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Trade integration and spatially balanced development

Implications for Uganda and Rwanda

Marius Brülhart
Olivier Cadot
Alexander Himbert

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Trade integration and spatially balanced development: Implications for Uganda and Rwanda[1]

Marius Brülhart[2]
Olivier Cadot[3]
Alexander Himbert[4]

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Abstract

This paper explores empirically whether regional trade liberalization—through improved trade facilitation or lower tariffs—can be expected to contribute to more balanced spatial development. Using high-resolution spatial data on light emissions as a proxy for economic activity, we document the existence of a "border-shadow effect" whereby border regions are, on average, less developed than others. Then, using an instrumental-variable approach, we show that trade liberalization dampens the border-shadow effect, encouraging activity in border regions. Using agricultural production data at a high level of geographical resolution, we show that the causal channel of our result is the development of trade-enabled productive activities rather than that of directly trade-related services. We use our results to simulate the effect of an improvement in Uganda's trade-facilitation performance on its spatial development, highlighting a strong effect on border regions.

Keywords: International trade, EAC, Agglomeration, trade facilitation

JEL numbers: F13, F15

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[2] Faculty of Business and Economics, University of Lausanne, and CEPR

[3] Faculty of Business and Economics, University of Lausanne, CEPR and FERDI

[4] Faculty of Business and Economics, University of Lausanne.

1 Introduction

This paper explores whether efforts—by governments and development partners—to encourage regional trade integration in East Africa through trade-facilitation measures can be expected to help lift backward regions out of poverty, as opposed to fostering the agglomeration of population and wealth in large cities. We find that, indeed, trade facilitation can be a powerful vehicle to reduce spatial inequality.

The persistence of spatial inequality in economic development is an important policy question. Border regions are often less developed than interior regions. For instance, night-light emissions (a good joint proxy for economic activity and population density) are one-third lower at land borders than 200 km inland from the border; throughout this paper, we will call this the "border shadow". In Sub-Saharan Africa (SSA), ethnic groups straddling borders suffer from systematically lower incomes (Michalopoulos and Papaioannou, 2013), and border regions have proved more prone to conflicts. This has been observed, historically, in Uganda and the DRC.

Against this background, whether enhanced trade integration is a mitigating or aggravating factor of spatial inequality is an open question. According to the World Bank's 2009 *World Development Report* (WDR),

> "[t]he openness to trade and capital flows that makes markets more global also makes subnational disparities in income larger and persist for longer in today's developing countries. Not all parts of a country are suited for accessing world markets, and coastal and economically dense places do better. China's GDP per capita in 2007 was the same as that of Britain in 1911. Shanghai, China's leading area, today has a GDP per capita the same as Britain in 1988, while lagging Guizhou is closer to Britain in 1930."[5]

If the WDR's conjecture is true, improvements in trade integration may have the unwanted effect of further marginalizing poorer regions and accelerating urban migration, undoing the efforts of development partners to promote balanced growth and reduce rural poverty.

However, the academic literature is more ambiguous than the WDR quote above suggests (see Brülhart, 2011 for a survey). In particular, Krugman and Livas-Elizondo (1996) argued that the growth of oversized metropolises in many developing countries after independence was at least partly due to the inward-looking trade policies they adopted. Their reasoning, drawing from the seminal work of Krugman (1991) was that the main centripetal (agglomeration) factor was the strength of firms' backward and forward linkages (to markets and suppliers). As trade liberalization would reduce the dependence of firms toward domestic markets and suppliers, location close to them would become less crucial relative to congestion effects, leading to dispersion.

However, other models deliver sharply different predictions. For instance, if trade liberalization reduces farmgate prices for key crops, it could push farmers out of agriculture and increase population agglomeration in already overcrowded cities. Such concentration effects are predicted by models such as Monfort and Nicolini (2000) or Monfort and van Ypersele (2004), and be

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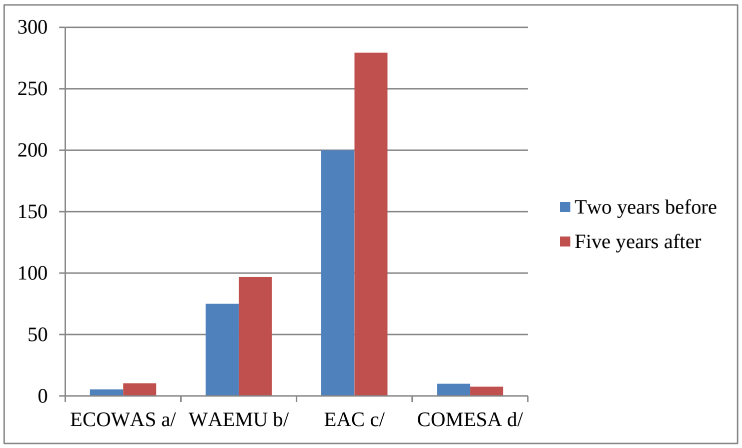
[5] World Bank, World Development Report 2009, p. 12; quoted in Brülhart (2011).

expecially relevant for SSA countries, where a large part of the population still lives in rural areas and relies on relatively inefficient agriculture for its subsistence.

The case of East Africa is a particularly interesting one in this regard, as regional integration efforts have been relatively successful compared to other, largely ineffective South-South schemes on the African continent and elsewhere. This is illustrated in Figure 1, which shows trade-intensity indices (TII) for four trade agreements in SSA. The EAC stands out both for its high pre-agreement TII and for the increase in its TII after the agreement was formed.

Figure 1: Trade-intensity indices before and after RTA formation



Notes: Time periods: 1991-92 and 1997-98 for ECOWAS and COMESA, 1992-93 and 1998-99 for WAEMU, 1997-98 and 2003-4 for EAC. WAEMU members excluded from ECOWAS. The trade intensity index is calculated here as the ratio of the bloc's share in members' exports to its share in non-members' exports.
Source: Adapted from de Melo and Tsikata (2014), Table 2.

