Economic Development in Myanmar's Border Regions: Evidence from Nightlights *

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Abstract

We study the evolution of nightlights in Myanmar's border regions between 2013 and 2019, a period of pronounced trade liberalization. We find towns on busy border crossings with China and Thailand to have grown disproportionately, as did some towns further inland along border crossing road corridors. However, rural areas in border regions between the main towns did not seem to benefit from the increased trading opportunities, nor did locations situated off the main road corridors. Moreover, border regions with India even saw a reduction in average nightlight intensity, and light growth on the foreign side of border crossings was generally more pronounced than on the Myanmar side. Our findings suggest that political tensions and other constraints might be preventing Myanmar border-region populations from benefiting from the opportunities of cross-border trade.

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1 Introduction

Over the last decade, Myanmar has taken great strides towards opening up its economy to international trade. Merchandise trade as a share of GDP increased from 27% in 2010 to over 50% in 2018. Myanmar's exports diversified away from raw materials (especially natural gas) into industrial goods and consumer products. The stock of inward FDI increased from USD 14bn to USD 31bn over the same period. These developments were accompanied by an increase of GDP per capita from USD 850 to USD 1'310. While causation could run in either direction, it seems highly plausible that at least some of Myanmar's income growth is due to its economy's increased integration into global value chains.

The opening-up of Myanmar's economy was a deliberate policy strategy. Export taxes were lowered and export and import licenses were eliminated for a wide range of goods. Import tariffs are relatively low in international comparison, with an average applied tariff of less than 5% and a maximum tariff rate of 40%. The Myanmar government also overhauled its legislation to support private investment domestically and from abroad.

In this note, we explore to what extent the opening of cross-border economic relations has helped to promote economic activity in Myanmar's border regions. Border regions in Myanmar are both less economically developed than the country's lowland and urbanized interior, and they are prone to violent conflict (Bissinger et al. (2020)). Recent spatial general equilibrium economic models as well as evidence from a number of countries suggest that one effect of opening trade may be to stimulate economic activity in hitherto less developed regions in the proximity of international borders. The aim of the research reported here is to explore whether and in what precise way this phenomenon can also be observed in the case of Myanmar. As a proxy measure for economic activity we resort to fine-grained satellite readings of night-light intensity – a by now widespread tool for analysing the spatial economy in the presence of otherwise sparse data.

Our note is structured as follows. In Section 2, we present our data and estimation methods. Section 3 describes the geographic distribution of economic activity in Myanmar. The core of our analysis is Section 4, in which we document how light gradients in border regions have evolved since Myanmar's opening to trade. Section 5 concludes.

2 Data and Methodology

2.1 Nightlight Data

Nightlight data can serve as a proxy for economic activity. Levels and changes in nightlight intensity have been shown to be highly correlated with local incomes. For countries in which official statistics about economic activity are scarce or imprecise, nightlight data can offer remarkably precise estimates. (Henderson et al. (2012); Tilottama et al. (2010)) Moreover, nightlight data are available at a very fine geographical scale. This allows us to evaluate spatially heterogeneous effects.

The collection of nightlight data started as a byproduct of measurements by meteorological satellites. In recent years, there have been technological advancements, in particular with regard to the precision and storage capacity of these satellites. This offers more precise data for the more recent years, but it significantly complicates comparisons of measurements before and after changes in the measurement technology.

Specifically, from 1992 until 2013, satellite readings were produced using the *Defense Meteorological Program (DMSP) Operational Line-Scan System (OLS)*.[1] The grid cells underlying these measurements had a resolution of about one square kilometer. Nightlight values were reported as integers, ranging from 0 to 63. The top coding at 63 does not allow to distinguish different light intensities in the brightest places, typically in major cities.[2] Over the years, different satellites were used. As these satellites lacked onboard calibration, there might be differences in the overall level of nightlight intensity across different years (Henderson et al. (2012); Elvidge et al. (2009)). This should, however, affect all areas within Myanmar in a similar fashion.

Since 2012, nightlight data have been collected using the new *Visible Infrared Imaging Radiometer Suite (VIIRS) Day/Night Band (DNB)* technology, with 2013 being the first year for which we have full coverage.[3] With this current technology, data are available in even finer resolution, with grid cells measuring about 420m in length and width.[4] The current system collects data on a continuous scale and without top coding. Onboard calibration allows for a meaningful comparison across years (Elvidge et al. (2017); Shi et al. (2014); Chen and Nordhaus (2015)). For our years of interest (2013 and 2019), the data are reported as monthly averages. In order to obtain annual values, we computed averages of the monthly files, weighted by the amount of cloud free observations per month.[5]

2.2 Border Crossings and Road Data

With the grid cells of the nightlight data as our units of observations, we need a way of categorizing those units in terms of their proximity to the border. A simple solution would be to consider the geodesic distance of each grid cell to the closest point at the border. This, however, would ignore the realities of topography and transport infrastructure. We therefore define proximity to the border as the road distance to border-crossing points.

We take our road data from the *Myanmar Information Management Unit (MIMU)*.[6] In order to be able to process them with GIS software, we cleaned the file, mostly by connecting apparent gaps that obviously belong to the same road. Whenever possible, we validated our interpolations with Google Maps or ArcGIS basemaps.

From the Ministry of Commerce in Myanmar, we received two lists of border crossings. We refer to border posts that figure on one of those two lists as "major crossings".[7] Moreover, we manually verified all points at which a road intersects with a country border. This was done using Google Maps and ArcGIS basemaps. Whenever there is a road large enough to cross the border by car, we marked that point as a "minor crossing". We did not categorize points as minor crossings that involve water crossings without a visible bridge. It is not clear to what extent the border-crossing roads we identify correspond to legal border-crossing points. To the extent that the minor crossings are not in fact open to formal

[1] The data can be accessed at `https://eogdata.mines.edu/dmsp/downloadV4composites.html` (last accessed: 28.06.2020).
[2] This is a more severe problem when the focus of a study lies on variations within the bigger and richer urban areas of the world.
[3] For 2013, data were collected using both the old and the new satellite technology.
[4] Accessible via `https://eogdata.mines.edu/download_dnb_composites.html` (last accessed: 28.06.2020).
[5] For the year 2016, the data are available on an annual as well as on a monthly basis. Our aggregation method matches one of the annual composites.
[6] Data available at `http://geonode.themimu.info/layers/geonode%3Ammr_rdsl_250k_mimu` (last accessed: 28.06.2020).
[7] We dropped some border posts that are on the lists but are located far away from the border. This includes for example border posts and trading zones at sea ports.

cross-border traffic, they could nonetheless be used for informal trade. We perform all our analyses for the two categories of crossings combined, as well as for major crossings and for minor crossings separately.

