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Assessing the impact of infrastructure investments using customs data:  
The case of the greater Mekong Subregion corridor and the People's  
Republic of China

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# ASSESSING THE IMPACT OF INFRASTRUCTURE INVESTMENTS USING CUSTOMS DATA

THE CASE OF THE GREATER MEKONG SUBREGION CORRIDOR  
AND THE PEOPLE'S REPUBLIC OF CHINA

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Yasuyuki Sawada, and Ruo Shangguan*

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## ABSTRACT

This paper provides new evidence of the effects of road construction on both domestic and international trade flows in the People's Republic of China (PRC) using customs data and information on transport investments in the region, including those supported by multilateral development banks. We find that road construction helped to reduce trade costs significantly from 2000 to 2011, supporting the catch-up of inland regions in the PRC to its coastal cities. The ad valorem rate of internal trade costs decreases by 20%, and the ad valorem rate of international trade costs decreases, on average, by 15.3%, with substantial heterogeneity of effects across sectors. Using satellite and customs data, we also document that the construction of the Kunming–Bangkok Expressway led to local economic growth and higher regional specialization in accordance with comparative advantage, suggesting the role of the road construction in facilitating market integration across borders in the Greater Mekong Subregion.

**Keywords:** development impact, infrastructure, economic growth, trade, job creation, regional specialization, market integration

**JEL codes:** R40, R41, F10, F13

# 1 Introduction

Governments, international development organizations, and financial institutions invest substantially in transportation infrastructure projects around the world. For example, the People's Republic of China's (PRC) National Trunk Highway System costs more than \$120 billion over 15 years (Faber, 2014). More recently, the PRC's Belt and Road Initiative has promoted transportation infrastructure across Asia, Europe, and Eastern Africa. To evaluate the return on investments and inform future policy decisions, it is important to understand how improved connectivity affects the process of industrialization and the overall welfare of people living in the affected regions.

This paper explores the role of road construction in shaping trade patterns in the PRC from 2000 to 2017 and in facilitating market integration across borders. To provide new evidence, we study transportation projects partially supported by the Asian Development Bank (ADB) in the Greater Mekong Subregion (GMS), an area comprising countries located along the Mekong River, i.e., Lao People's Democratic Republic (Lao PDR), Thailand, Viet Nam, Myanmar<sup>1</sup>, and Cambodia. During the review period, the PRC's trade expanded exponentially, and significant investments were made to improve the road network within the PRC, creating useful opportunities for researchers to study the effects of road construction on trade costs.

We first document the major patterns of trade flows from 2000 to 2017. Since joining the World Trade Organization in 2001, the PRC's international trade expanded rapidly, especially for electrical equipment and related products, which accounted for more than 40% of the PRC's total exports after 2006. However, this total number hides the significant heterogeneity among different regions within the PRC.

Infrastructure projects also contribute to the process of regional integration between the PRC and neighboring Southeast Asian countries. In this paper, we analyze the case of the Kunming–Bangkok Expressway that connects Kunming, the provincial capital city of Yunnan Province, and Bangkok. The expressway greatly facilitates road transportation between the PRC and Thailand. Using the PRC's customs data, we document a substantial compositional change in both exports and imports between Yunnan Province and Thailand during this period. Three points are worth noting. First, agricultural products replaced chemical products as the main export from Yunnan Province to Thailand. With climate and agricultural conditions suitable for growing high-value plants in Yunnan Province, this shift implies an increase in resource allocation

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<sup>1</sup>Effective 1 February 2021, ADB placed a temporary hold on sovereign project disbursements and new contracts in Myanmar.

efficiency consistent with regional comparative advantage. Second, the share of trade conducted via road transportation increased significantly after the construction of the expressway. Third, the customs ports in Kunming accounted for a major share of trade after the expressway was constructed. These facts are consistent with the important role of transport infrastructure in facilitating connectivity and market integration across regional borders.

To complement the facts above, we use geo-coded satellite and customs data to perform a difference-in-differences (DID) analysis of the effects of road construction on economic activities. The road networks that included and did not include this expressway were used to construct separate sets of distances to the border with each neighboring county, and the difference is used to measure treatment effects. Intuitively, the larger the magnitude of distance reduction, the higher the treatment measure, and the greater the benefit from the expressway's construction. To address the concern that the location choice of this expressway was not random, we utilize changes in the build-up level captured by daytime satellite images (1987–1995) and nighttime luminosity (1994–1997), both of which predate the road project, as the placebo test. To test the effects on trade, we employ the change in maritime exports as the placebo test since road construction is less likely to benefit maritime trade. We find consistent evidence that road construction leads to a higher share of built-up areas, higher nighttime lights intensity, and more extensive trade growth for regions that experience a higher treatment, i.e., for regions that are connected to the new road construction, and such effects are found to be nonexistent in the placebo tests. We thus provide strong evidence for a positive effect of infrastructure construction on economic activity.

We also estimate the internal and international trade costs for Chinese exporters in 2000 and 2011. Our study uses information on domestic trade flows contained in the customs data. Using Chinese customs data, we measure the exports from each city in the PRC to each foreign destination via each port. Holding the origin city and destination constant, higher internal trade barriers decrease exports that go through a specific port, and this relationship allow us to extract trade costs from a standard gravity equation estimation. As a proxy for trade costs, we calculate the shortest distance from each city to each port using the Chinese road network data and the prefecture boundary provided by Baum-Snow et al. (2017). To guide the empirical analysis, we extend the Eaton and Kortum (2002) model to include an internal trade cost component and derive a gravity equation that allows us to separate the trade costs from other components that determine trade flows.