Most of the literature on trade and spatial concentration in developing countries has relied on either cross-sectional approaches using crude aggregate proxies such as trade-openness indices and overall spatial concentration indices, or case studies (in particular Mexico or China) with limited external validity. By contrast, we use high-resolution spatial data on night-light emissions as a proxy for economic activity. We also use an instrumental-variable approach where overland trade between neighboring countries is instrumented by a trade-facilitation variable, the score of the countries straddling the border in terms of the World Bank's Logistics Performance Index (LPI). Our approach enables us to document a "border-shadow" effect whereby border regions are systematically less developed than regions away from borders. We also show that cross-border trade mitigates this effect, leading to more balanced spatial development.

The paper is organized as follows. Section 2 provides background information on trade facilitation and integration in East Africa, as well as a simple conceptual framework to guide the empirical exploration. Section 3 describes the data used in the estimation in some detail, as its use in economics has spread only recently. Section 4 discusses estimation issues, Section 5 presents and discusses the results, and Section 6 concludes.

2 Background

2.1 Trade facilitation in East Africa: Where do we stand?

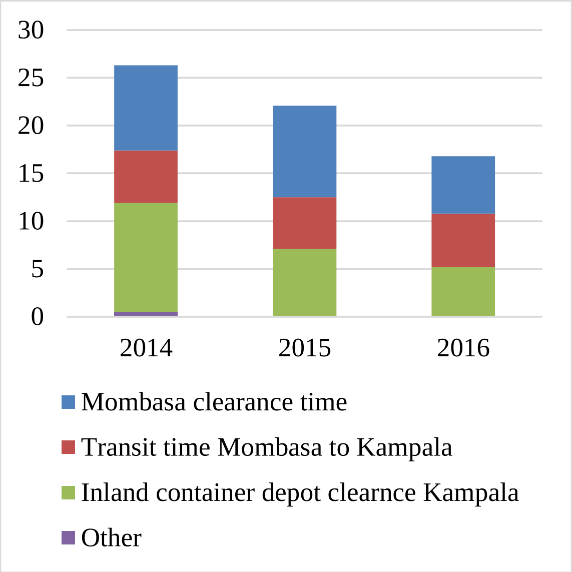
Although regional trade in key staples such as maize is active in East Africa (World Bank 2009), regional markets remain imperfectly integrated. For instance, Versailles (2012) estimates that the region's borders induce, on average, deviations from the law of one price by 13 to 20 percent. Two factors have been frequently cited as major contributors for the continuing lack of integration in spite of regional free-trade agreements (EAC and COMESA): non-tariff barriers (NTBs) and lack of trade facilitation.

In order to address non-tariff barriers, a monitoring mechanism was put in place in the EAC in 2009 allowing the private sector to flag issues that would be picked up for inter-governmental negotiations with the objective of eliminating them. After a somewhat difficult debut, the mechanism has proved reasonably successful, with 104 measures satisfactorily dealt with between 2009 and 2016 (of which 35 percent were taxes and 20 percent were either technical regulations or prohibitions) and 25 measures remaining unaddressed (Calabrese and Eberhard-Ruiz, 2016). As of 2016, tax-related—typically the hardest to resolve—accounted for 40 percent of the unresolved cases and a third of the resolved ones; quality and safety standards accounted for a quarter of the unresolved cases and only 10 percent of the resolved ones; prohibitions accounted for eight percent of the unresolved cases and 10 percent of the resolved ones; while trade-facilitation measures accounted for 28 percent of the unresolved cases and 40 percent of the resolved ones.

Thus, although trade-facilitation cases typically took longer to be resolved (nine months on average, against only four months for, say, tax measures) there was substantial progress in this area (Calabrese and Eberhard-Ruiz, 2016). Trade-facilitation measures include customs automation through the adoption and regular upgrading of ASYCUDA, the use of post-control audits and risk management, and the adoption of international standards including, *inter alia*, the WTO's Agreement on Customs Value, the revised Kyoto convention on the simplification and harmonization of Customs procedures, the revised Arusha Declaration on Customs Integrity (Zake 2011), and the creation of one-stop border posts (OSBPs). OSBPs allow trucks to be checked only once each way, cutting crossing times by factors of four or five, from over a day to a few hours. This is quite important, as time delays have been shown to restrict trade pretty much like tariffs (Freund and Rocha 2011), while reductions in clearance and crossing times have substantial effects on the ability of firms to export and grow (Volpe et al., 2015). OSBPs have been established in East Africa, e.g. in Malaba, at the border between Kenya and Uganda, in 2006, and in Chirundu, at the border between Zambia and Zimbabwe, in 2009, where crossing times were reduced substantially (Ben Barka, 2012); however, both pre-date the creation of the monitoring mechanism so even the one at Malaba cannot be attributed to it.

As a result of these improvements in trade facilitation and in spite of lingering issues, transit times along the Northern corridor have been going down, driven by reduced container clearance times at Mombasa and Kampala (Figure 2). These improvements owe much to continued technical assistance from development partners.

Figure 2: Transit times along East Africa's Northern corridor, 2014-2016, in days

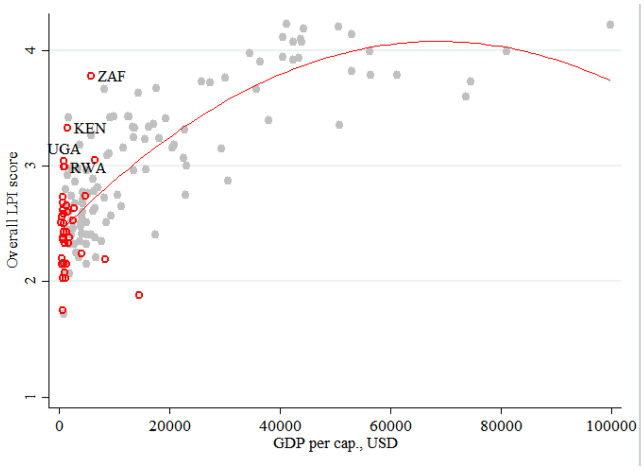


Source: Eberhard-Ruiz and Calabrese (2017)

Transit costs have also gone down substantially along the Northern corridor, but, according to Eberhard-Ruiz and Calabrese (2017) not too much should be made of this as the drop in transit costs over the last few years is largely attributable to lower fuel costs, other components of transit costs having remained constant.