	Thailand	China	India	Bangladesh	Laos	Total
Major	6	4	2	1	1	14
Minor	10	18	4	1	0	33
All	16	22	6	2	1	47

Table 1: Number of border crossings

Table 1 shows the number of crossings identified in our data, per category and neighbor country. Figure 1 shows the geographical location of these crossing points, as well as the road network that we use to measure the distance from a grid cell to the nearest crossing.

Our analysis focuses on border regions along road corridors, defined as grid cells located within 10 kilometers from a road and within 200 kilometers from the nearest border crossing, along that road (following Brülhart et al. (2019)). Grid cells are matched to the border post they are closest to (road distance). Figure 2 shows the grid cells that fulfill these criteria. They are located along road corridors that connect border crossings with the interior of the country.

Table 2 provides summary statistics on our basic lights data. We consider a total of 988,700 grid cells. The overwhelming majority of those grid cells (94% in 2013 and 88% in 2019) were essentially dark, which we define as having a light intensity below 0.25. In the last two columns of Table 2, we compute average distances to the nearest border crossing for grid cells in each nightlight interval. Interestingly, the average distance to the border of the most brightly lit grid cells (nightlight intensity > 2) increased over our sample period. This is *prima facia* evidence against the hypothesis that trade liberalization has attracted economic activities towards the borders.

	# Observations		Mean Distance[a]	
Nightlight Intensity	2013	2019	2013	2019
Smaller than 0.25	925,882	868,143	109.89	110.44
Between 0.25 and 0.5	40'036	90,611	111.35	105.66
Between 0.5 and 1	15'573	20,037	110.05	107.11
Between 1 and 2	4'906	5,842	109.26	112.50
Between 2 and 5	1'906	2,683	110.74	114.61
Larger than 5	397	1,384	95.34	99.52
Total	988,700	988,700	109.94	109.94

a) Mean Distance = average(road distance to border + geodesic distance to road) in kilometers

Table 2: Grid cells

Additional descriptive statistics are provided in Table 3, where we report average nightlight intensities of grid cells along road corridors to different neighboring countries. In panel (a) of Table 3, we report averages across all grid cells, and in panel (b) we show averages only across grid cells that were not essentially dark across both sample years (i.e. with a nightlight intensity of > 0.25 in both years). We see that Myanmar has on average got brighter, consistent with economic growth. When we focus on the 'non-dark' grid-cells summarized in panel (b), we find that border regions with Bangladesh experienced the strongest increase in night lights, followed by those with China and those with Thailand. Border

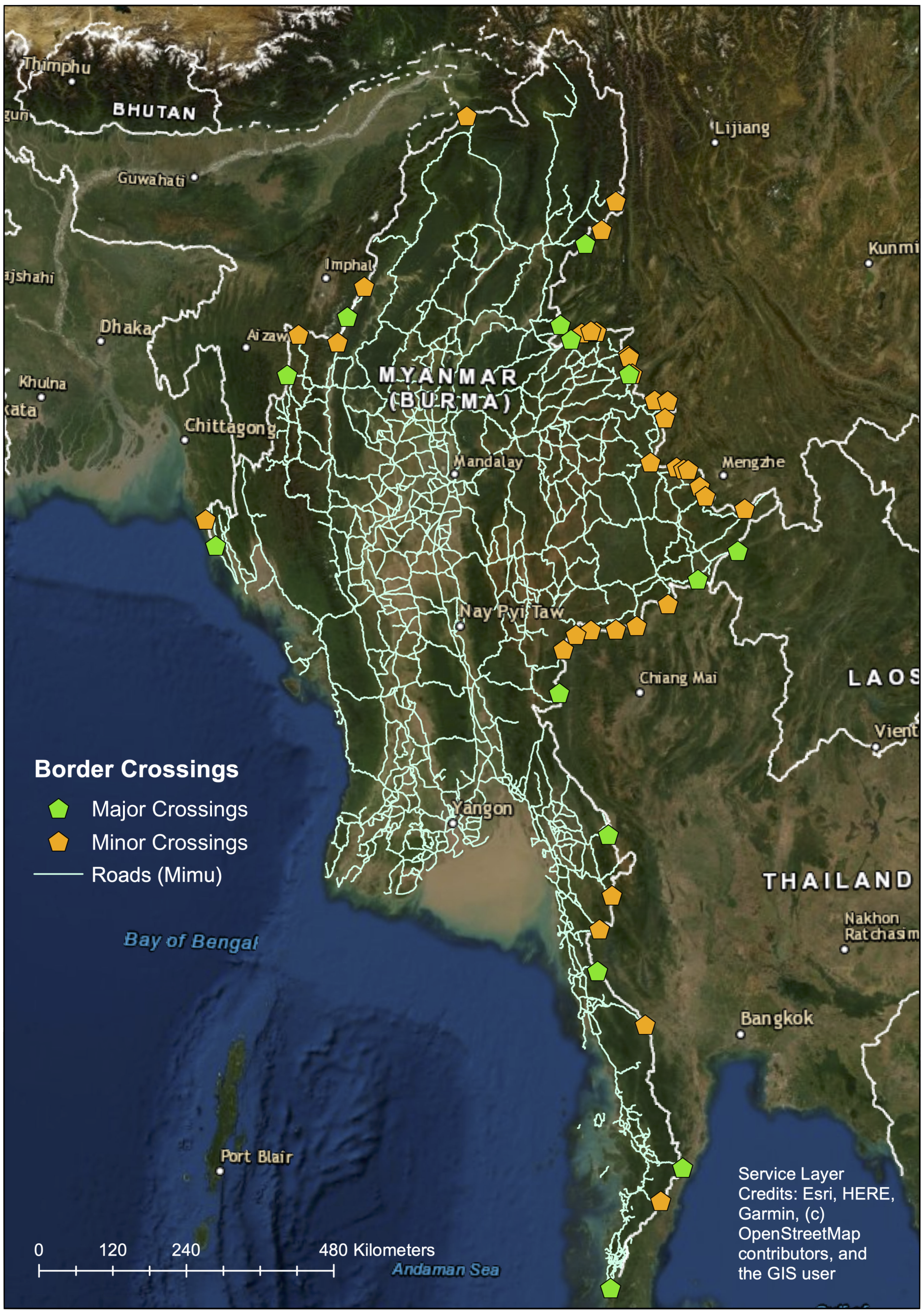
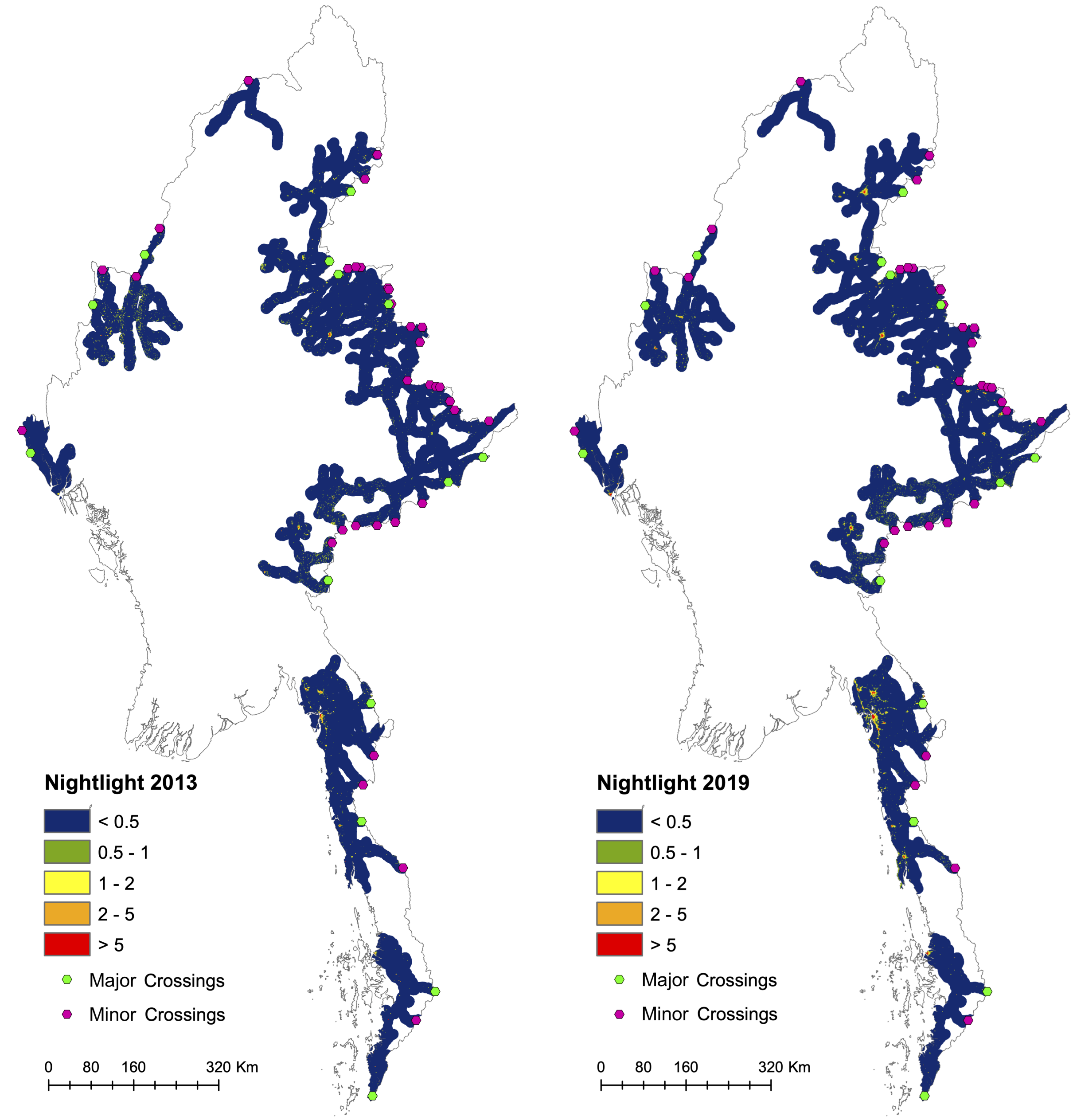