We find that road construction helped to significantly reduce trade costs from 2000 to 2011. On average, the ad valorem rate of internal trade costs decreased by 20.0%, and the ad valorem rate of international trade costs declined by 15.3%. We also document a substantial heterogeneity of effects across economic sectors.

Lastly, we provide further evidence supporting the role of infrastructure in improving connectivity. Because maritime transportation is one of the primary means of transporting goods overseas from the PRC, coastal areas have a natural comparative advantage in participating in international trade. Using the distance to the nearest custom port that allows maritime transportation as a measure of "inlandness," we show that trade volumes decline substantially as one moves to more inland regions of the PRC. This trend, however, is partially offset by the construction of roads that connect these inland regions to main transit corridors and reduce internal trade costs. Moreover, using the estimated trade costs, we show that access to ports has a strong explanatory power in terms of provincial outputs, with a coefficient similar to that found in Donaldson and Hornbeck (2016).

## 2 Background

This paper is part of an effort to quantify the effects of road infrastructure development on trade in Yunnan Province and the GMS. We believe that the estimates in this paper can be valuable inputs for infrastructure projects. Asian Development Bank (2021) (2021) noted that the development of regional connectivity among international trade hubs would strengthen regional value chains, which in turn would help unlock the benefits from integration into global value chains. This ADB study highlighted the importance of (i) regions' physical connectivity to Bangkok as well as online routing systems to evaluate and monitor up-to-date road connectivity more efficiently; (ii) reducing border crossing times, which accounted for much of the total transport time between origin and final destinations in the GMS; and (iii) connecting regional production centers to seaports through multimodal transportation as available (i.e., roads, railways, waterways, and airports). In this paper, we note the impact of these modes of transportation available for trade. In Kucheryavy et al. (2021), we laid out a multi-sector version of Desmet et al. (2018) model that allows for a rich impact of infrastructure projects on immigration choice and industrial composition. Nose et al. (2021) adopted a reduced-form approach to evaluate the effect of highway construction between the mountainous PRC–Viet Nam border and industrial hubs in northeastern Viet Nam. They found that improved accessibility due to the GMS transport investments had significantly expanded the market potential of the treated districts, with a strong agglomeration of



manufacturing firms along the highway in both core and peripheral cities. Further, the agglomeration increased the value added (i.e., productivity) of firms disproportionately more in the rural peripheries.

Our paper contributes to the large and growing literature on the effects of transportation infrastructure improvements on economic outcomes, as surveyed in Redding and Turner (2015) and Redding (2022). Closest to our paper are the studies that focus on the PRC. These studies can broadly be divided into two categories: the ones that used a DID approach and the ones that conducted general equilibrium analysis. Faber (2014), Baum-Snow et al. (2017), Baum-Snow et al. (2020), Banerjee, Duflo, and Qian (2020), and He et al. (2020), among others, belong to the first category employing a DID approach. One important finding in these papers is that, on average, transportation infrastructure improvements in the PRC in the 1990s and 2000s had only a small or even negative impact on economic activity in locations with improved transportation infrastructure relative to other locations. This observation holds despite the fact that different studies focused on different units of observation in the PRC: For example, Faber (2014) and He, Xie, and Zhang (2020) compared peripheral counties within the same prefecture, Baum-Snow et al. (2017) contrasted central cities across different prefectures; and Baum-Snow et al. (2020) looked across prefectures. However, the average effects estimated by these studies can conceal the heterogeneity of outcomes depending on other characteristics of locations. For example, Baum-Snow et al. (2020) observed that prefectures in the PRC that are regional population centers had positive (relative) economic outcomes, while hinterland prefectures had negative effects. He, Xie, and Zhang (2020) suggested that poorer peripheral counties within a prefecture had a positive (relative) effect of infrastructure on gross domestic product (GDP) growth, while richer counties within the same prefecture had a negative effect. We differentiate from these studies by analyzing both the domestic and international trade impact of transport infrastructure and increased connectivity along trade routes.

Tombe and Zhu (2019), Fan (2019), Xu and Yang (2021), Ma and Tang (2022), and Fan, Lu, and Luo (2023), among others, belong to the second category of studies on the PRC that utilized the general equilibrium modelling approach, which allowed them to find absolute (as opposed to relative) effects of transportation infrastructure improvements on economic outcomes. Tombe and Zhu (2019) had found that reductions in internal trade and migration costs in the PRC during the 2000s had a more significant impact on regional development than declines in international trade costs. While Tombe and Zhu (2019) lacked direct measures of transport infrastructure, they estimated internal trade and migration costs based on data on aggregate trade and migration flows between regions in

the PRC. Fan (2019) expanded on this work by isolating the effects of Hukou (household registration) system reforms in the PRC during 1997–2000 and estimated internal trade costs and their impact on the Chinese domestic economy and international trade.

Taking a more sophisticated approach, Xu and Yang (2021) provided refined estimates of international trade costs in the PRC at two points in time (2000 and 2013), utilizing data on aggregate trade flows between regions as well as travel times between locations in the PRC, calculated from digitized maps of the PRC's highway networks. Their estimates indicated substantial welfare gains for inland provinces.

Fan, Lu, and Luo (2023) innovatively employed Chinese customs data to estimate internal trade costs, finding that expressway construction in the PRC during the 2000s led to about a 10% increase in aggregate exports, a 14% boost in domestic trade, and a 5% increase in overall welfare. In our paper, we adopted a similar methodology to Fan, Lu, and Luo (2023) to estimate internal trade costs. However, we extended this method to differentiate between exports to various foreign destinations, with a particular focus on GMS countries.

Ma and Tang (2022) conducted an impressive study, collecting detailed information on various transportation networks in the PRC (e.g., roads, railways, and waterways) from 1995 to 2017. Their research highlighted that infrastructure improvements in the PRC could yield substantial absolute effects on aggregate output, particularly in the short term.