All in all, countries like Rwanda and Uganda score relatively well by the World Bank's Logistics Performance Index (LPI). Figure 3 shows overall LPI scores by country against their income level in current U.S. dollars, with SSA countries shown as red, empty circles and all other countries as grey points. LPI scores rise rapidly with income up to roughly $40,000 per capita, after which they seem to flatten out. Besides Kenya, both Uganda and Rwanda are above the fitted curve and largely above other SSA countries, a remarkable performance given that the last two are landlocked.

Figure 3: LPI scores compared, 2016



Note: Sub-Saharan countries are shown as red circles; other countries as grey points. The red curve is a fitted OLS polynomial. GDP per capita is for 2015 in current U.S. dollars. ZAF: South Africa; KEN: Kenya; UGA: Uganda; RWA: Rwanda.
Source: World Bank, World Development Indicators

Thus, while the record of regionalism in SSA has so far been uneven at best (see de Melo and Tsikata, 2014), East Africa, and in particular the EAC, has been relatively successful not only at eliminating intra-bloc tariffs, but also at reducing non-tariff barriers and adopting positive trade-facilitation measures, resulting in reduced transit times along the main transport corridor. We now turn to the effect to be expected from these changes on patterns of location of economic activity.

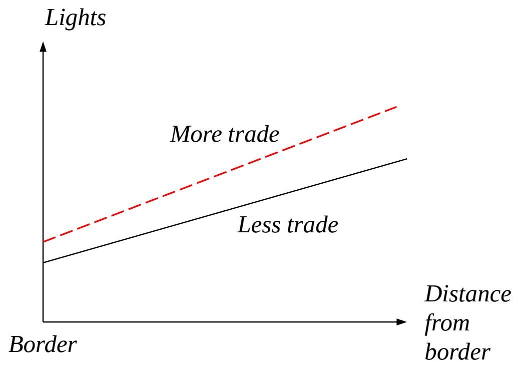
2.2 Does trade foster spatial inequality?

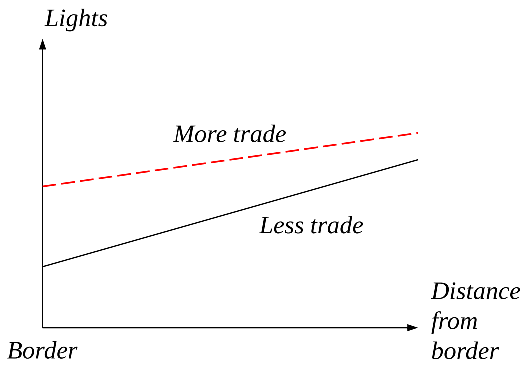
Continued efforts by development partners to encourage regional trade integration in East Africa raise the question as to whether trade integration can be expected to help lift the poorest populations out of poverty, beyond average gains. In particular, given the high level of income disparity between large cities and backward regions in SSA, one may wonder whether regional trade can give a boost to peripheral regions.

Figure 4 illustrates two scenarios that describe the hypothesis we are testing. The vertical axis measures night-light emissions captured by satellites, our proxy for population and economic activity. The horizontal one measures distance from the border along a given cross-border highway. In both panels, light emissions rise with distance from the border (the “border shadow” effect). In the regression equation we will put to the data, this effect will be measured by the coefficient on a linear term in distance from the border. In both panels, as the curve shifts up, more trade raises light emissions at all distances from the border; in the regression equation, this effect will be measured by the coefficient on a linear term in trade volumes. The difference between the two panels lies in the combined effect of more trade and distance from the border. In panel (a), more trade reinforces the effect of distance, with the curve becoming steeper as it moves up. In that case, activity rises more where there is already relatively more (away from the border). This corresponds to an agglomeration scenario. In panel (b), more trade dampens the effect of distance, with the curve becoming flatter as it moves up. In that case, activity rises more where there is relatively less (close to the border). This corresponds to a dispersion scenario. In the regression analysis, this combined effect will be measured by the coefficient on an interaction term between trade volumes and distance from the border.

Figure 4: Trade and agglomeration, two scenarios

(a) Agglomeration (b) Dispersion





Which scenario prevails is the result of complex forces on which the literature has not come to a clear consensus (see Brülhart, 2011 for a survey). On one hand, the so-called "Krugman-Livas" hypothesis (Krugman and Livas-Elizondo, 1996) states that in a closed economy, agglomeration forces stem from forward and backward linkages (to markets and to suppliers) which are weaker in an open economy where firms source and sell abroad. In that case, trade liberalization leads to dispersion. However, other forces can play an important role and generate starkly different outcomes. For instance, the main centrifugal force in the seminal economic-geography model of Krugman (1991) is the presence of immobile farmers; if trade liberalization leads to lower producer prices for agricultural products and accelerated urban migration, it can lead to agglomeration instead of dispersion (see e.g. Monfort and Niccolini, 2000, or Monfort and van Ypersele 2003). Which outcome emerges also depends on how trade develops after liberalization. For instance, if trade liberalization leads to trade creation rather than trade diversion so that trade with the rest of the world develops faster than inland regional trade, industrial activity may cluster either around main ports (Mombasa in the case of East Africa). On the contrary, if trade diversion dominates, industrial activity may spread away from them in order to escape international competition (on this, see Brülhart et al. 2004 or Crozet and Koenig-Soubeyran 2004). Finally, border regions may develop on such a large scale that they overcome traditional poles around the capital city, leading to re-agglomeration at a different location. This has been documented e.g. in the case of Mexico after NAFTA. Thus, whether trade-facilitation efforts lead to dispersion or agglomeration remains largely an empirical question, to which we now turn.