Figure 1: Border crossings



(a) 2013

(b) 2019

Figure 2: Myanmar's border-region road corridors

Source: VIIRS vcm annualized. Earth Observation Group, Payne Institute for Public Policy.
Notes: "Major Crossings" indicate customs posts as communicated by the Myanmar authorities. "Minor Crossings" indicate border-crossing roads as visible on Google Maps. Nightlight is measured on a continuous scale. Within the border road corridors that we study, the brightest grid cell in 2013 has a nightlight intensity of 37.09, while in 2019, the brightest intensity is 96.15.

regions with India and Laos in fact experienced a drop in average luminosity.[8]

	2013	2019	Observations
Thailand	0.095	0.229	403,929
China	0.112	0.204	401,116
India	0.160	0.195	142,745
Bangladesh	0.056	0.197	36,949
Laos	0.099	0.220	3,961
All neighbors	0.110	0.213	988,700

(a) All observations

	2013	2019	Observations
Thailand	0.763	1.205	15,965
China	0.851	1.806	6,506
India	0.539	0.492	3,668
Bangladesh	1.235	5.553	124
Laos	0.592	0.343	39
All neighbors	0.756	1.273	26,302

(b) Conditional on > 0.25 in both periods

Table 3: Average Nightlight Intensity

2.3 Econometric Specification

Our baseline regression specification is as follows:

$$\begin{aligned}\ln(\text{Light}_{ijt}) &= \beta_0 + \beta_1 \times \text{Distance}_{ij} + \beta_2 \times \text{Distance}_{ij} \times \text{Y2019}_t + \beta_3 \times \text{Onroad}_i + \beta_4 \times \text{Onroad}_i \times \text{Y2019}_t \\ &+ \beta_5 \times \text{Atborder}_{ij} + \beta_6 \times \text{Atborder}_{ij} \times \text{Y2019}_t + \beta_7 \times \text{Y2019}_t + \boldsymbol{\gamma}_j \times \textbf{Crossing}_j + \varepsilon_{ijt}, \quad (1)\end{aligned}$$

where Light denotes the measured nightlight intensity of a grid cell i associated with border crossing j in year t, Distance denotes grid cell i's distance from the nearest border crossing j measured by following the road, Y2019 is a dummy variable set to one if the year t is 2019, Onroad is a dummy variable for grid cells located within 500 meters of a road, Atborder is a dummy variable for grid cells located within 20 kilometers of the border crossing point, Crossing is a vector of dummy variables (fixed effects) for each boder crossing j, and ε is a stochastic error term.

Similar to regression equation 1, we estimate the following specification for a graphical non-parametric representation of nightlight gradients with respect to distance from the border:

$$\begin{aligned}\ln(\text{Light}_{ijt}) &= \beta_0 + \sum_{k=1}^{10} \Big[\beta_k \times \text{DistanceBin}_{kij} \times \text{Y2019}_t\Big] + \sum_{l=1}^{9} \Big[\beta_{l+10} \times \text{DistanceBin}_{lij} \times \text{Y2013}_t\Big] \\ &+ \beta_{20} \times \text{ToRoadDistance}_{ij} + \boldsymbol{\gamma}_j \times \textbf{Crossing}_j + \nu_{ijt}, \quad (2)\end{aligned}$$

where DistanceBin denotes 20-kilometer segments along road corridors than run towards border crossing points as shown in Figure 3, ToRoadDistance is the geodesic distance to the nearest point on the road corridor of grid cells that are located up to 10 kilometers away from the road, and ν is a stochastic error term.