Beyond the context of the PRC, our paper is related to the large literature that examines the effects of transportation infrastructure improvements on economic outcomes within other countries: Fajgelbaum and Redding (2022) studied Argentina; Bird and Straub (2020) examined Brazil; Bogart et al. (2022) looked at data from the 19th century England; Ghani, Goswami, and Kerr (2016), Asturias, García-Santana, and Ramos (2018), Donaldson (2018), Asher and Novosad (2020), and Alder (2023) studied India; Rothenberg (2013) focused on Indonesia; Volpe Martincus, Carballo, and Cusolito (2017) studied Peru; Coşar and Demir (2016) and Coşar et al. (2021) worked on Türkiye; Balboni (2021) used data from Viet Nam; and Baum-Snow (2007), Duranton, Morrow, and Turner (2014), Donaldson and Hornbeck (2016), Herzog (2021), and Allen and Arkolakis (2022) examined the United States.

Finally, this paper is related to the literature that analyzed the impact of infrastructure improvements across different countries: Jedwab and Moradi (2016) and Jedwab and Storeygard (2021) reviewed the effects of railroad and road infrastructure investments in Africa; Bird et al. (2020), Lall and Lebrand (2020), and de Soyres, Mulabdic, and Ruta (2020) measured the effects of the Belt and Road Initiative on the economies in Central Asia and beyond; Heiland et al. (2022) inspected the effect of the expansion of the Panama

Canal (completed in 2016) on trade flows and the welfare of countries around the world; and Ducruet et al. (2023) highlighted the effects of containerization in the mid-20th century and the related development of ports on economic outcomes of different locations around the world.

### **3 Data**

This section describes the data we used and the main patterns in the data that we focused on in subsequent analyses. To give a general background, we report overall trade trends using Chinese customs data. To inform the study on the Kunming–Bangkok Expressway, we also report the main patterns with the Lao PDR and Thailand as the only destinations for truck traffic originating from Yunnan Province.

#### **3.1 Measurement of Trade Flows**

We used recent Chinese customs data from the years 2000, 2006, 2011, and 2017. This 17-year period covers several significant events, including the PRC's accession to the World Trade Organization and the global financial crisis. In all the 4 years indicated, the customs data record the origin city of each exporter, the port through which the trade happens, and the overseas destination of the exported goods. This provides us with valuable information on internal trade flows within the PRC. The data also include the mode of transportation and the trade quantity and value under each specific category.

#### **3.2 Measurement of Economic Activity**

Using the satellite images of Landsat and nighttime lights (NTL) data, we calculated the measures of economic activities for each county in Yunnan Province. For Landsat data, we used 8 years from 1987 to 2019 (i.e., 1987, 1990, 1995, 2000, 2005, 2010, and 2015) to study the changes in land cover over a 30-year period. The raw data are from the United States Geological Survey, with a spatial resolution of 30 meters. Then, using the supervised classification technique in machine learning, each pixel in the land cover data has been classified into one of four categories: (i) body of water, (ii) vegetation, (iii) bare land, and (iv) built-up area. We used the share of built-up area as a measure of economic activity at the county level to complement the NTL data, which measures the intensity of light from two sources: the Defense Meteorological Satellite Program and the Visible and Infrared Imaging Radiometer Suite. The NTL data are reported annually for

the period from 1994 to 2021. The Visible and Infrared Imaging Radiometer Suite is the newer data source that replaced the Defense Meteorological Satellite Program starting 2012; therefore, caution should be used when comparing the two different kinds of NTL data (Gibson et al., 2021).

### 3.3 Measurement of Road Network

We employed the Chinese road network data and the prefecture boundary provided by Baum-Snow et al. (2017). In the prefecture boundary data, each county is defined as a geometric object, usually a polygon, together with a six-digit administrative code. To match the location information in trade data, we aggregated six-digit counties to four-digit prefectures. The road network data contain the location of each road in the PRC in 1999 and 2010. During this period, the aggregate length of high quality expressways expanded substantially in the PRC (Fan, Lu, and Luo, 2023). We obtained the coordinates of prefectures in the PRC from Baidu Map<sup>2</sup> and coordinates of world cities from simplemaps<sup>3</sup>. This allowed us to calculate the arc length distance between any pair of locations using the Haversine formula. Figure 1 shows the network of national highways (blue lines) in Yunnan Province in 1999, and the geometric boundaries depict the counties within Yunnan Province. The national highway system was designed in a way that connects all counties within the province, including Mohan Port located on the PRC's border with the Lao PDR, as indicated in the figure by a red dot. However, the road conditions are poor, with only a small number of lanes and a low speed limit.

Figure 2 plots the high quality expressway in Yunnan Province in 1999, 2010, and 2021. The digital road map for 2021 was obtained from the National Catalogue Service For Geographic Information. Consistent with the overall trend, the network of high quality expressways expanded significantly in Yunnan Province during the review period. The section of the Kunming–Bangkok expressway in the PRC (highlighted in red) is referred to as the Kunming–Mohan Expressway and is given the official number of G8511 in the PRC's national highway system. After connecting with Boten inside the Lao PDR, the highway passes through the northern part of the country before entering Thailand at Chiang Khong via the Fourth Thailand–Lao PDR Friendship Bridge, which facilitates truck crossings over the Mekong River. The highway then connects to the Asian

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<sup>2</sup>This information is obtained from GitHub website. <https://github.com/pfinal/city> (accessed 15 January 2023).

<sup>3</sup>This information is Obtained from SimpleMaps. World Cities Database. <https://simplemaps.com/data/world-cities> (accessed 15 January 2023).