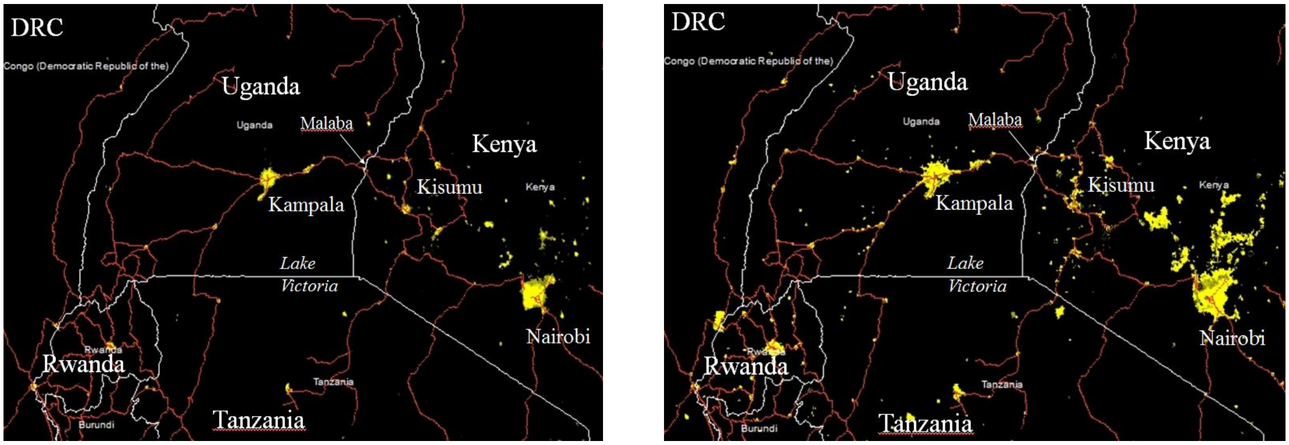
3 Data

As mentioned, we use night lights captured by satellites to proxy for the joint density of population and economic activity at the sub-national level, where national-account data on economic activity are rarely available. Night-light data have been collected by the U.S. Air Force since the 1970s and declassified early on, with digital archiving beginning in 1992. Today, the data can be retrieved and manipulated relatively easily using ArcGIS software and the use of night-light data as a proxy for economic activity has spread in the literature (see e.g. Sutton et al., 2007, Henderson et al., 2012, Baum-Snow and Turner, 2012, Henderson et al., 2012, Pinkowsky 2013, or Storeygard, 2016).

Raw data from satellites is cleaned by masking clouds, identifying the light signal (radiance) from ambient "noise", aggregating, filtering temporary flares (e.g. lightnings or fires), and geo-referencing by cells of 2.5 arc-minutes, or 5 km at the equator, for the entire planet. The resulting radiance variable is scored on a scale from zero to 63. In spite of the cleaning, two issues remain for econometric estimation. First, geo-referenced light scores are censored at zero or 63 in some regions. Right-censoring at 63 is rare (0.1 percent of all cells) and is found in cities. Left-censoring at zero is more common and is prevalent in Sub-Saharan Africa (92 percent of all cells). When relevant, this can be taken care of by using appropriate estimators. Second, light scores are spatially correlated for two reasons, one economic and the other technical. First, activity and settlements tend to agglomerate, so light in a cell makes it more likely that there will be light in adjacent cells. Agglomeration in East Africa is visible in Figure 5, which also shows, in panel (b), that agglomeration has been intensifying over the period where night lights have been recorded.

Second, satellites move and the light signal captured by their lenses suffers from "overglow". This is particularly visible along coastlines where offshore cells close to brightly-lit coastal areas seem to emit light. This can be corrected, albeit imperfectly, using standard spatial-correlation techniques (see Pinkowsky, 2013).

Figure 5: Lights intensity in East Africa



(a) Night lights in 1995

(b) Absolute increase in night lights, 1995-2013

Note: Major higways are shown in red, national borders in white, an night lights in different shades of yellow depending on their intensity (panel a) or the intensity of their increase (panel b). Light intensity not corrected for overglow.
Source: ArcGIS software

In order to disentangle the respective contributions of economic activity and population density on light emissions, one can control for population density using population data from the Gridded Population of the World (GPW), a dataset developed by the Socioeconomic Data and Applications Center (SEDAC) at Columbia University. The data originates from national censuses and is allocated to geo-referenced cells using an algorithm that takes into account geographic characteristics that affect human settlements as well as spatial interdependence (agglomeration). However, controlling for population density has the disadvantage of introducing a constructed (and possibly endogenous) variable on the right-hand side of the estimation equation; in the regressions presented in this paper, we do not attempt to disentangle activity vs. population agglomeration.

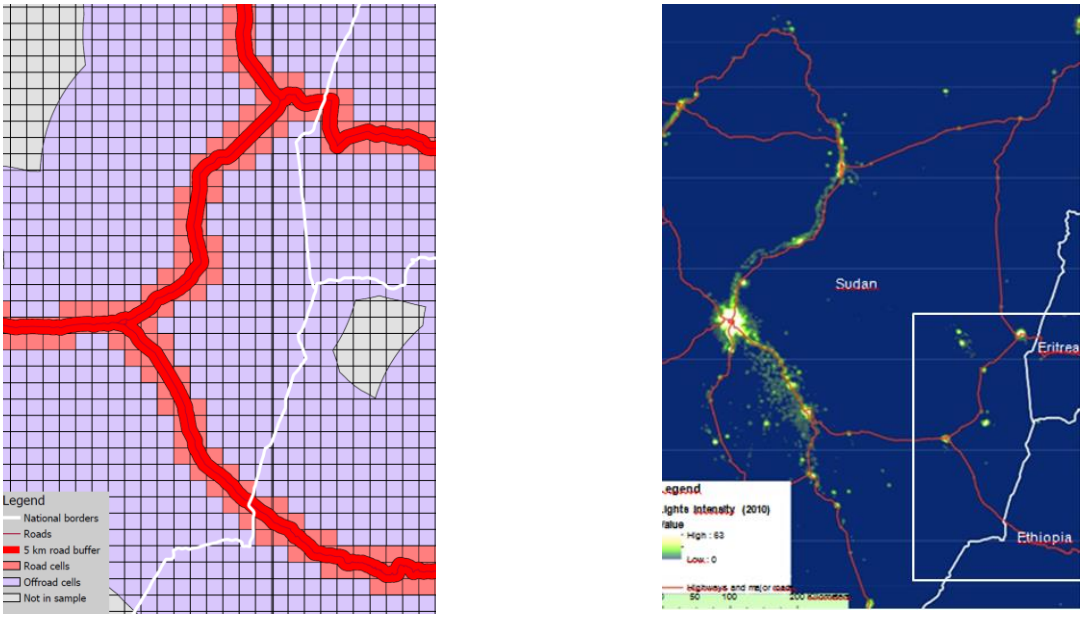
Land-use data comes from the Center for Sustainability and the Global Environment (SAGE) of the University of Wisconsin. Data on the main crops grown in cells of 10 × 10 km is available from

Earthstat from Monfreda, Ramankutty, and Foley (2008).[6] Altitude data comes from SRTM30Plus dataset developed by the Scripps Institution of Oceanography at the University of California, San Diego. Road location data comes from the ESRI dataset, which itself draws on national data and gives the location and size of cities (independent from the light data) as well as that of ports and airports. Finally, trade data comes from the United Nations' COMTRADE database, tariffs from UNCTAD's TRAINS, and LPI data from the World Bank. We use years from 2007 onward for which LPI data is available.