3 Geographic Concentration of Economic Activity in Myanmar

In Myanmar, growing economic activities and opportunities are mostly located in the central states, while many peripheral regions are afflicted by poverty and conflict. Figure 3 shows that trading firms, and accompanying job opportunities, are highly concentrated in the central states of the country, often

[8] Sample sizes for Bangladesh and Laos, however, are quite small, which is why we shall not focus on these border regions below.

located within industrial parks or special economic zones (SEZs). All trading firms are in urban areas and 85 percent of those are found in the Yangon Region (CSO (2017)). Between 2015 and 2017, the regions with a higher initial presence of GVC firms experienced a larger increase in per-capita income (Figure 3). While this is a simple correlation where many factors are at play, evidence suggest that this increase likely worked through the employment channel, as the number of jobs in firms that both import and export grew about 8% faster than in firms that export only or do not trade at all (Jaud and Kukenova (2020)). This positive effect on employment and income is likely to have contributed to poverty reduction in those same regions, although the lack of data on poverty rates at the subnational level makes it impossible for the time being to test for this directly.

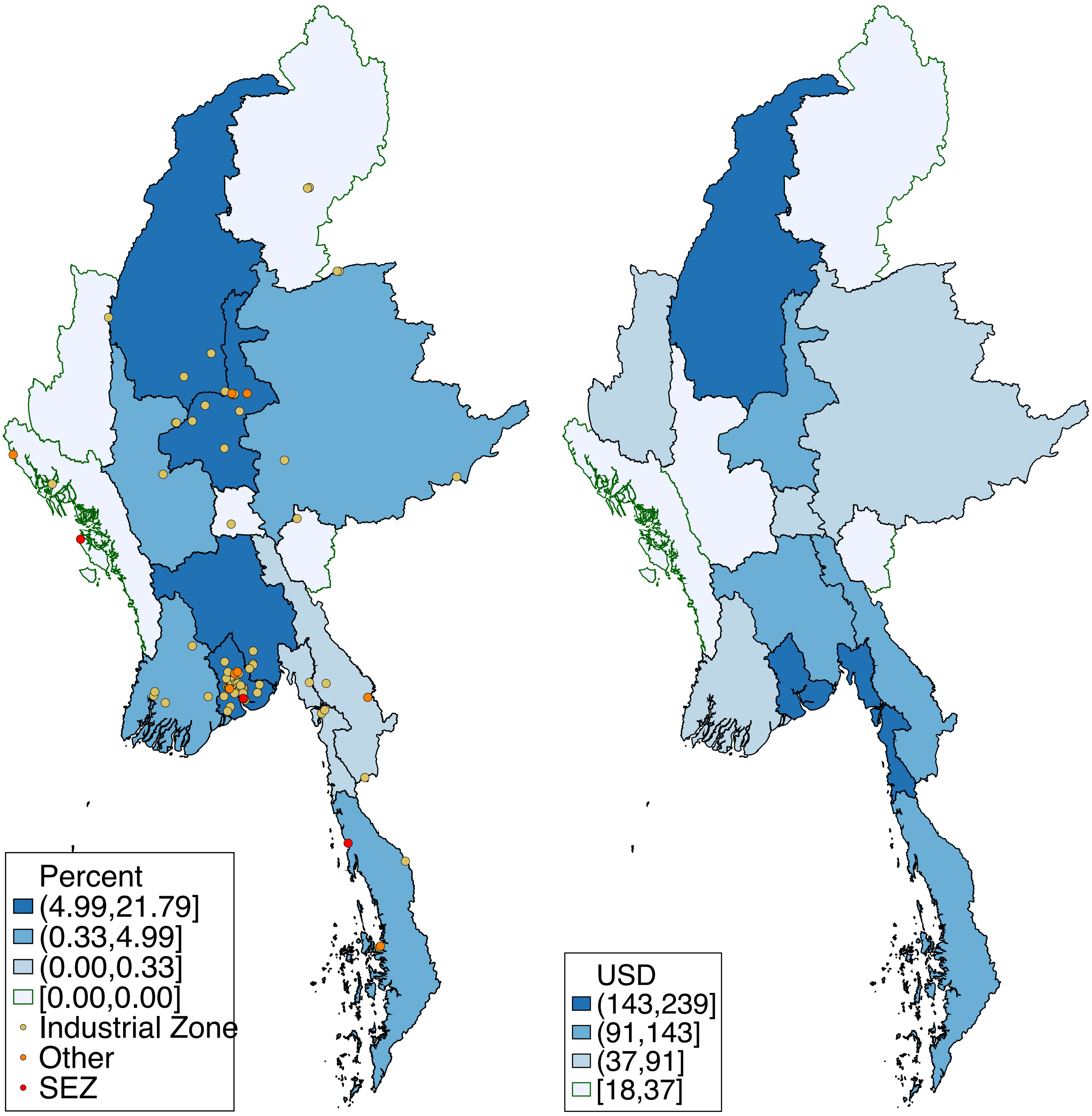
Nightlights captured by satellites as a proxy for economic development confirm this result. The intensity of nightlights increased between 2003 and 2019, along with the economic development of the country. However, most activities remained concentrated in large urban centers such as Yangon, Nay Pyi Taw (modern capital of Myanmar founded in 2005) and Mandalay (Figure 3). Yet, according to most spatial economic models and empirical evidence from other countries, more open trade policy typically induces spatial de-concentration of economic activities towards border regions (Atkin and Donaldson (2015); Redding and Rossi-Hansberg (2017)). Myanmar's concentration of activities in the central states after many years of inward-oriented policies is consistent with the predictions of these theories. Related to this, the incidence of poverty is highest in border regions including in Chin state, where fully 58 percent of the population live below the national poverty line of 1'590 kyat a day (roughly US$1 per day), followed by Rakhine State (41.6 percent) and Kachin state (37 percent). Central states Bago (17.4 percent) and Mandalay and Yangon regions (just over 13 percent each) have among the lowest poverty headcounts (Myanmar Living Conditions Survey (2017)).

Since trading firms agglomerate in urban centers to access necessary inputs, infrastructure and services, their expansion may contribute to reinforcing spatial inequality. Tanaka (2020) shows how trade liberalization disproportionately favored the expansion of Burmese firms located close to airports. Myanmar has 63 industrial zones in operation in all but Chin State, but 65 percent are located in the Yangon Region alone and most exporting firms are concentrated in industrial hubs of Yangon and Mandalay. Border areas, however, are often out of government control, and extreme poverty has led local population to engage in illegal activities including opium poppy cultivation and smuggling.

