penalty.

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[15] Other models assessing the impact of uncertainty on logistics are found in Arvind, Raballand, and Marteau (2007), which focuses on minimizing the sum of freight transportation costs, overheads, and hedging costs associated with inventory, and Ettema and Timmermans (2006), which focuses on information provision in a model informed by examples drawn from urban commuting in developed countries.

The exporter's payoff function is of an "iceberg" type. The exporter delivers one unit of the good, and earns revenue of unity if delivered on time. Penalties for being early or late erode the value of the good to the exporter until it reaches a minimum of zero. Let t_t denote the travel time of the truck once the exporter starts it moving. Similarly, let t_s denote the time between when the truck starts moving and the ship arrives in port. The exporter's problem is to choose a time to start the truck such as to maximize his payoff. This time is expressed relative to the ship's expected arrival time, i.e. "I start the truck at the time that I expect the ship to be t_s days away from the port."[16] Since there is only one relative time scale between the truck and the ship, the exporter's choice problem is written with t_s as the choice variable, rather than t_t.

Assume the payoff function is uniform and continuous in the time early or late, and denote the per-day penalty for arriving before the ship by α and after the ship by β. Then the payoff function, $P(t_s, t_t)$ can be written as follows:

(1) $P(t_s, t_t) = \max(1 - \alpha (t_t - t_s)), t_t - t_s \leq 0,$

$P(t_s, t_t) = \max(1 - \beta(t_t - t_s)), t_t - t_s \geq 0.$

It remains to specify the probability distributions of truck and ship arrival times. The expected distribution of ship arrival times at the moment the truck departs has a log-normal probability density function $\phi_s (\ln(t_s))$. This corresponds to a situation in which

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[16] This behavior corresponds with the anecdote about pineapples at the beginning of the paper. It also corresponds to observed behavior in other transport systems. The literature cited by Ettema and Timmermans (2006) indicates that the most common response of drivers to new information about the state of the traffic system is to change departure time, although changing routes is also common. Our model assumes a single route. In some cases in Africa (e.g. Burkina Faso, Niger, Zambia) multiple routes to the port exist and enter into the decision-making process.

there is a long tail of large values for the delay, such as might be caused by inefficiencies in liner port stops in other countries prior to the port the exporter uses. The expected distribution of truck arrival times at the moment the truck departs is a winsorized log-normal distribution $\phi_t^*\ln(t_t))$, derived from the log-normal distribution $\phi_t\ln(t_t))$ with low values concentrated at $t_t = 2$. This represents a technologically feasible best performance for an improved road at 2 days transit time, and a similarly long tail for unfortunate events.[17]

With this information, we can write the exporter's decision problem as

$$(2) \quad Max \quad w.r.t. \quad t_s \int_{-\infty}^{\infty} \phi_s \; (\ln((t_s)) \int_{-\infty}^{\infty} \phi_t^* \; (\ln(t_t)) \; P(t_s, t_t) \; dt_t \; dt_s$$

The quality of the logistic system can now be expressed as the expected value of the exporters' payoff, given the probability distributions of truck and ship arrival times. There are five variables that define the state of the logistics system at any given time:

- *Road quality*, defined as the mean of $\phi_t(\ln(t_t))$. This describes how rapidly one can travel on the road under normal conditions. Lowering the mean improves road quality. Paving the road, adding lanes, or fixing potholes may be instruments for improving road quality.

- *Road uncertainty,* defined as the standard deviation of $\phi_t\ln(t_t))$. Roads with the same mean travel time may have different degrees of uncertainty in travel time. Many of the policies that improve road quality will also improve road uncertainty, but the proportion of improvement between the mean and the variance may be

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[17] Arvis, Raballand, and Marteau (2007) provide evidence that distributions of wait times in African logistics processes are log-normal, including road transit times and dwell times for transit containers in port.

different for different interventions. Some polices, like reducing the number of

unauthorized roadblocks, may be particularly focused on road uncertainty.

- *Ship uncertainty,* defined as the standard deviation of ϕ_s $(\ln(t_s))$. This reflects

  uncertainty in the arrival time of the ship as perceived by the exporter at the

  moment the truck departs. We make no attempt to distinguish between uncertainty

  arising from physical difficulties with the movement of ships and uncertainty

  arising from the exporter's imperfect information.[18] Accordingly, instruments to

  lower ship uncertainty may include improvements in port or liner procedures,

  improvements in procedures in the ports on the liner route prior to the port the

  exporter uses, and improved information.[19]

- *Early penalty*, described above as α. Costs of being too early to the port may take

  the form of spoilage, theft, warehousing fees, or opportunities for port employees

  to demand "speed payments" to move up in the queue.

- *Late penalty*, described above as β. Late penalties may take the form of rejected

  goods, discounts demanded or penalties charged by the buyer. The case of

  "spoilage for being late" is included in the above.[20] Late penalties also vary by the

  type of goods being exported. For example, they may be higher for perishable

  than non-perishable goods.

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[18] This distinction is captured in other models of travel time uncertainty, such as that of Ettema and Timmermans (2006).

[19] An example of this is the Mobiship program of the Ghana Shippers Council, which provides members with information on vessel movements by cell phone.