Our unit of analysis is a geo-referenced cell of 10 × 10 km along cross-border highways, up to 200 km away from each border and 5 km on each side of the highway, as shown in Panel (a) of Figure 6. In order to be part of our analysis, a road needs to cross any land border in the world and be classified by national authorities as either "highway" or "major road" in the ESRI dataset. For each road cell, we compute the distance of its center to the closest border along the border-crossing road, as well as the distance to the next port as potential trade hub (as a control variable).

In sub-Saharan Africa, activity and population tend to cluster strongly along highways; thus, most cells away from our 5-km buffer zone have zero emissions, as illustrated in panel (b) of Figure 6, which shows a wider area than Panel (a). Thus, by focusing on road cells, we do not lose much information. However, in order to verify that while activity builds up near borders along cross-border roads, it doesn't "suck up" activity in neighboring off-road areas, we also consider off-road cells up to 100 km away from cross-border roads within our 200-km buffer zone around borders. For off-road cells, distance to the border is the sum of distance to the closest road cell plus distance from that road cell to the border along the road (rather than bird-flight).

Figure 6: The unit of observation, a 10 × 10 km cell along a cross-border highway



(a) Our unit of observation

(b) Night lights and highways

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[6] There may have been changes in land use during the years since the data was collected. Errors in the measurement of crop data bias our estimates toward zero, i.e. work against our hypothesis. We are grateful to Ritwika Sen for attracting our attention to this issue.

Note: The area covered by panel (a) is shown by the white rectangle in panel (b), where roads are shown in red, borders in white, and night lights in yellow.
Source: ArcGIS software.

All in all, counting on-road and off-road cells, we obtain around 260,000 cells per year for the years 1995, 2000, 2005 and 2010. Finally, we define as our dependent variable the average light intensity emitted by each cell in a given year.

Although our application concerns East Africa (more specifically Uganda and Kenya), in order to have enough degrees of freedom, estimates are obtained from regression analysis covering all cross-border highways in the world for which LPI data for the two countries straddling the border is available. However, in order to ensure that SSA is no exception to our results, we also run our regressions on a sub-sample of all African cross-border highways.

4 Estimation

The specific spatial dimension of our dataset provides a sharp channel of identification, as we expect at least the majority of trade between neighboring countries to run along road corridors. For each cell, we also control for the presence of ports closer than the closest land border; thus, we identify only locations where trade with the neighboring country is most likely to be carried out using the road corridor. The very fine geographic resolution of our dataset also enables us to exploit within-country variation using various geographical control variables.

Formally, let *i* be a 10 × 10 km geo-referenced cell located along highway *r(i)* in country *c(i)*, at a road distance $d_i \leq 200$ km from the closest land border between country *c(i)* and neighboring country *c'(i)*. Let ℓ_{it} be the light emission from cell *i* after correction for overglow in year *t*, $v_{c(i)c'(i),t}$ be the value of exports from *c(i)* to neighboring country *c'(i)* in year *t*, and $\boldsymbol{C}_i$ a vector of control variables including altitude, distance to the nearest port or airport, and a dummy variable equal to one if the dominant ethnic group is the same on both sides of the border.

Our baseline estimation equation is

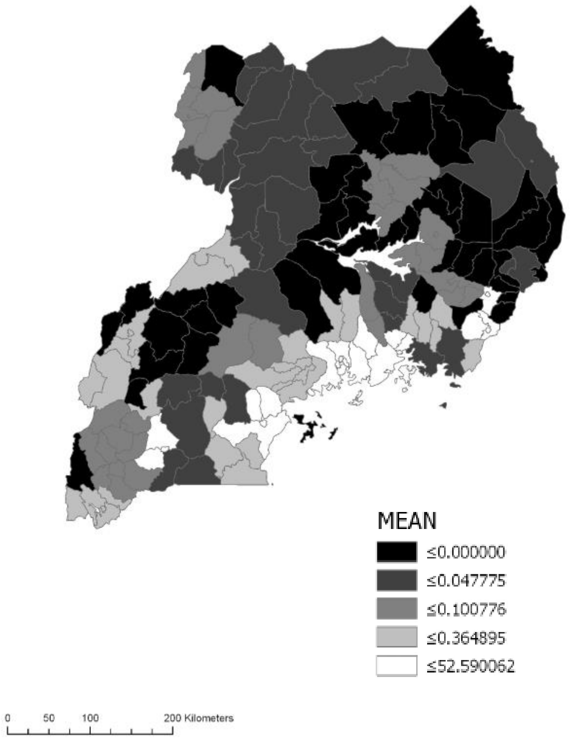
$$\ell_{it} = \beta_0 + \beta_1 d_i + \beta_2 v_{c(i)c'(i)t} + \beta_3 \left(d_i v_{c(i)c'(i)t} \right) + \boldsymbol{\beta}_4 ' \mathbf{C}_i + \delta_{r(i)} + \delta_t + u_{it} \tag{1}$$

The main identification problem with equation (1) is the possible endogeneity of exports. Many factors, such as the construction of factories for reasons not picked up by (1) (say, subsidies for the development of backward regions) may lead to both more lights and more trade. In order to avoid endogeneity bias, we use an instrumental-variable (IV) approach and instrument exports by the product of the LPI scores of countries *c(i)* and *c'(i)*. Thus, we exploit only the variation in exports explained (in a first-stage equation) by cross-country (and time) variation in levels of trade facilitation, as proxied by LPIs. Equation (1) also controls for heterogeneity between regions through road fixed effects $\delta_{r(i)}$. Alternative specifications control for political-economy and other region-specific factors through region-time and neighbor country-time fixed effects, with very similar results (not reported for brevity).