In Figures 4 and 5, we show the distribution of nightlights in Myanmar, and how that distribution has evolved since 2003. Because of the change in measurement method in 2013, we separately show changes between 2003 and 2013 (Figure 4) and between 2013 and 2019 (Figure 5). The figures provide stark illustrations of the gap in economic development between Myanmar and its neighboring countries, all of which evidently have higher nightlight intensities. The light maps also illustrate starkly how economic development was mainly concentrated along the central Yangon-Mandalay corridor.

A direct government intervention to counteract that centripetal development pattern could be to encourage firms to move to border regions through direct or indirect inducements. Elements of such a policy could include of providing security as well as access to services and transport infrastructure (World Bank (2016)).

However, greater trade across overland borders could bring job opportunities and raise income of poor households in border areas even in the absence of place-based policies. Across countries, economic activities tend to become sparser as one gets closer to borders (Brülhart et al. (2019)). However, good trade

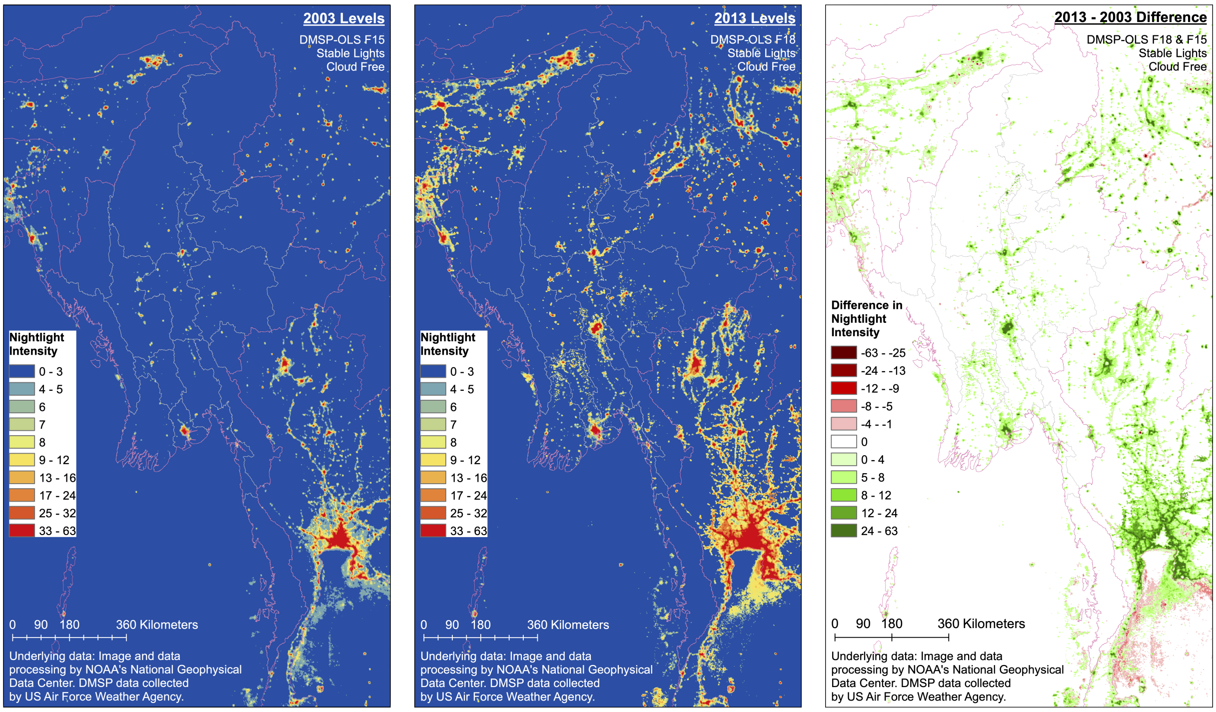


(a) Percent share of GVC firms in total firms employment, 2015 with industrial zones (2019)

(b) Change in per capita income, 2015 - 2017

Figure 3: Employment, Income and GVC Firms

Source: Myanmar business survey data 2015 and Myanmar CSO 2015 and 2017.
Notes: GVC firms are firms that both export and import. GVC firms share of employment is measured as the total number of employees reported by all GVC firms over the total number of employees reported by all registered firms within each state. Income is measured as the GDP per capita in constant US 2010 dollars at the state level.



(a) 2003 (b) 2013 (c) Difference 2013 - 2003

Figure 4: Nightlights in Myanmar, old satellite system (DMSP)

Source: Image and data processing by NOAA's National Geophysical Data Center. DMSP data collected by US Air Force Weather Agency. 2003 data from the DMSP-OLS F15 Stable Lights Cloud Free. 2013 data from the DMSP-OLS F18 Stable Lights Cloud Free.
Notes: Spots colored from blue to red mark night lights of increasing intensity. The third map shows the difference of the two years, with increasing nightlight intensity depicted as green.

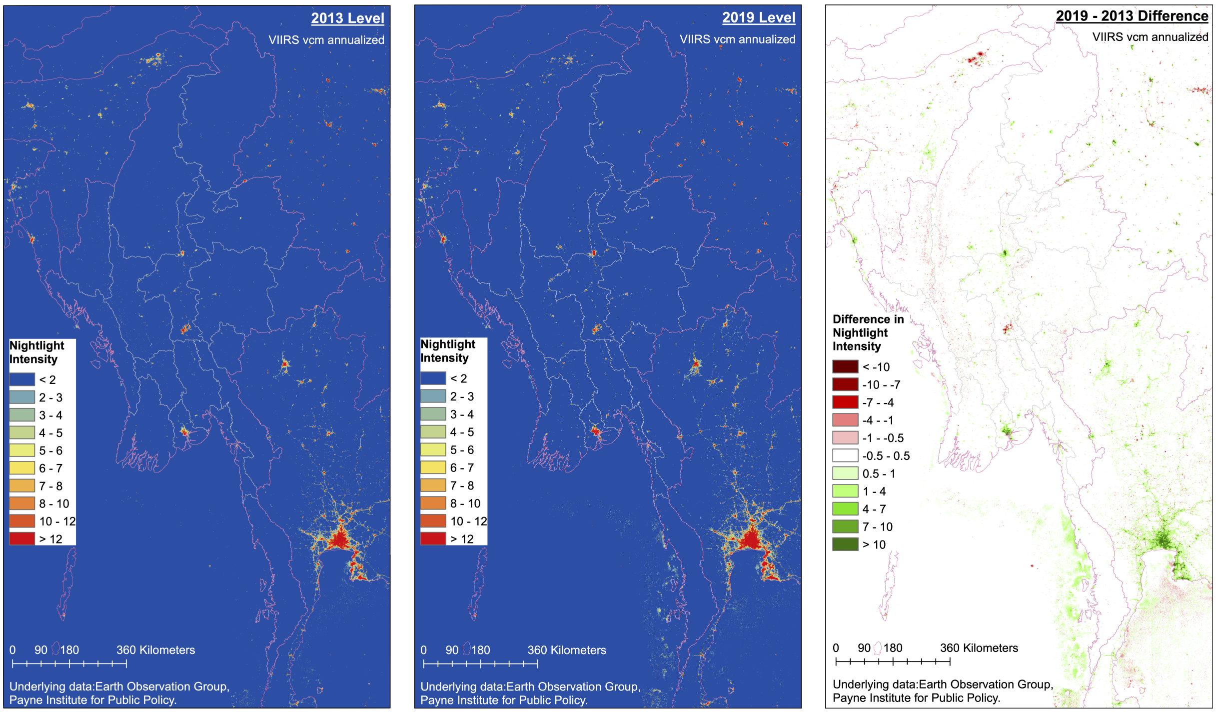
facilitation and logistics services across overland borders can attenuate this effect. Moreover, facilitating local cross-border trade can be an important means for addressing food security issues faced by poor populations in the border areas and in increasing incomes in farming communities.