[20] Late penalties may be considered to have both a fixed and a variable component, because missing the ship at all is always a negative event. Adding a fixed penalty may be somewhat more realistic than the present model which only has a variable component. We choose the present representation to limit the parameter space, and compensate for the limitation by choosing values for the simulation such that the late penalty is usually greater than the early penalty.

We choose a range of settings for the five variables in order to explore their interaction. We consider variation in two variables at a time, leaving the other three at their default values.[21] This allows us to explore the interactions between the variables.

Consider first the interaction between ship uncertainty and road uncertainty, as portrayed in Figure 4. The relationship between these variables is highly non-linear, and suggestive of a low-level poverty trap. When both road uncertainty and ship uncertainty are high, as in the lower right of the diagram, marginal reductions in uncertainty have relatively low payoffs. In this situation, reducing road uncertainty is more valuable than ship uncertainty, because it is more closely tied to the exporter's decision variable. At low levels of road and ship uncertainty, in the upper left of the figure, marginal reductions in either kind of uncertainty become more valuable, suggesting that there are increasing returns to the reduction of uncertainty.

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[21] Road and ship variables are measured in days, and penalties are measured in per-day loss of the exported good. The default values and ranges for the five variables are as follows: Road quality 3 (range 2 to 4); road uncertainty 0.8 (range 0.2 to 1.0); ship uncertainty 0.5 (range 0.1 to 1.0); early penalty 0.15 (range 0.05 to 0.25); late penalty 0.4 (range 0.2 to 0.6).

Figure 4

Ship uncertainty x road uncertainty
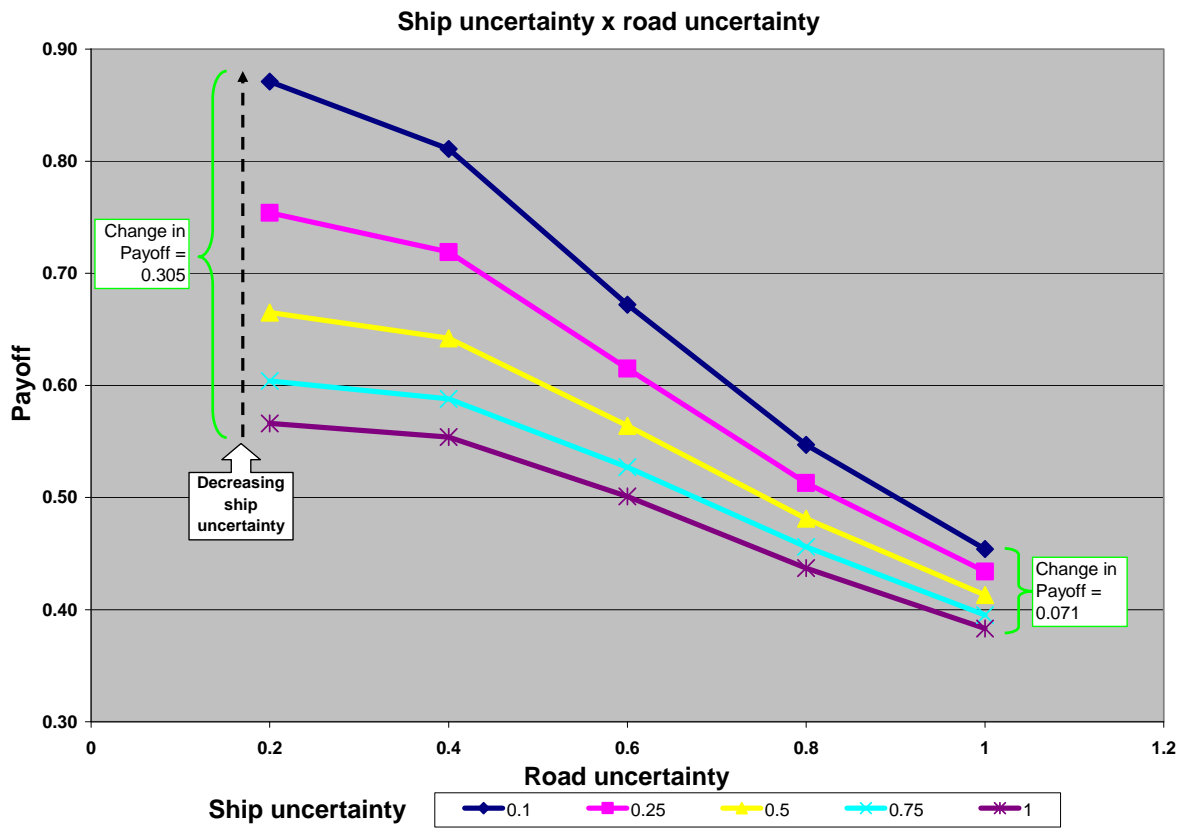
Consider now the relationship between road uncertainty and road quality, as in the figure below.