5 Results

As a first pass at the data, Figure 7 shows average light intensity per district in Uganda in 2010. Lighter shades of grey correspond to higher levels of light intensity. The border-shadow effect is not clearly discernible; instead, the picture suggests a “Northern effect” whereby Northern districts emit little light, while Southern ones, in particular along the Nairobi-Kampala-Kigali corridor, emit more light, being generally more developed.

Figure 7: Patterns of light intensity in Uganda, 2010



Source: Authors’ calculations

However, if one averages out lights by bands along inland borders,[7] the border-shadow effect comes out more clearly in the case of Uganda and Rwanda (Figure 8).

Figure 8: The border-shadow effect

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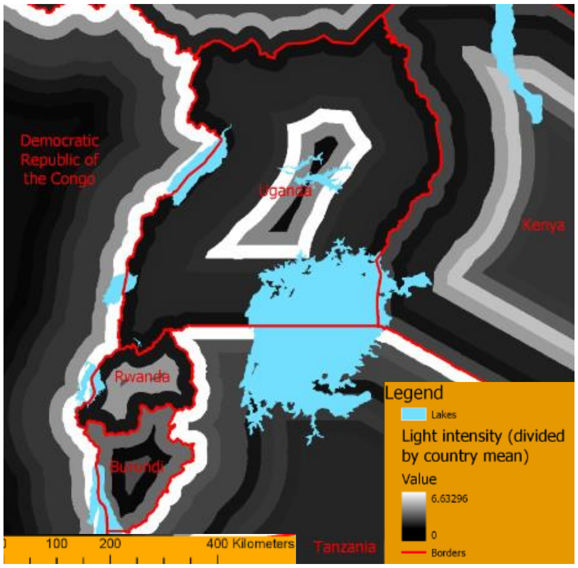
[7] In this and the econometric analysis that follows, the term “border regions” means regions next to inland borders; coastal regions are not considered as border regions.



Source: Authors' calculations

In order to identify the border-shadow effect unambiguously, we need to go beyond mere observation and to control systematically for confounding influences through regression analysis. Table 1 and Table 2 show estimation results for equation (1). Table 1 instruments exports with the product of the overall LPI score of the two countries straddling the border. Table 2 uses only the score in the infrastructure category of the LPI as instrument. In both tables, columns (1) and (2) present OLS and IV results for estimations based on the full sample of all border-crossing highways in the world, while columns (3) and (4) replicate the exercise on a sub sample of all African border-crossing highways. The dependent variable is light emissions per cell and thus picks up the joint effect of economic activity and population density. As geo-referenced population data is constructed by extrapolation, this is the cleanest approach. Results using lights per capita, available upon request, are quite similar. The coefficient on distance to the border is positive and significant, documenting the border-shadow effect (the positive slope of the curves in Figure 4). The coefficient on trade is also positive, suggesting that more trade shifts the curves upward as illustrated in Figure 4. Finally, the coefficient on the interaction term is negative, suggesting that the dispersion scenario of Figure 4b holds on average.

Table 1: Baseline regression results, LPI overall score

Dependent Variable: Average light intensity (logs)				
Sample	World	World	Africa	Africa
Estimator	OLS	IV	OLS	IV
	(1)	(2)	(3)	(4)
Effect on road cells				
Distance from border (in 10km)	0.287***	0.289***	0.284***	0.254***
	(0.011)	(0.015)	(0.027)	(0.030)
Exports (in logs)	0.218***	0.356***	0.172***	0.243***
	(0.024)	(0.064)	(0.027)	(0.039)
Exports X Distance	-0.020***	-0.020***	-0.012	-0.033***
	(0.002)	(0.003)	(0.008)	(0.012)
Additional effect on offroad cells				

Offroad × Distance to road	-0.009***	-0.009***	-0.005***	-0.004***
	(0.000)	(0.000)	(0.000)	(0.000)
Offroad × Exports	-0.030	-0.073	-0.016	-0.094
	(0.023)	(0.058)	(0.027)	(0.107)
Offroad × Exports × Distance to road	-0.002***	-0.001***	-0.001***	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)
Offroad × Exports × Distance to border	0.018***	0.019***	-0.001	0.019
	(0.002)	(0.003)	(0.007)	(0.012)
Instrument	Overall LPI	Overall LPI	Overall LPI	Overall LPI
Road FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES
Controls	YES	YES	YES	YES
F-Statistic		194		82
R-squared	0.623	0.623	0.448	0.447
Observations	373,346	373,346	90,629	90,629

Looking at the additional effects on off-road cells, we find light intensity to gradually decrease with increasing distance to the road. Interestingly, the interaction terms with trade are insignificant on offroad cells in the sub sample analysis in Africa, suggesting that African road and offroad cells are affected in the same way by an increase in exports.

All effects, linear and interacted, come out stronger when instrumenting trade with LPI scores (overall score in the first two columns, scores on infrastructure in the last two). This may be due to a variety of reasons; a plausible one is that overland trade is poorly measured, so that the variation of measured trade that is not correlated with variations in LPI scores has a strong measurement-error component.

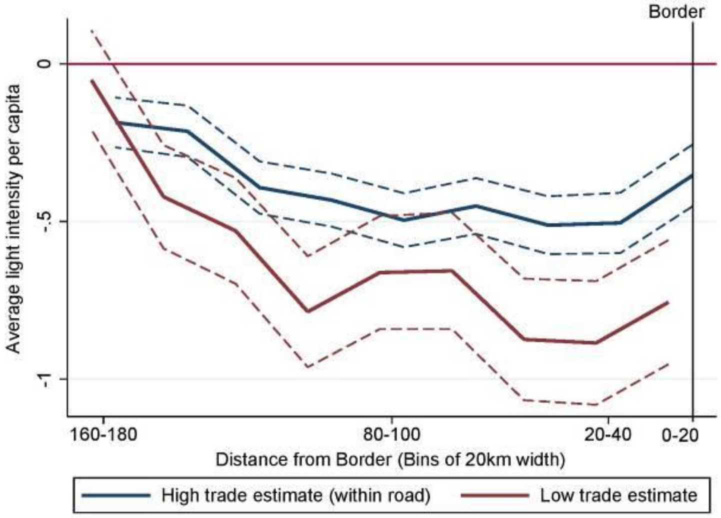
Table 2: Baseline regression results, LPI infrastructure score