Highway that links Chiang Rai and Bangkok. The construction of the Kunming–Mohan Expressway started in 1997 and had mostly finished by 2008. The Fourth Thailand–Lao PDR Friendship Bridge was opened to the public in December 2013.

### 3.3.1 Construction of Shortest Path Length

This subsection describes how we calculated the shortest route along the road network for use in later analysis. For each origin city and port city, we calculated the shortest distance between them as follows. The first step is to construct a graph of locations using the data. We abstracted each city using its geometric centroid so that moving from one city to another is viewed as moving between their centroids. We connected the centroid of each city with the nearest points on each type of road network. Of course, points are connected sequentially along a road. The geographical distance between each pair of points is calculated using the Euclidean distance based on the coordinates of points in the projected map.<sup>4</sup> For high quality expressways, we multiplied the geographical distance by 0.5 to get the effective distance, following the practice in Fan, Lu, and Luo (2023). The effective distances are the same as the geographical distances for ordinary highways and for lines that connect prefecture centroids and roads. This way, we constructed a graph that connects the centroids of prefectures via different road networks. Finally, the shortest path was calculated by applying Dijkstra’s algorithm (Dijkstra, 1959) to this graph.

Figure 3 shows an example of the above algorithm that calculates the shortest path from Beijing to Tianjin. Ordinary highways are plotted in blue lines, while high quality expressways are plotted in red lines. The blue circles show the centroids of the two cities, and the green squares show the connection points between each road network and the city centroids. The shortest path is plotted in the green line. The length of this path is 174 kilometers (km), which is close to 143 km, the distance between Beijing and Tianjin reported by Google Maps.

## 4 Trends in Data

### 4.1 Overall Patterns

In this section, we documented the changes in trade patterns over time as transport infrastructure changes. Table 1 presents definitions for Harmonized System (HS)

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<sup>4</sup>It is verified that the distance calculated this way is approximately the same as the distances reported in the raw data.

sections. Table 2 (2000 and 2006) and Table 3 (2011 and 2017) show the total annual exports from the PRC to the rest of the world by the HS sector. In all years, Sector 16 (machinery and mechanical appliances, etc.) is the most important sector in terms of export value. The total export value of goods under Sector 16 increased from \$69.12 billion to \$400.92 billion in 2006, \$799.73 billion in 2011, and \$983.64 billion in 2017, reflecting average annual growth of 116.9%. Sector 16's share of total export value increased significantly from 29.9% in 2000 to 42.2% in 2006 and remained stable around this level in both 2011 and 2017. Two other sectors stand out as important sources of exports. The total export value of Sector 11 (textiles and textile articles) grew from \$46.02 billion in 2000 to \$258.46 billion in 2017, but its value share decreased from 19.9% in 2000 to 11.4% in 2017. The next most important sector is Sector 15 (base metals and articles of base metal). These three sectors together accounted for about 60% of the PRC's exports in 2011 and 2017.

Table 4 shows total imports from the rest of the world to the PRC by each sector. Since we do not have import data for 2011, the table includes only 3 years. Sector 16 (machinery and mechanical appliances, etc.) also has the highest import value, which jumped from \$80.57 billion in 2000 to \$626.86 billion in 2017. Its import value share increased from 38.4% in 2000 to 41.2% in 2006, before declining to 35.3% in 2017. On the other hand, the importance of Sector 5 (mineral products) grew over time. Its total import value surged from \$23.65 billion in 2000 to \$377.34 billion in 2017, while its import value share rose from 11.3% to 21.3% over the same period.

## **4.2 Trade between Yunnan Province and Thailand**

To illustrate the potential effects of expressway construction, we next showed the trends in trade between Yunnan Province and Thailand. In 2000, construction of the Kunming–Mohan Expressway started, and the major parts were finished by 2011. Table 5 shows total export value by HS sector from Yunnan Province to Thailand, revealing a significant shift in the contents of trade between 2000 and 2011. In 2000, Yunnan Province mainly exported chemical products (Sector 6) to Thailand; but from 2011, vegetable products became the top category of exports. The value of the vegetable product (Sector 2) exports increased about 7,000 times between 2000 and 2011. Since the climate of Yunnan Province is suitable for plant cultivation, this shift is consistent with the comparative advantage of Yunnan Province in producing vegetables. Indeed, Kunming's Dounan flower market is among the largest in Asia. In terms of total value, the exports of agricultural products, which include Sectors 2 and 4 in the HS

classification, more than doubled from 2011 to 2017. Table 6 shows the trends of imports from Thailand by Yunnan Province. While the value of imports was almost negligible in 2000, vegetable products again accounted for most of the imports, which is not surprising given Thailand's importance as a global rice producer. In 2017, imports of vegetable products accounted for around 65% of the total import value, and optical products were the second-most important category of imported products. Overall, the total trade value grew more than 16 times between 2000 and 2011, and more than 41 times between 2000 and 2017, showing a tremendous increase in the economic connection between Yunnan Province and Thailand after the expressway was built.

Next, we describe the port choice for exports. For each international trade transaction, a customs port must be chosen for the goods to cross the border. There are 42 customs ports in the PRC. For each port, there are different points of entry corresponding to different geographical locations and transportation methods. Due to geographical limitations, not every customs port has all transportation methods. Half of the ports (21) have points of entry for sea transportation.

Table 7 depicts trade between Yunnan Province and Thailand by port. Since Yunnan Province does not have a seaport, exporters must transport their goods to a coastal city in order to use maritime transportation. In 2000, the ports of Huangpu, Zhanjiang, and Nanning, which are located in Guangdong and Guangxi Zhuang Autonomous Region, were the major points of entry chosen by exporters in Yunnan Province. Starting from 2011, when the expressway was completed, Kunming became the top choice for Yunnan Province exporters, with Kunming accounting for 65.8% of Yunnan Province's export value in 2011 and 55.9% in 2017.