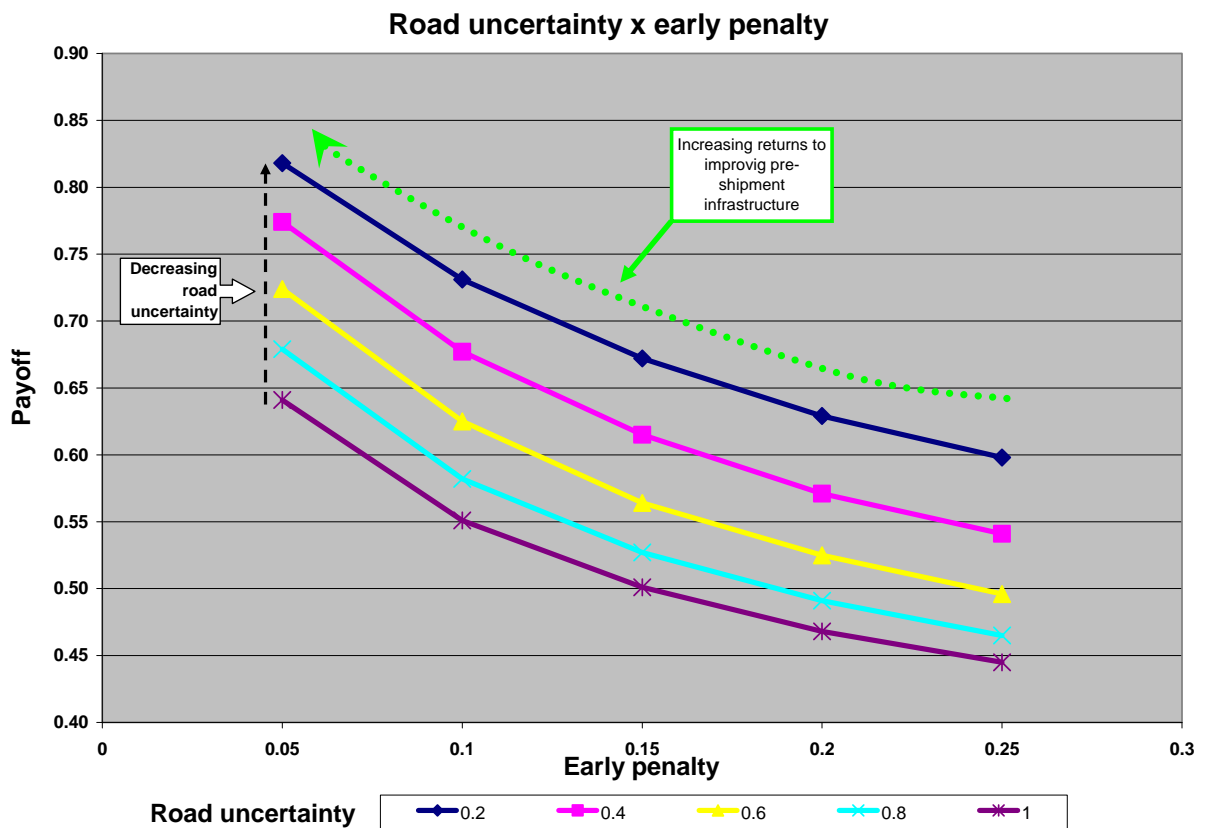Figure 5

Road uncertainty x road quality
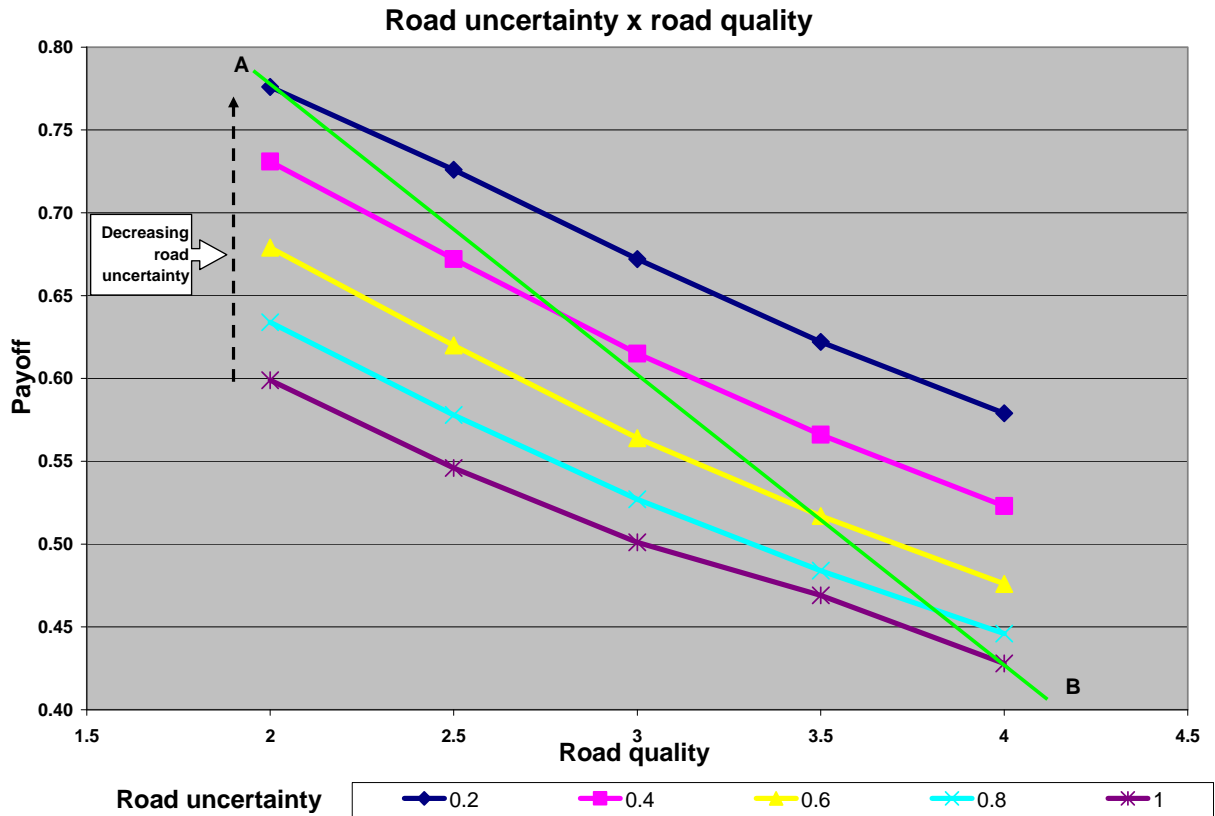
It appears that road quality and road uncertainty are close substitutes for each other, in the sense that improving either yields rewards to the exporter's payoff of comparable magnitude. If, as is surely the case in almost all transport systems, more time-consuming trips have a greater variance of arrival time than less time-consuming trips, then comparisons between different countries or goods are likely to involve comparisons between low mean-low variance trips and high mean-high variance trips. This suggests that estimates of the value to time in trade of the Hummels type, which treat time as implicitly certain, may overstate the "value of time" as it would be measured if duration and uncertainty could be decomposed. That is, econometric estimates of value in time may produce relationships similar to the line AB, while data that were capable of decomposing time and uncertainty would produce estimates corresponding to the more