Dependent Variable: Average light intensity (logs)				
Sample	World	World	Africa	Africa
Estimator	OLS	IV	OLS	IV
	(1)	(2)	(3)	(4)
<u>Effect on road cells</u>				
Distance from border (in 10km)	0.253***	0.277***	0.241***	0.259***
	(0.016)	(0.018)	(0.037)	(0.027)
Exports (in logs)	0.180***	0.296***	0.176***	0.226***
	(0.030)	(0.081)	(0.024)	(0.032)
Exports X Distance	-0.017***	-0.018***	-0.011***	-0.025***
	(0.001)	(0.001)	(0.002)	(0.009)
<u>Additional effect on offroad cells</u>				
Offroad X Distance to road	-0.008***	-0.010***	-0.004***	-0.003***
	(0.000)	(0.000)	(0.000)	(0.000)
Offroad X Exports	-0.027	-0.051	-0.013	-0.082
	(0.020)	(0.039)	(0.031)	(0.099)
Offroad X Exports X Distance to road	-0.003***	-0.002***	-0.002***	-0.002***
	(0.000)	(0.000)	(0.000)	(0.000)
Offroad X Exports X Distance to border	0.010***	0.012***	0.003	0.011
	(0.003)	(0.001)	(0.004)	(0.009)
Instrument	LPI Infrastructure	LPI	LPI	LPI Infrastructure

		Infrastructure	Infrastructure	
Road FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES
Controls	YES	YES	YES	YES
F-Statistic		174		58
R-squared	0.623	0.623	0.448	0.447
Observations	373,346	373,346	90,629	90,629

Figure 9 replicates Figure 4 based on our dataset. To construct this graph, we pool our observations into 20-kilometer bins in terms of distance from the border. We then split the sample into a `high trade' (blue line) and a `low trade' (red line) group. For each group we estimate our baseline empirical model with these bins as categorical explanatory variables. The graph plots point estimates and 95% confidence intervals for all distance bins up to 200 kilometers from the border, with the furthest bin taken as the reference group.

Figure 9: How trade affects the border shadow

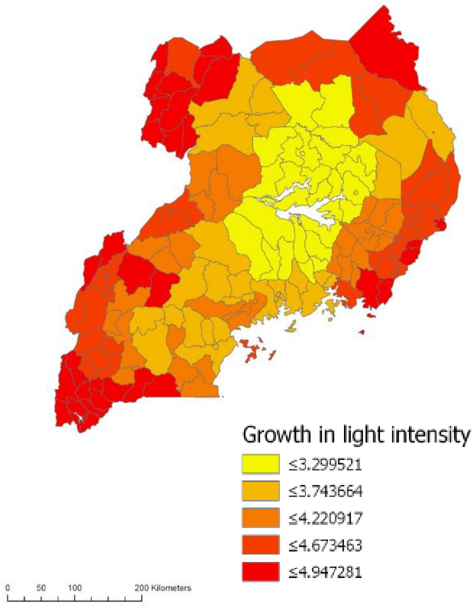


Source: Authors' calculations.

The pattern suggested by the data clearly fits the dispersion scenario. Interestingly, there seems to be a blip in light emissions very close to the border. This may reflect the presence of activities linked directly to cross-border trade, such as amenities for truckers etc. Those may, incidentally, reflect poorly-functioning borders, as long waiting times for trucks generate local activity and smuggling activities typically require physical presence at the border.

Figure 10 summarizes graphically the main argument of this paper. If Uganda were to raise its overall LPI score to the level of Kenya, a relatively modest improvement (see Figure 3), the result in terms of additional economic activity would be distributed across Uganda's territory as shown, with larger percentage increases (4.6-4.9 percent) shown in red and smaller (less than 3.3 percent) in yellow. Clearly, border regions would benefit most from a uniform improvement in trade facilitation at all border posts.

Figure 10: Simulated light emission increase from country-level improvement in trade facilitation, by district, Uganda



Note: The simulated trade-facilitation improvement is a rise in Uganda’s LPI score to the level of Kenya’s. The procedure to generate simulated increases in night lights is as follows. First, we take the centroid of each district. Second, we calculate the road distance from that centroid to the next border. Third, we use regression results from the first and second stages to a) predict the growth in trade if only Uganda’s LPI rises to the level of Kenya, keeping the LPI of the relevant neighboring country constant, using first-stage regression coefficiens ; and b) predict how much light would go up given that predicted growth in trade, using second-stage regression coefficients.
Source: Author calculations using ArcGIS software.

While the development of border area would contribute, as discussed, to more balanced spatial development, it is important to bring some nuance in the interpretation of our results. In the case of Uganda, Figure 7 shows that central-Northern areas (in black) are particularly underdeveloped. Figure 10 suggests that those do not stand to benefit particularly from improvements in trade facilitation. By contrast, Western border districts along the Nairobi-Kampala-Kigali corridor stand to benefit strongly, as do Southern ones close to the border with Rwanda.

5.2 Robustness and extensions

In some cases, a large city (with population over 100,000 inhabitants) is reached along the cross-border highway less than 200 km away from the border. In that case, estimation should disregard the portion of the road after the city. Table 3 shows estimation results when this is done and the sample is split between “censored” roads (those hitting a city before the 200 km bound), which we call “urban”, and “uncensored” ones, which we call “rural”. For the sake of simplicity, we report only the results on road cells, ignoring off-road ones.