Table 8 shows the exports between Yunnan Province and Thailand by transportation method. Although maritime transport is the major choice in all years, its value share decreased from 97.8% in 2000 to 51.9% in 2011. Meanwhile, the value share of road transport increased from 1.1% in 2000 to 43.8% in 2011. The value share of air transport also increased from 0.9% in 2000 to 3.1% in 2006, and to 13.7% in 2017. The increasing importance of road transport shows the potential impact of road infrastructure projects in facilitating the international shift in production activities, and is consistent with the increasing use of Kunming as the port of clearance.

The change in the PRC's inland policy underlined the significant shift in the composition of trade between Yunnan Province and Thailand. In the PRC, rural land is collectively owned, and the transfer of ownership is not allowed. Moreover, under the Household Contract Responsibility System initiated in the early 1980s, the right to use land is evenly distributed to rural households. Although this reform greatly increased

agricultural production by solving the incentive problem underlying the People's Commune System, the farmland became fragmented, so the adoption of modern farming techniques critical for returns-to-scale in agricultural production became difficult. Realizing this problem, the government has implemented a series of policies to promote rural land circulation since the 2000s. Consistent with the objective of these policies, Wang et al. (2018) found that the circulation rate of rural land in Yunnan Province significantly increased from 2003 to 2013.

## 5 Economic Effects of Kunming-Bangkok Expressway

This section analyzes the effects of the Kunming–Bangkok Expressway on economic activities in Yunnan Province. We first discussed the distance measure that serves as the treatment indicator for different regions in Yunnan Province, then presented evidence showing that the construction of the expressway impacts economic activities, as measured by satellite images and customs data.

We define  $DistMh_{it}$  as the distance to Mohan port along the road network in year  $t$  for each county  $i$  in Yunnan Province. Two networks are considered to represent two different time points. In the first network, we used only the national highway in 1999 to represent the network available before the construction of the expressway. In the second network, we added the expressway G8511 to the national highway in 1999 to capture the change in the road network after the construction of the expressway. We assume that the driving speed for the expressway is twice as fast as the national highway's to capture the quality difference. After calculating the distance for both the before and after periods,  $\Delta \ln DistMh_i$  is calculated as the log difference of the distance under two networks. We therefore define  $TreatInt_i = -\Delta \ln DistMh_i$  as the intensity of treatment from the construction of the expressway. For counties with a larger magnitude of distance reduction, the potential benefit tends to be higher. Figure 4 shows the distribution of  $TreatInt_i$  across counties in Yunnan Province. Naturally, the difference is higher in magnitude for counties near the expressway. Conditional on the arc distance to the expressway, the counties with a better connection to the expressway through the national highway will also have a larger difference and thus more intensive treatment.

To measure the change in economic activities at the county level, we relied on daytime and nighttime satellite images. Figure 5 plots the amount of built-up area for each county in Yunnan Province over time. To save space, we show only plots for 1987, 1995, and 2019. For each county, we counted the number of pixels that are classified as buildings by the machine learning algorithm, then divided the count by the total number of pixels. The



counties with red color are those that have a greater change in the share of built-up areas, and counties with white color are those for which we do not have valid observations. It is clear from the figure that there has been a significant increase in the share of built-up areas during the review period. Figure 6 plots the average NTL intensity for each county over the years. Again to save space, we plot for 1999, 2004, 2009, and 2019 only. The gradual increase in the NTL intensity is visually clear, with the brightest region corresponding to Kunming city. The dramatic increase in the NTL intensity in 2019 may be the result of the switch of satellite discussed earlier instead of real economics. Therefore, in later analysis, we separate the sample periods that use different satellites.

## 5.1 Level Regressions

To estimate the effect of expressway construction on local economic outcomes, we estimate the following regression:

$$y_{it} = \alpha_0 + \alpha_1 \text{TreatInt}_i \times \text{AfterCons}_t + \alpha_2' X_{it} + \psi_i + \psi_t + \epsilon_{it}, \quad (1)$$

where for the outcome variable  $y_{it}$ , we use  $\ln(\text{NTL}_{it} + 1)$  and  $B\text{Share}_{it}$  to represent the NTL intensity and building share respectively;  $\text{AfterCons}_t$  is a year dummy equal to 1 if year  $t$  is later or equal to 1998,  $\psi_i$  and  $\psi_t$  are the county and year fixed effects, respectively; and  $X_{it}$  is the vector of county attributes. The underlying identification strategy is DID. For each county, we calculate the difference in economic activity over time. Then we compare counties that are more affected by the expressway construction with those that are less affected. Because there are other expressways that affect the connectivity of counties, we restrict the sample to counties that are within 50 kilometers of the expressway.

Results using NTL intensity are reported in Table 9. The first column shows the estimate of  $\alpha_1$  without controlling for county-specific attributes, and the second column shows the estimate of  $\alpha_1$  controlling for the land area and total population in each county in year  $t - 1$ . Both estimates report a positive, significant estimate of  $\alpha_1$ , supporting the hypothesis that counties with a larger reduction in the distance to the border due to the expressway's construction tend to have greater NTL intensity. Since we control for county fixed effects and year fixed effects, any time-invariant county attributes that confound the estimation result are already controlled for. Due to data limits, we have only county attributes since 2001 for a subset of the counties. Therefore, the number of observations is smaller in the second column. That the two columns report similar estimates is reassuring.

Table 10 reports the estimates using the share of built-up areas as the outcome variable. The estimate in the first column is positive and significant, showing that counties with higher treatment tend to have a larger share of built-ups, consistent with the finding using NTL intensity. When we controlled for lagged county land area and total population, the effect has become only marginally significant. We also note that the sample size has shrunk due to data limitation.