mildly sloped isoquants shown in the figure. This observation is not meant to negate the value of existing estimates of value in time. Instead, it suggests that these estimates might in fact correspond to the value of improving a time-and-uncertainty bundle. The relevance of this observation depends on the existence and effectiveness of policy instruments, such as reductions in roadblocks, which may be more closely associated with uncertainty than with time per se.

Finally, consider the tradeoff between road uncertainty and the early penalty.

Figure 6

The curvature in this figure suggests that there are increasing returns to interventions that improve conditions of goods queuing to enter the port, or to be placed in a loading position on the apron once they have entered the port. Such interventions include improved warehousing and security, cold storage facilities to reduce spoilage,

and efforts to reduce corruption in the export yard. The increasing returns arise from the fact that the better these conditions are, the more profitable it is for the exporter to arrive sufficiently early to avoid the more severe penalty of missing the ship. That is, the tradeoff between the perceived costs of arriving early or arriving late is mitigated.

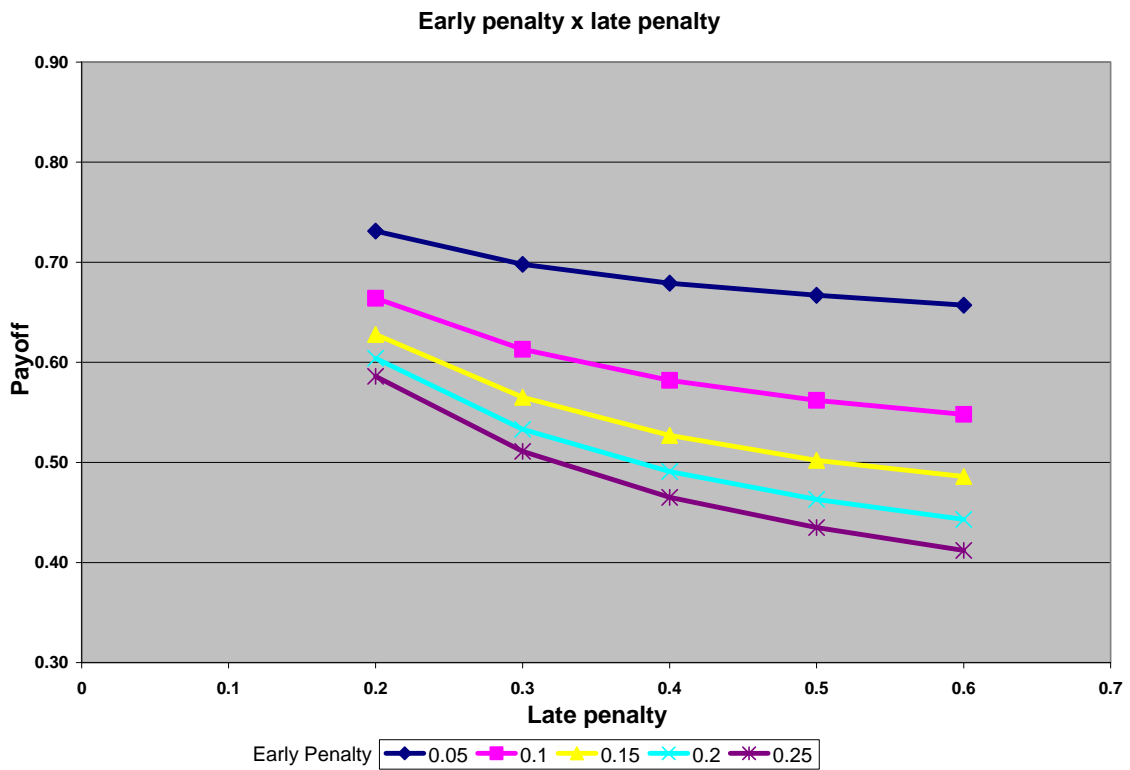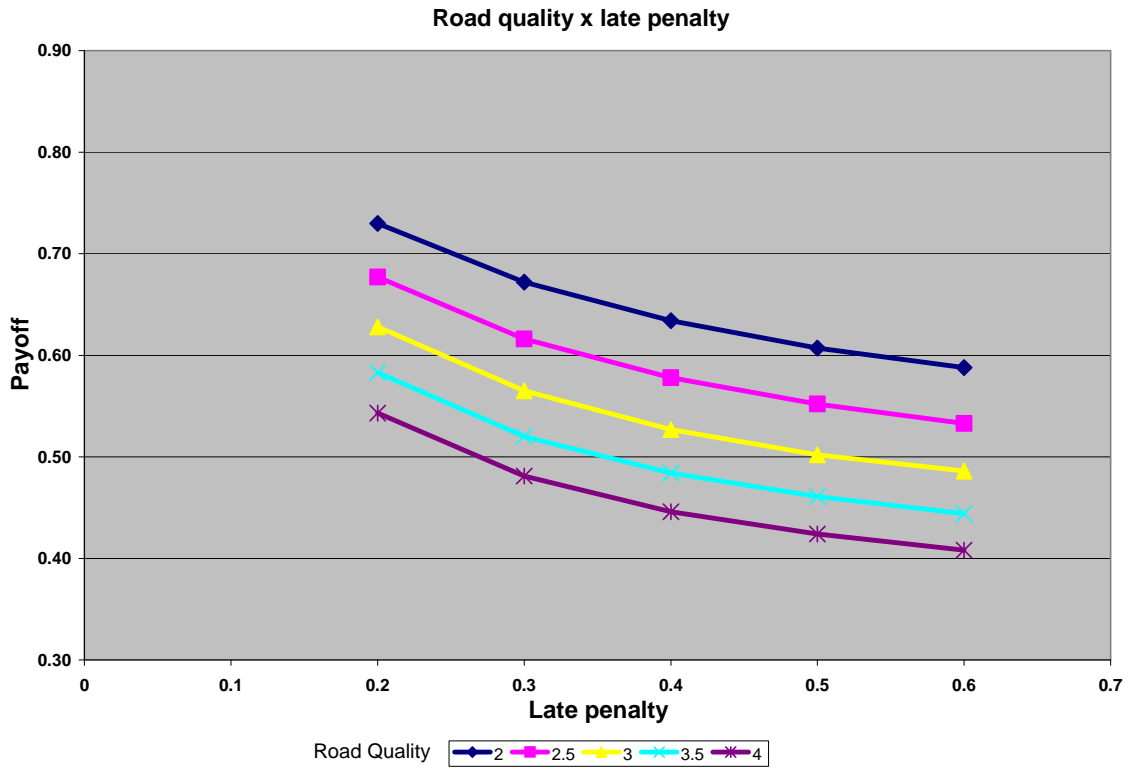Additional results from the simulation model are presented in figures in an Appendix.