International evidence also suggests that trade can promote peace. Research on thirteen conflict-afflicted Sub-Saharan African countries shows that positive external (agriculture-related) income shocks reduce the probability of violent conflict within a given locality. The relationship is stronger in localities that are more open to trade (Berman and Couttenier (2015)). The reason is that the more connected localities are, the more affected by foreign demand their income is. The effect is also stronger in localities close to natural resources and therefore typically more prone to violent conflict.

In the following Section, we therefore explore how Myanmar's border regions have fared in the wake of the trade liberalization that occurred in the last decade.

4 Economic Development of Border Regions

Across countries, economic activities tend to become sparser as one gets closer to borders (Brülhart et al. (2019)). This "border shadow" is visible in Myanmar too, when considering the country as a whole (see Figure 5). Our main focus here is on road corridors up to 200km from border crossings. These corridors



(a) 2013 (b) 2019 (c) Difference 2019 - 2013

Figure 5: Nightlights in Myanmar, new satellite system (VIIRS)

Source: VIIRS vcm annualized. Earth Observation Group, Payne Institute for Public Policy.
Notes: Spots colored from blue to red mark night lights of increasing intensity. The third map shows the difference of the two years, with increasing nightlight intensity depicted as green.

are shown in Figure 2 with a color-coding indicating nightlight intensity.

Trade across overland borders has been growing, accounting for 30% of Myanmar's international trade in 2019, up from 20% in 2014 (CEIC data and World Bank (2016)).[9] Myanmar outbound cargo mainly consists of agriculture products, frozen fisheries products, woods and minerals, while inbound cargo from China and Thailand is mostly machinery, clothing and various consumer products. The increase in cross-border trade owes to the development of corridor projects including the east-west and southern economic corridors connecting Myanmar to Vietnam through Thailand, Laos, Cambodia.[10]

Figure 6 shows our main results. It reports the estimated light gradients along road corridors running inland from border crossings, where the origin of the horizontal axis represents locations at the border crossing and the right edge represents locations within 200 kilometers of the border crossing. When all data are pooled (panel "All"), we observe essentially no evidence of a border shadow in 2013: the gradient of lights as one moves away from the border was essentially flat.

By 2019, however, two patterns had changed. First, locations within 20 kilometers of the border had on

[9] The Muse border post is currently the largest border crossing with China, while Myawaddy is the main gate for cross border trade with Thailand. Cross-border trade with India is mainly handled through Tamu.
[10] The new China-Myanmar economic corridor project covering both rail and road infrastructures under the Chinese "Belt and Road Initiative" will connect Kunming, the capital of Yunnan province in southwestern China through Muse and Mandalay to Kyaukpyu in Rakhine State, which could provide a major additional boost to trade with China.

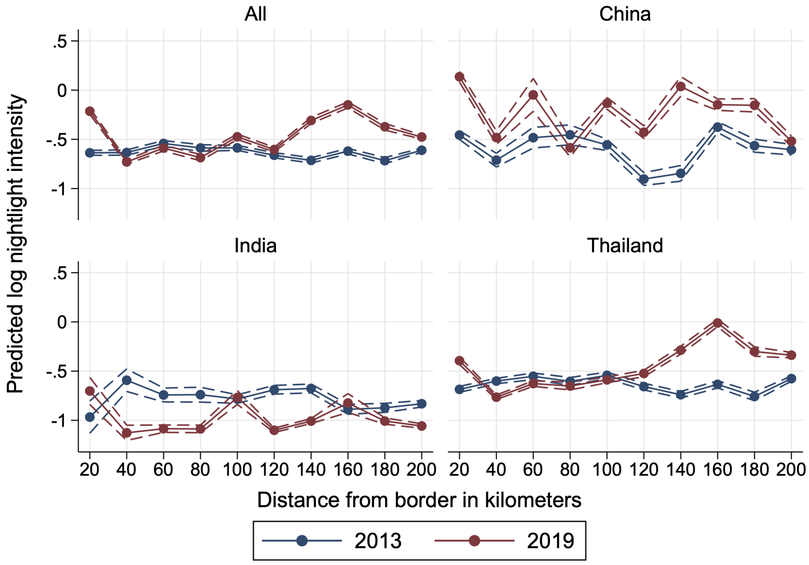


Figure 6: Light gradients along border-crossing road corridors, by neighbor

Notes: The graph shows point estimates of regressions of pixel-level nightlight intensity (in natural logs) on distance to the nearest border crossing as illustrated in Figure 2, where distance is modeled as a set of dummy variables for bins of 20km. The graphs plot estimates for all distance bins up to 200 kilometers from the border, with the most distant bin in 2013 taken as the reference group. Blue lines are for night lights in 2013, and red lines are for night lights in 2019. Dashed lines are 95% confidence intervals. Panel "All" represents the full data sample, including all border crossings shown in Figure 2. Panels "China", "India", and "Thailand", report the corresponding estimates for road corridors leading to those respective neighbor countries.

average become significantly brighter. This is consistent with increased cross-border trade stimulating activity close to the border. Second, locations between 120 and 200 kilometers of the border have witnessed even stronger increases in nightlights. This effect at first sight runs contrary to the hypothesis that trade liberalization stimulates economic development in a way that gradually declines with distance from the border. Myanmar's trade liberalization seems if anything to have produced a border shadow where previously there had been none.

These patterns are mirrored in the regression estimates of equation 1 shown in Table 4. While the coefficient on distance from the border had been slightly negative in 2013, it had turned significantly positive by 2019.