Table 3: Regression results, highways leading to cities

Dependent Variable: Average light intensity (logs)

Sample	World		Africa	
Estimation	OLS	IV	OLS	IV
	(1)	(2)	(3)	(4)
Effect on rural area road cells				
Distance to border	0.041	0.055	0.019	0.022
	(0.026)	(0.037)	(0.014)	(0.016)
Exports (logs)	0.101***	0.189***	0.095***	0.147***
	(0.036)	(0.051)	(0.029)	(0.053)
Distance x Exports	-0.006	-0.008	-0.003	-0.003
	(0.004)	(0.009)	(0.004)	(0.006)
Additional effect on urban area road cells				
Road leading to city	0.753***	0.799***	0.955***	0.934***
	(0.043)	(0.034)	(0.146)	(0.159)
Distance to border	0.175***	0.198***	0.202***	0.217***
	(0.042)	(0.044)	(0.048)	(0.081)
Bilateral exports	0.199	0. 231	0.049***	0.080***
	(0.162)	(0.174)	(0.016)	(0.23)
Distance × Exports	-0.023***	-0.029***	-0.016***	-0.020***
	(0.006)	(0.008)	(0.001)	(0.003)
Instrument	Overall LPI	Overall LPI	Overall LPI	Overall LPI
Road FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES
Controls	YES	YES	YES	YES
F-Statistic		53		19
R-squared	0.539	0.512	0.551	0.536
Observations	62,455	62,455	18,783	18,783

Rural roads show no border shadow, while urban ones show a strong one. Urban roads also show the result obtained on the whole sample, namely a dampening of the border-shadow effect as overland trade grows, suggesting that activity agglomerated in urban centers tends to spread along roads leading to borders as trade intensifies. Moreover, we find that the increase in trade leads to a significant increase in activity along highways that run through rural areas both when we estimate the effect on the global sample as well as in the African sub sample. While in the global sample, we find no additional increase in light intensity along urban roads as result of a trade liberalization, we find urban roads to grow faster than rural roads within Africa.

The growth of activity near the border as trade intensifies could be due to two distinct causal channels. On one hand, increased light emission could be due to the growth of service activities directly related to trade, such as roadside amenities for truckers. Indeed, as already discussed, activity peaks near border points could reflect dysfunctional borders, with long truck stations and a host of activities such as smuggling requiring physical presence. On the other hand, they could be due to the growth of trade-enabled productive activities, such as the production of crops for export. In order to disentangle these two channels of influence on spatial patterns of activity, we now turn to a different approach. For each geo-referenced cell, we identify the primary crop grown on that cell, in terms of acreage, as a proportion of the cell's total arable land. We then instrument exports of that crop by the tariff imposed on it by the neighboring country. In the second-stage equation, light emissions are "explained" by exports of the main crop instrumented by the tariff on that crop. Results are shown in Column (1) of Table 4, with Column (2) showing a placebo exercise where we use total trade instead of trade in each cell's main crop. Distance to the border, exports of the main crop, and the interaction of distance with exports are all significant at the one-percent level in Column (1). Again, the result is strongly suggestive of a dispersion effect. By contrast, in Column (2), the interaction term capturing the dispersion effect is not significant, although the direct effect of total trade remains, as expected, significant.

Table 4: Effect of agricultural trade

Dependent variable: Average light intensity per capita (logs)
Sample: World
Estimator: IV

	(1)	(2)
Measure of openness	Crops	All exports
Distance to border	0.540***	0.044
	(0.132)	(0.038)
Exports to neighbor country (logs)	1.345***	0.451***
	(0.259)	(0.037)
Exports to neighbor country × distance	-0.051***	-0.001
	(0.013)	(0.002)
Controls	Altitude, ethnicity, ports, airports	
Road FE	Yes	Yes
Year FE	Yes	Yes
State × Year	No	No
Neighbor Country × Year	No	No
R^2	0.266	0.446
F-statistic first stage	42	1451
No. of observed cells	33,329	33,329
Observations	87,994	87,994

* p < 0.1, ** p < 0.05, *** p < 0.01
Standard errors clustered at cell level.
Note: Column (1) estimates the baseline equation by weighting cells according to the share of land used to grow the major agricultural crop and by instrumenting crop-exports with crop-tariffs. Column (2) estimates the baseline equation using the same weights as in (1) but instrumenting overall exports with average tariffs

Thus, the results in Table 4 suggest that the effect we capture is that of trade facilitation (or, in the case of tariffs, trade liberalization) on trade-enabled productive activities rather than on directly trade-related services.

6 Concluding remarks

Our results, obtained from an exhaustive panel of all country pairs sharing a border and with LPI scores over the period 1995-2010, document the existence of a “border-shadow” effect whereby border regions are systematically less developed than others. We find that this border-shadow effect applies to Rwanda and Uganda, two landlocked East African countries that heavily depend on overland trade. This is a surprising result in view of the result in Henderson et al. (2012) who showed, also using night lights, that inland areas in Africa had not grown more slowly than coastal regions. Our combined results suggest that it is not landlockedness per se that holds back economic development, but rather proximity to borders.

Most importantly, we show, using an instrumental-variable approach, that overland trade predicted by the product of the LPI scores of the countries straddling the border mitigates the border-shadow effect. Thus, in accordance with the Krugman-Livas hypothesis, international trade (in our case, regional integration) leads to more balanced spatial development. As backwardness has tended to go side-by-side with exposure to violence in SSA and in particular in Uganda, whose Northern provinces have been plagued by recurrent strife, fostering the development of peripheral regions may carry the added benefit of reducing the exposure of populations located in those regions to violence.

We also show, by focusing on agricultural trade, for which we have precise geo-referenced data (in contrast to manufacturing, where the exact nature of goods produced in a geo-referenced cell, if any, are not documented) that the effect we are capturing reflects the dispersion of trade-enabled productive activities rather than that of directly trade-related services such as roadside amenities.

Our results have potentially important implications for the ongoing debate about whether more trade is conducive to inclusive development or to increased spatial inequality. Given that, as the literature suggests and as we document in this paper, border areas tend to be less developed than inland ones, the positive effect of overland regional trade on activity in those regions can contribute to more balanced spatial development.

Our approach carries no direct implication for the effect of overland trade on income inequality between households. However, our results on agricultural trade make it possible to conjecture that selective liberalization/facilitation of overland trade in crops grown primarily by farm households with above-average incomes would lead to a widening of within-cell income inequality, working at cross purposes with the reduction in between-cell income inequality due to a more balanced spread of economic activity. Conversely, liberalization/facilitation of overland trade in crops grown primarily by farm households with below-average incomes would lead to a narrowing of within-cell income inequality, reinforcing the effect of a more balanced spread of economic activity. We leave the exploration of this issue for further research.

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