Conclusion

The costs associated with movement to port in developing exporting countries are non-trivial. These costs have three dimensions: financial costs of land transport, opportunity costs of time in slow processes, and uncertainty associated with unpredictable arrival times and incomplete information. For the case of landlocked countries in SSA, we have shown that these costs arise from complex interactions among multiple physical and policy features of the trading partners, and from interactions among groups of countries geographically associated with each other along transport corridors.
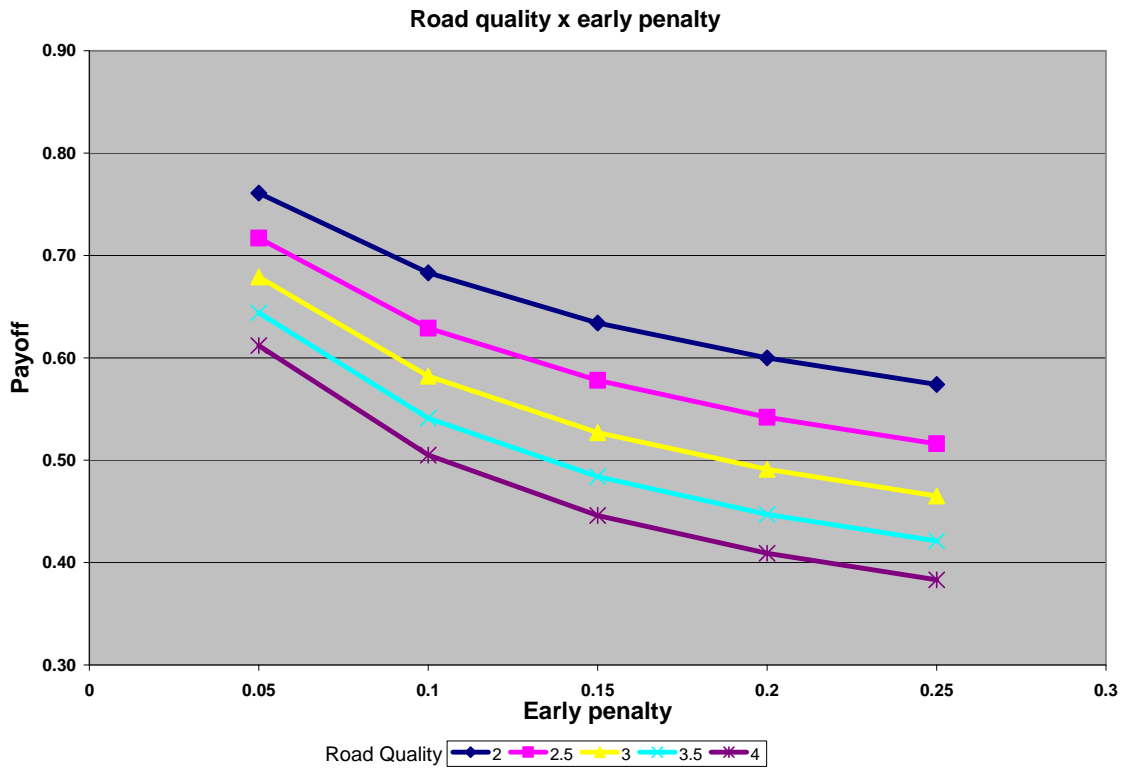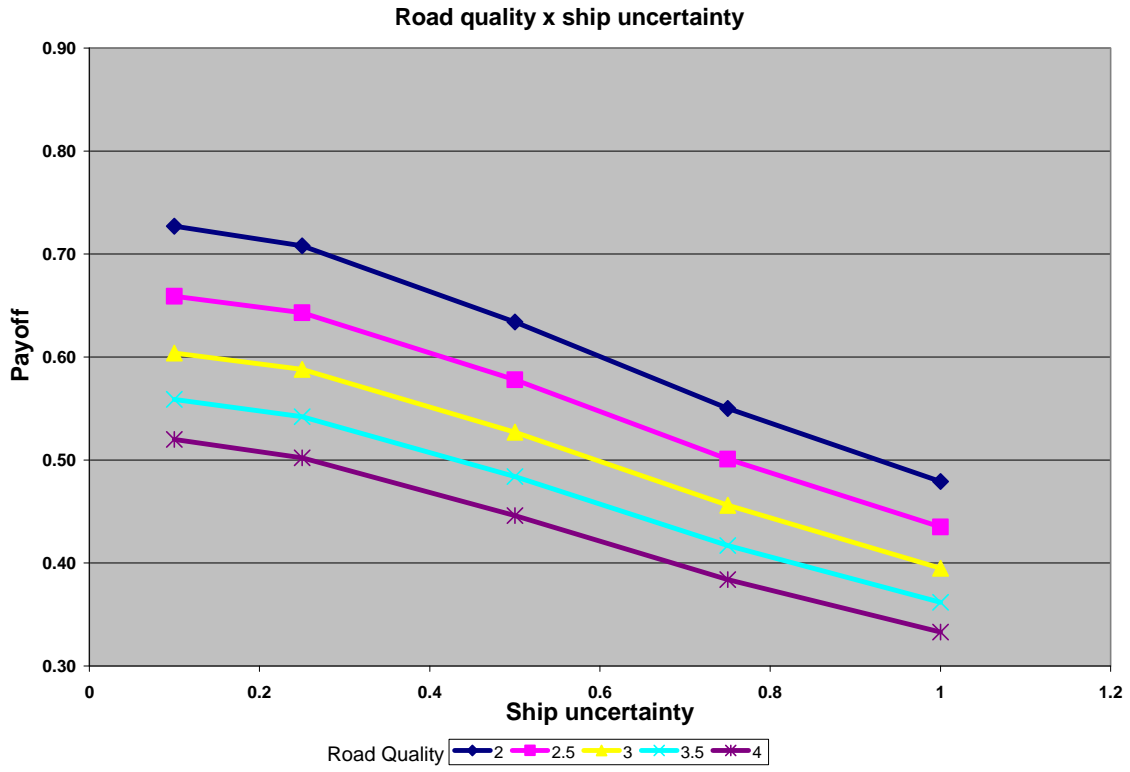
We have also shown that the distribution of the burden of movement-to-port costs across countries and products tends to bias SSA's comparative advantage in favor of products such as metals and niche agricultural products that have high value-to-weight ratios, to disadvantage primary agricultural products, and to frustrate efforts to enter into markets for manufactured goods involving multiple steps of transport in the value chain.