It is interesting to decompose the pooled estimate for all border crossings into subsets of crossings to different neighbor countries. Figure 6 shows clearly that locations immediately adjacent to all three main borders have seen significant increases in nightlights. The increase in lights along cross-border road corridors some 120 kilometers or more inland from the border post, however, is a phenomenon specific to roads to China and Thailand. In fact, border regions with India seem to have suffered a significant loss of nightlight intensity over our sample period.[11]

Why is it that nightlights evolved non-monotonically with respect to distance from the Chinese and Thai

[11] Again, the results illustrated in Figure 6 are shown in greater detail in the regression estimates of Table 4.

	Dependent variable: logarithm of nightlights					
	All border crossings				Major	Minor
	All	China	Thailand	India	All	All
Road distance from	-0.005***	-0.006**	-0.003**	-0.011***	-0.008***	0.002*
border in 10km	(0.001)	(0.002)	(0.001)	(0.002)	(0.002)	(0.001)
Road distance * 2019	0.020***	-0.003	0.030***	0.009***	0.016***	0.013***
	(0.001)	(0.003)	(0.001)	(0.002)	(0.002)	(0.001)
Within 500m of road[a]	0.094***	0.156***	0.109***	-0.041	0.165***	0.057***
	(0.012)	(0.023)	(0.016)	(0.033)	(0.018)	(0.016)
Within 500m * 2019	0.514***	0.338***	0.464***	0.707***	0.367***	0.582***
	(0.019)	(0.035)	(0.023)	(0.073)	(0.026)	(0.027)
Within 20km[b]	-0.006	0.247***	-0.080***	-0.288***	0.109***	-0.059**
	(0.016)	(0.033)	(0.018)	(0.083)	(0.027)	(0.019)
Within 20km * 2019	0.425***	0.171***	0.417***	0.428***	0.316***	0.347***
	(0.023)	(0.050)	(0.027)	(0.085)	(0.039)	(0.030)
Border crossing FE	yes	yes	yes	yes	yes	yes
N	52'604	13'012	31'930	7'336	23'558	29'046

Robust standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

a) Dummy variable, baseline category: Between 500m and 10km air distance from road

b) Dummy variable, baseline category: Between 20km and 200km road distance from border crossing

Regression also includes a constant term, as well as a dummy for the year 2019 as opposed to 2013

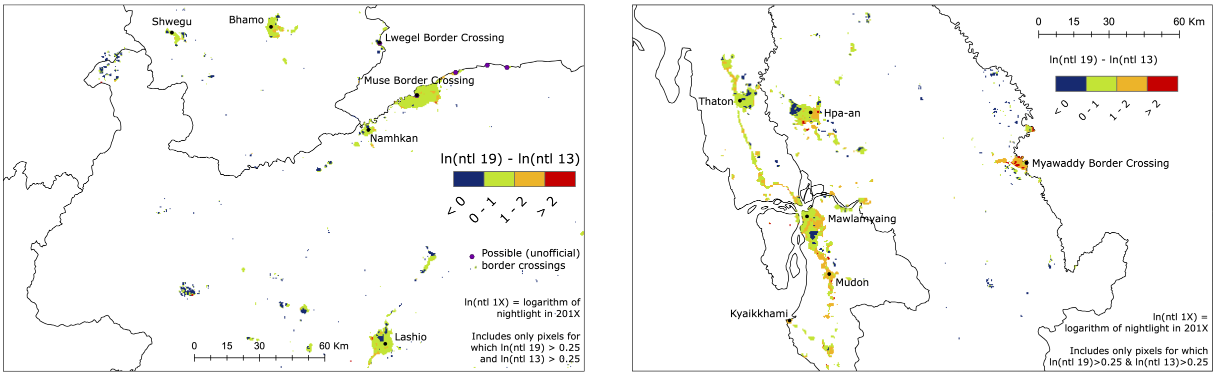
Table 4: Regressions by neighbor and by crossing type

borders? Figure 7 shows the likely explanation. It zooms into the border regions near the main crossings to China (Muse, northeastern Myanmar) and to Thailand (Myawaddy, southeastern Myanmar). These maps show clearly that the border towns themselves have seen strong increases in nightlights over our 2013-2019 sample period. In the immediate hinterlands of the border towns, however, no significant change in nightlight intensity is apparent. Strong increases in lights can only be discerned further inland from the border crossings, at the nearest large towns. In the case of China, that is Lashio (170km from the border) and in the case of Thailand it is Mawlamyaing (120km from the border).

Part of the explanation for why trade liberalization in Myanmar has not led to increases in lights within the first approximately 120 kilometers of border crossings may be due to simple topography: Myanmar's borders mainly run through mountainous regions, and the fertile lowlands typically are located at a considerably distance from the border.

However, our estimates consider changes in lights. The fact that low-lying, more densely populated regions have more lights at any given point in time is not what informs our results. Indeed what we might be observing is another well-studied phenomenon in economic geography: agglomeration economies. There is a large academic literature to document the discontinuous spatial effects of trade liberalization: while towns and cities might benefit disproportionately, surrounding rural areas could benefit much less or even lose out in terms of productivity and per-capita incomes (e.g. Redding and Rossi-Hansberg (2017)). In that sense, it is not surprising, to see larger towns in the interior of border regions to benefit more from increased trade openness than rural areas closer to the border itself.

Nonetheless, it is is striking how, apart from the border towns themselves, locations within the first



(a) Border region with China (Muse crossing)

(b) Border region with Thailand (Myawaddy crossing)

Figure 7: Two examples of border regions

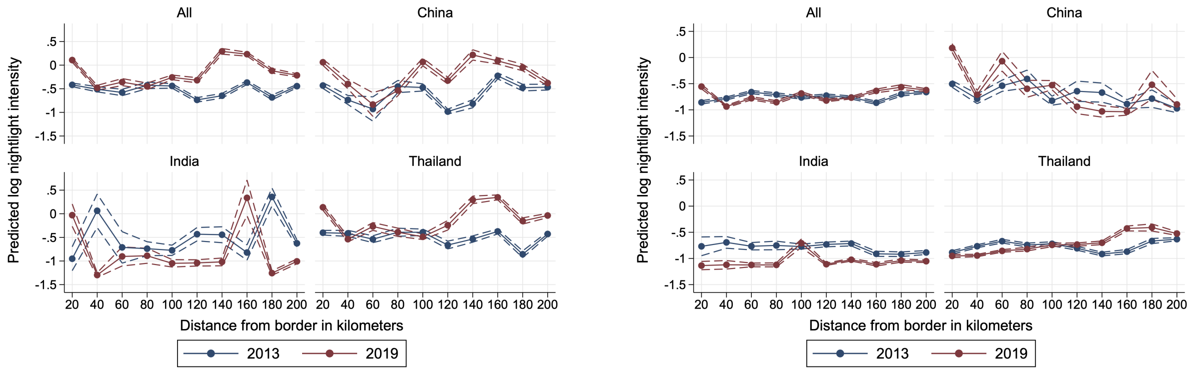
120 kilometers of the the border do not seem to have seen significant growth since the opening of Myanmar's trade. This does not conform with the worldwide average. Brülhart et al. (2019), pooling all countries across the globe, find that border shadows of non-urban locations also significantly brighten up as cross-border trade is liberalized. Hence, the lack of visible impact on regions between 20 and 120 kilometers of Myanmar's land borders seems to be a special phenomenon suggesting barriers to the dissemination of trade-induced effects in rural regions.