## 5.2 First-difference Regressions

To complement the regressions in level, we ran the following regressions in first difference:

$$\Delta y_{it} = \beta_0 + \beta_1 \text{TreatInt}_i + \psi_t + \epsilon_{it} \quad (2)$$

where for the outcome variable  $y_{it}$ , we included  $\ln(NTL_{it} + 1)$  and  $BShare_{it}$  to represent the NTL intensity and building share respectively. Running the regression in first difference helps to cancel out the factors that are time-invariant and helps to mitigate the concern in our identification strategy. If the expressway is chosen to pass through counties with higher growth potential, then we would overestimate the effect of expressway construction. To alleviate this concern, we used the periods before the expressway construction as the placebo test. Because the expressway has not yet been constructed, we should not see any significant effects on our treatment. Because of the potential concern in data measurement, we utilized the periods before 2013 for NTL regression.

Table 11 reports the estimation results for the NTL intensity. The first column shows that the treatment did not have a significant effect for the period before 1997 when construction began on the Kunming–Mohan Expressway. Between 1998 and 2012, there is a significant treatment effect. The counties with a greater change in distance tended to have a larger increase in NTL intensity.

Table 12 shows the regression results using the changes in building share as the measure of economic outcome. Similarly, for the periods before the expressway's construction, there is no evidence that counties with higher treatments tended to have a higher growth rate in building share. But the effect is estimated to be significant after the expressway's construction.

## 5.3 Effects on Trade Flows

Finally, we investigate the effects of expressway construction on trade flows. For that purpose, we replace the outcome variable with changes in export value. For each year,

our panel contains detailed export values from each customs region to Thailand, for each HS 8 code, each kind of transportation method, and each port. In light of the over trends reported in subsection 4.2 of this paper, we aggregated the categorical variables to capture the major differences. Therefore, in the regressions reported below, the index  $i$  represents a cell defined by its geographical region, type of product being agricultural or nonagricultural, method of transportation being road or maritime, and port of clearance being Kunming and non-Kunming. To construct a balanced panel for each cell, we imputed a zero trade value for unobserved cells each year. This makes sense since the customs data recorded universe of all export transactions. Because the expressway also connects to the Lao PDR, we include exports from Kunming to the Lao PDR as well. We reported estimation results separately for road and maritime transportation, as the expressway's construction was more likely to benefit road transportation. The regressions using maritime transportation can thus be viewed as a placebo test. We controlled for the destination, port, product category, and year fixed effects in all the regressions using changes in trade values.

Table 13 reports the estimation results. As shown in the first column, the regions that experienced a higher reduction in the distance tended to have a larger increase in the export value. The elasticity is around 6, which means that a 10% decrease in distance could lead to a 60% increase in exports. This result suggests that the high growth of trade during the data period is concentrated in regions that benefit more from the expressway's construction. Moreover, the second column shows that such an effect is much smaller and statistically insignificant for maritime transportation, supporting that our estimates do capture the benefits of road construction. This estimate, however, do not distinguish between generating trade or sorting (reallocating) trade. This is important since the impacts on welfare will be more positive if the road generates more trade instead of reallocating trade from elsewhere. Nonetheless, given the magnitude of trade growth, it is very likely that the generating effect is present.

## 6 Estimation of Trade Costs

In this section, we use nationwide data to infer the reduction of trade costs due to the construction of high quality expressways. In the first subsection, we proposed a simple model to guide the analysis, and in the second subsection, we performed the analysis. Later subsections will explore the implications of the estimation results.

## 6.1 Model

We rationalized the data with an extension of the standard Eaton and Kortum (2002) model that featured an internal trade cost component between origin cities and ports. In the model, locations include Chinese cities and foreign countries. A continuum of goods is indexed by  $\omega$ . City  $i$  can produce any good with a constant marginal cost  $c_i$ . For goods to be exported from a Chinese city to a foreign destination, a port must be chosen. To explain the fact that each city exports from different ports to the same country, we assumed that there is a city–port shock to the trade costs, in addition to the standard iceberg costs. The bilateral trade costs thus have three components: (i) the cost from the origin city to the port, (ii) the cost from the port to the foreign destination, and (iii) an origin–port shock. Formally, the trade costs from the origin city  $i$  to a foreign destination  $j$  are equal to  $\frac{\tau_{id}\tau_{dj}}{v_{id}(\omega)}$ . We assumed perfect competition, thus the price of a good produced in city  $i$  faced by a buyer in destination  $j$  and shipped via port  $d$  is equal to

$$p_{idj}(\omega) = \frac{c_i \tau_{id} \tau_{dj}}{v_{id}(\omega)}. \quad (3)$$

Effectively, the shock also incorporated the efficiency differences in producing goods across cities. We made the standard assumption that  $v_{id}$  follows an independent and identically distributed Fréchet distribution across goods, with location parameter  $T_{id}$  and shape parameter  $\theta$ .

Representative consumers in destination  $j$  choose consumption quantity  $Q(\omega)$  to maximize the the constant elasticity of substitution (CES) utility function:

$$U = \left[ \int_0^1 Q(\omega)^{\frac{\sigma-1}{\sigma}} d\omega \right]^{\frac{\sigma}{\sigma-1}}, \quad (4)$$

where  $\sigma$  is the elasticity of substitution. The buyers in the destination  $j$  chooses the minimum price for each good,

$$p_j(\omega) = \min_{i,d} \{p_{idj}(\omega)\}. \quad (5)$$

Let  $X_{idj}$  denote export value from origin  $i$  to destination  $j$  via port  $d$ , and  $X_j = \sum_l \sum_k X_{lkj}$  as the total expenditure of country  $j$ . Following the same procedure as in Eaton and Kortum

(2002), we obtained a closed-form solution for the share of trade from origin  $i$  to destination  $j$  via  $d$  as

$$\pi_{idj} \equiv \frac{X_{idj}}{X_j} = \frac{T_{id} (c_i \tau_{id} \tau_{dj})^{-\theta}}{\Phi_j}, \quad (6)$$

where  $\Phi_j = \sum_l \sum_k T_{lk} (c_l \tau_{lk} \tau_{kj})^{-\theta}$ .