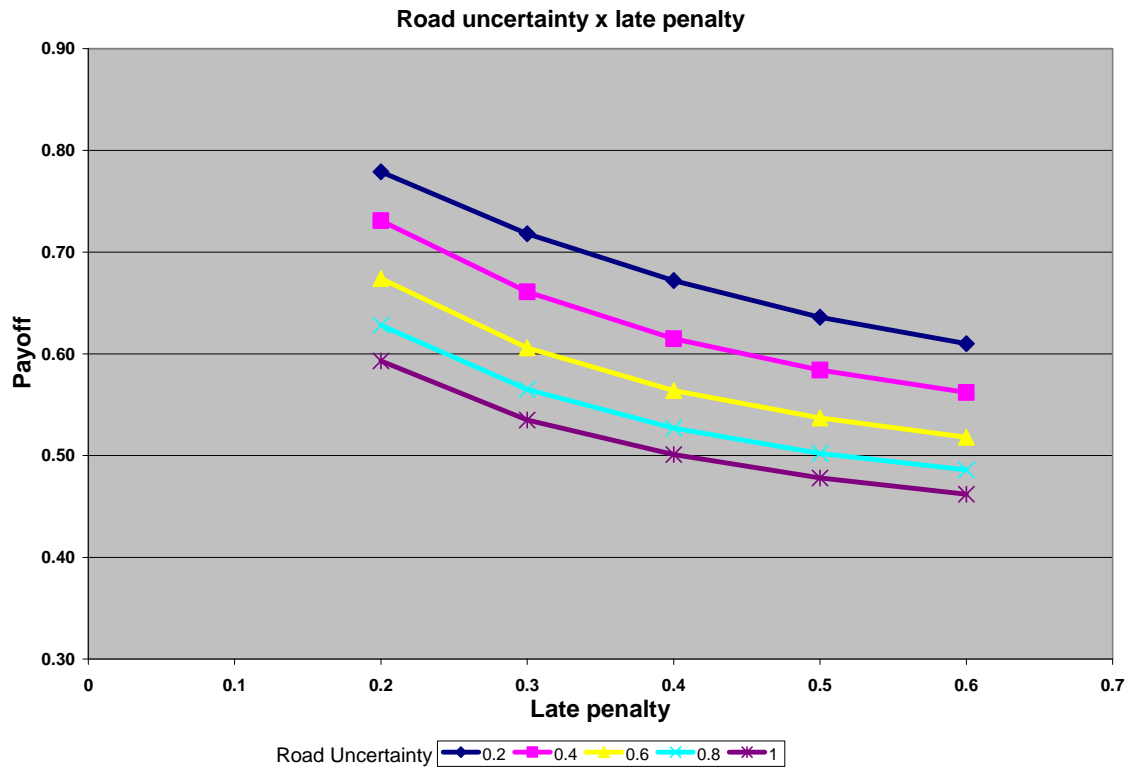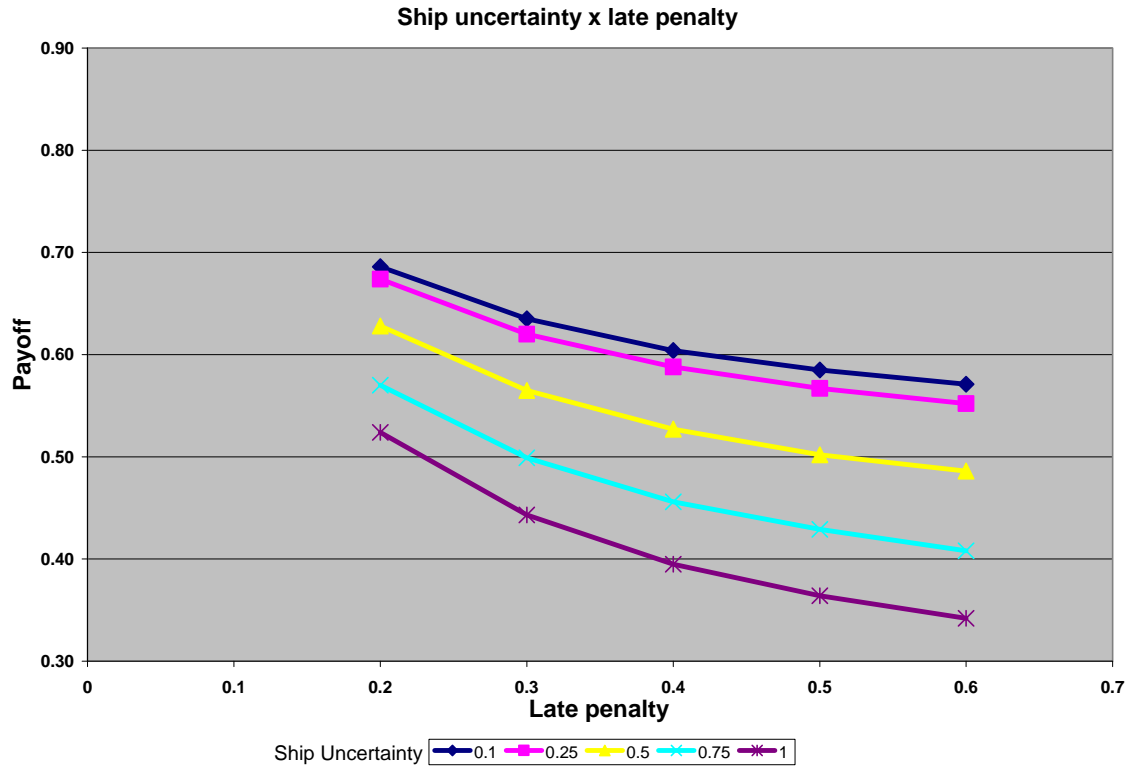
As the simulation results make evident, certain investments have a low rate of return unless other aspects that are serving as bottlenecks are addressed. For example, paving (or all-weatherizing) and increasing the number of lanes on an interstate highway
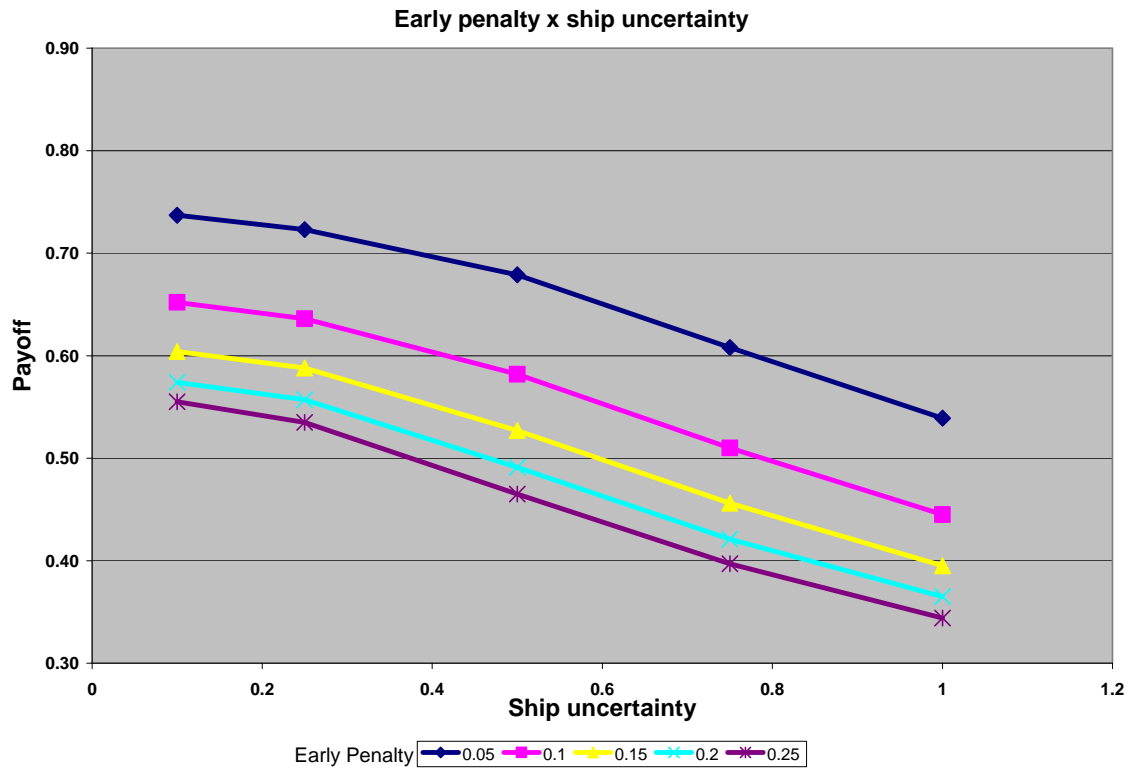
will likely provide little benefit if users still encounter 5 to 30 roadblocks lasting