Another indication that economic impulses from trade liberalization have not yet spread widely in Myanmar can be gleaned from the regression results shown in Table 4. First, the regressions show that any increases in nightlights that existed were tightly concentrated around road corridors (within 500 meters of the main roads, according to our definition). Away from the main roads, Myanmar's border regions have essentially remained dark.

Two further observations underscore the particular nature of Myanmar's liberalization effects. One is that lights along roads to "minor" border crossings have increased much less than along roads to "major" border crossings (Figure 8). This is particularly stark with China, where the trade effects seem to be entirely confined to the corridors leading to major crossings. This suggests that the scope for small-scale and informal trade across minor border crossings as an engine of border-region development in Myanmar is quite limited.

Finally, it is worthwhile returning to Figure 5, the third panel of which shows changes in nightlights between 2013 and 2019 for all of Myanmar as well as for its neighboring countries. This map shows clearly that light intensity has in fact dropped in most of Myanmar's western border regions (Rakhine, Chin and Sagaing) as well as in some eastern regions (especially Kayah). The third panel of Figure 5 furthermore suggests that locations on the foreign side of the Myanmar border grew more strongly than those on the domestic side.[12]

[12] Compare, for example, Muse in Myanmar to adjacent Ruili in China, or Myawaddy in Myanmar to adjacent Mae Sot in Thailand. In both cases, there is clear evidence of stronger light growth on the foreign side of the border crossing. The same phenomenon is evident across the border with Bangladesh, where it might however be linked to the presence of displaced people.



(a) Major border crossings

(b) Minor border crossings

Figure 8: Light gradients along border-crossing road corridors, by neighbor and crossing type

Notes: The graph shows point estimates of regressions of pixel-level nightlight intensity (in natural logs) on distance to the nearest border crossing as illustrated in Figure 2, where distance is modeled as a set of dummy variables for bins of 20km. The graphs plot estimates for all distance bins up to 200 kilometers from the border, with the most distant bin taken as the reference group. Blue lines are for night lights in 2013, and red lines are for night lights in 2019. Dashed lines are 95% confidence intervals. Panel "All" in Figure 8a represents all major border crossings, as shown in Figure 2. Panel "All" in Figure 8b represents all minor border crossings, as shown in Figure 2. Panels "China", "India", and "Thailand", report the corresponding estimates for road corridors leading to those respective neighbor countries.

5 Conclusions

We have analyzed the evolution of nightlights in Myanmar's border regions over a period of pronounced liberalization of cross-border trade (2013-2019).

Most models of economic geography as well as the bulk of available evidence from other countries suggest that reducing border barriers promotes economic activity the more the closer a region is to the border.

We find this logic to apply to Myanmar only partially. Some towns on busy border crossings with China and Thailand did grow disproportionately, as did some towns further inland along border crossing road corridors to those neighboring countries. This suggests that increased trading opportunities did raise incomes along some of the main trading routes.

However, rural areas in border regions between the main towns did not seem on the whole to benefit from the increased trading opportunities, nor did locations situated off the main road corridors. This suggests that the benefits of trading opportunities were confined to urban populations and did not disperse widely in space.

Moreover, most increases in lights of border regions that we observe were confined to the eastern border. Border regions with India on average saw a reduction in nightlight intensity. Even in the east, light growth on the foreign side of the main border crossings was much more pronounced than on the Myanmar side.

In sum, these observations suggest that political tensions and other constraints might be preventing Myanmar border-region populations from benefiting fully from the opportunities that liberalized cross-border trade could offer.

References

Atkin, D. and Donaldson, D. (2015). Who's Getting Globalized? The Size and Implications of Intra-national Trade Costs. NBER Working Papers 21439, National Bureau of Economic Research.

Berman, N. and Couttenier, M. (2015). External Shocks, Internal Shots: The Geography of Civil Conflicts. *Review of Economics and Statistics* 97: 758–776.

Bissinger, J., Kyaw Min Maw, A., Barron, P. and Rahardja, S. (2020). Business in Conflict-Affected Areas of Myanmar. Mimeo, World Bank, Washington DC.

Brülhart, M., Cadot, O. and Himbert, A. (2019). Let There Be Light: Trade and the Development of Border Regions. CEPR Discussion Papers 13515, CEPR Discussion Papers.

Chen, X. and Nordhaus, W. (2015). A test of the new viirs lights data set: Population and economic output in africa. *Remote Sensing* 7: 4937–4947.

CSO (2017). Myanmar Micro, Small, and Medium Enterprise Survey 2017.

Elvidge, C. D., Baugh, K., Zhizhin, M., Hsu, F. C. and Ghosh, T. (2017). VIIRS Night-Time Lights. *International Journal of Remote Sensing* 38: 5860–5879.

Elvidge, C. D., Ziskin, D., Baugh, K. E., Tuttle, B. T., Ghosh, T., Pack, D. W., Erwin, E. H. and Zhizhin, M. (2009). A Fifteen Year Record of Global Natural Gas Flaring Derived from Satellite Data. *Energies* 2: 1–28.

Henderson, J. V., Storeygard, A. and Weil, D. N. (2012). Measuring Economic Growth from Outer Space. *American Economic Review* 102: 994–1028.

Jaud, M. and Kukenova, M. (2020). Nature, Strength and Vulnerabilities of Global Value Chains: The Case of Myanmar. Mimeo.

Myanmar Living Conditions Survey (2017). Key Indicators Report. World Bank.

Redding, S. J. and Rossi-Hansberg, E. (2017). Quantitative Spatial Economics. *Annual Review of Economics* 9: 21–58.

Shi, K., Huang, C., Yu, B., Yin, B., Huang, Y. and Wu, J. (2014). Evaluation of NPP-VIIRS Night-Time Light Composite Data for Extracting Built-Up Urban Areas. *Remote Sensing Letters* 5: 358–366.

Tanaka, M. (2020). Rural Roads and Local Economic Development. *Review of Economics and Statistics* forthcoming.

Tilottama, G., Powell, R., Elvidge, C., Baugh, K., Sutton, P. and Anderson, S. (2010). Shedding Light on the Global Distribution of Economic Activity. *The Open Geography Journal* 3: 148–161.

World Bank (2016). Myanmar - Diagnostic Trade Integration Study (DTIS): Opening for Business.