To close the model, we let the marginal cost equal the wage in city  $i$ , or  $c_i = w_i$ , and write the labor market clearing condition as

$$w_i L_i = \sum_d \sum_j \pi_{idj} w_j L_j. \quad (7)$$

Later to solve the change, we also expressed the trade share in the “hat” form as

$$\hat{\pi}_{idj} = \frac{\hat{T}_{id} (\hat{w}_i \hat{\tau}_{id} \hat{\tau}_{dj})^{-\theta}}{\sum_l \sum_k \pi_{ilk} \hat{T}_{lk} (\hat{w}_l \hat{\tau}_{lk} \hat{\tau}_{kj})^{-\theta}}, \quad (8)$$

where for any variable  $X$  and its new value  $X'$  we define  $\hat{X} \equiv \frac{X'}{X}$ . The labor market clearing condition can also be written as

$$\hat{w}_i \hat{L}_i = \sum_d \sum_j \gamma_{idj} \hat{\pi}_{idj} \hat{w}_j \hat{L}_j, \quad (9)$$

where  $\gamma_{idj} \equiv \frac{\pi_{idj} w_j L_j}{w_i L_i}$ . Under the assumption that  $\hat{T}_{id} = 0$ ,  $\hat{L}_i = 0$ , we have

$$\hat{w}_i = \sum_d \sum_j \gamma_{idj} \frac{(\hat{w}_i \hat{\tau}_{id} \hat{\tau}_{dj})^{-\theta}}{\sum_l \sum_k \pi_{ilk} (\hat{w}_l \hat{\tau}_{lk} \hat{\tau}_{kj})^{-\theta}} \hat{w}_j, \quad (10)$$

so given the values of  $\gamma_{idj}$  and changes in trade costs, we can solve for change in wages.

## 6.2 Estimation

Equation (6) suggests the following specification:

$$\ln X_{idj} = -\theta \ln \tau_{id} - \theta \ln \tau_{dj} + \psi_{id} + \phi_j + \epsilon_{idj}, \quad (11)$$

where  $\psi_{id} = T_{id} c_i^{-\theta}$  and  $\phi_j = X_j \Phi_j$  represent origin and country fixed effects. In practice, we made use of the least-cost route distance between the origin  $i$  and port  $d$  to measure

the internal trade costs  $\tau_{id}$ , and the arc distance between port  $d$  and destination  $j$  as the measure of international trade costs  $\tau_{dj}$ , and assume that

$$-\theta \ln \tau_{id} = \gamma_1 \ln (Dist_{id} + 1),$$

$$-\theta \ln \tau_{dj} = \gamma_2 \ln Dist_{dj}.$$

Moreover, there are many origin–port pairs that had positive trade values in 2011 but had zero trade value in 2000. We found it important to incorporate these zeros into the estimation, otherwise the pairs with higher trade costs between origin cities and ports tend to be selected out of the sample, and the estimate of distance elasticity will become positive, contradicting the theory. Since our data also contain information on the product category and transportation method, we employed that information as well. The regression we estimate is thus

$$\ln (X_{idjsrt} + 1) = \gamma_0 + \gamma_1 \ln (Dist_{idt} + 1) + \gamma_2 \ln Dist_{dj} + \psi_i + \psi_d + \phi_j + \epsilon_{idj}, \quad (12)$$

where  $X_{idjsrt}$  represents total export value from origin city  $i$  to destination  $j$  via port  $d$  for products in sector  $s$  (defined using HS2 code) under transportation method  $r$ . To obtain estimates of  $\tau_{id}$  and  $\tau_{dj}$ , we need to take a stance on how large is  $\theta$ . We take  $\theta = 4$  from Simonovska and Waugh (2014).

Table 14 shows the estimation results. From 2000 to 2011, the distance elasticity decreased in absolute value from  $-0.261$  to  $-0.151$ , consistent with the assumption that improvements in road infrastructure reduce internal trade costs at the same distance. On the other hand, the distance elasticity with respect to the distance between port and foreign destination declined in absolute value from  $-0.320$  to  $-0.285$ , showing that the overall costs as well as the cost for travel between ports and foreign destinations decline. The magnitude of the decline in the distance elasticity is larger for the internal distance, consistent with the assumption that road construction significantly reduces domestic trade barriers.

Since the construction of roads helped to reduce the effective distance from an origin city to the nearest port, the reduction in trade costs cannot be read from the change in distance elasticity only. Figure 7 shows the distribution of trade costs in 2000 (first row) and in 2011 (second row). The mean of internal trade costs decreased from 1.402 to 1.202, equivalent to a 20% decrease in tariffs. This is also depicted in Figure 7.

The change in the extensive margin is substantial. In both observation years, there are 461 origin cities, 41 ports, and 209 unique destinations. In total, there were 252,563 unique

combinations that had positive trade in either 2000 or 2011. Out of all combinations, 176,737 combinations had zero trade value in 2000 and a positive trade value in 2011, and 15,309 combinations had a positive trade value in 2000 but zero trade value in 2011. Only 60,517 combinations had a positive trade value in both years. Since high trade barriers are likely a cause of zero trade, a sample excluding zero observations tends to select origin–destination pairs with low trade costs and thus cause an underestimation of trade costs.