anywhere from a few hours to a few days without any foreknowledge. Essentially,

despite the investment, effective transport costs do not decline. These investments may

have been more effective if used to reduce the number, time required, and uncertainty of

roadblocks. Reducing ship uncertainty when there is a high level of road uncertainty

results in a much lower return than when road uncertainty is low. Also, for any given

level of road uncertainty, the benefits to reducing early penalties (such as those associated

with both excessively unripe and rotten fruit, stolen goods, port waiting fees, etc.) depend

on the initial level of the penalty and increase with each reduction. The important role of

uncertainty is also highlighted by the simulation model. Although the model abstracts

from many features of actual trade logistics channels, it is rich enough to capture

substantial non-linearities in the payoffs to different interventions. In very bad

environments, interventions that reduce uncertainty may have low payoffs, while

reducing uncertainty in either land travel or shipping may have increasing returns once a

certain level of quality is achieved. This suggests that the interactions in trade logistics

systems deserve further examination, and that efforts to collect data both on uncertainty

and on the costs associated with entry-into-port and with late shipments may be very

useful.

Appendix

Road quality x late penalty

Payoff vs Late penalty

Road Quality: 2, 2.5, 3, 3.5, 4

Early penalty x late penalty

Payoff vs Late penalty

Early Penalty: 0.05, 0.1, 0.15, 0.2, 0.25

Road quality x ship uncertainty

Road quality x early penalty

Ship uncertainty x late penalty

Ship Uncertainty: 0.1, 0.25, 0.5, 0.75, 1

Road uncertainty x late penalty

Road Uncertainty: 0.2, 0.4, 0.6, 0.8, 1

Early penalty x ship uncertainty

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