### **6.3 Heterogeneity in Cost Reduction**

This section explores heterogeneity in the cost reduction effects of road construction projects. Table 15 reports the gravity equation estimate for 10 sectors that have the highest total export values in 2017. Columns (3) and (6) report the average inferred trade costs for each sector. There are substantial differences in trade costs. Sector 16 (machinery and mechanical appliances, etc.) has the highest internal trade costs. This may reflect the difficulty of shipping large machines via trucks. On the other hand, Sector 6 (products of chemical or allied industries) has the lowest internal trade costs. This is consistent with there being lower costs for standardized chemical goods. Table 16 reports the same estimate using the sample of 2011. When comparing across years between Table 15 and Table 16, the relative sizes of internal trade costs across sectors are very similar to those in 2000. For example, sector 16 and sector 6 are still the sectors with the highest and the lowest trade costs. This supports the notion that the estimated trade costs reflect the intrinsic nature of different goods. Moreover, we see a consistent decrease in internal trade costs across sectors. The external trade costs, however, change more dramatically. For example, for sector 16, the average external trade cost was 1.677 in 2000, which is nearly the lowest value. But it increased to 3.289 in 2011, ranking the second highest in that year. This probably reflects the change in destination compositions and is related to the change in global value chains. For example, if the PRC were to export more machine-related goods to trade partners in closer proximity, the model would interpret this change as an increase in external trade costs.

### **6.4 Effects on the Greater Mekong Subregion**

This section documents the estimates for the origins and destinations located in the GMS, where ADB has supported several road infrastructure projects. The selected destinations include the Lao PDR, Thailand, Viet Nam, Myanmar, and Cambodia. The selected origin

provinces in the PRC include Guangdong, Guangxi Zhuang Autonomous Region, and Yunnan Province.

Table 17 reports the estimated results. The estimated internal distance elasticity significantly decreased from  $-0.282$  to  $-0.041$  from 2000 to 2011, providing support to the claim that road construction in the region promotes trade.

## 7 Other Evidence

In this section, we show two further pieces of evidence that infrastructure projects promote connectivity and economic development across regions.

### 7.1 Inland Regions and Trade

Since water transportation is the primary method of international trade, it is often argued that coastal regions have a comparative advantage over inland regions in international trade. Since a custom port that allows for water transportation must be chosen for such trade, we measure the degree of “inlandness” of each custom region, defined by the five-digit customs code, as the distance between the region and the nearest port that allows for water transportation, which we denote as “ $Inland_i$ ” for region  $i$ . For each year, we regressed the logarithmic value of total exports of each region, denoted as  $\ln X_{it}$ , on the logarithmic value of inlandness, or  $\ln Inland_i$ . To minimize the selection effect, we ensured that the sample of regions is the same across all years. Specifically, we include the set of regions with positive trade for at least one year and for each region  $i$  in this set; zero trade value is imputed for year  $t$  if  $i$  is not observed with positive trade.

Table 18 reports the estimated results. Inlandness is a strong indicator of export values with an elasticity of about  $-1.0$ . Moreover, the magnitude of the elasticity declined substantially from  $-1.666$  in 2000 to  $-0.923$  in 2011, consistent with the view that the improvement of inland transportation infrastructure has a significant effect on reducing internal trade friction over time.

### 7.2 Port Access and Economic Development

Since most international trade is transported by water, access to ports is critical for regions to benefit from globalization. In this subsection, using the inferred trade costs from each origin to port, we explored the potential importance of port access to economic



development. Using the idea popularized by Donaldson and Hornbeck (2016), and also consistent with our model, we calculated the port access by

$$PA_{it} = \sum_d \tau_{idt}^{-\theta} X_{dt}, \quad (13)$$

where  $\tau_{idt}$  is the trade costs estimated in the previous section,  $\theta = 4$ , and  $X_{dt}$  is the total export value via port  $d$  in year  $t$ . Then we used the port access term to explain the GDP in each region. Since we only have GDP data at the province level, we average port access within each province to also determine province-level port access.

The result is shown in Table 19. Both GDP and port access are measured in US dollars. Since we control for province fixed effects, the identification comes from variation across years within each province. The relationship is significant both statistically and economically. A 10% increase in port access is associated with a 6% increase in provincial GDP. The magnitude is similar to the result reported in Donaldson and Hornbeck (2016).

## 8 Conclusion

In this paper, we explore the relationship between road construction and trade patterns in the PRC. We document that improved transport infrastructure has helped inland regions' trade growth by facilitating connectivity and lowering internal trade costs. We note that there may have been a sample selection bias, i.e., when individuals or groups in the sample studied differ from the population, for road transport versus sea transport given the nature of goods being transported, and therefore focus on changes in trade volumes and value for goods transported by roads in our analyses. Similarly, within country migration dynamics among coastal and inland areas in the PRC, which might have contributed to the clustering of commercial and residential areas around newly developed road corridors, are outside the scope of this paper and warrant further attention in the future. Finally, we also show evidence that investments in an enhanced road network have played a role in integrating regional markets in the PRC's Yunnan Province and the GMS.

## Tables and Figures

**Table 1: Harmonized System Sector Names**

Sector Number	Sector Name
1	Live animals; animal products
2	Vegetable products
4	Prepared foodstuffs; beverages, spirits and vinegar; tobacco and manufactured tobacco substitutes; products, whether or not containing nicotine, intended for inhalation without combustion; other nicotine containing products intended for the intake of nicotine into the human body
5	Mineral products
6	Products of the chemical or allied industries
7	Plastics and articles thereof; rubber and articles thereof
11	Textiles and textile articles
14	Natural or cultured pearls, precious or semi-precious stones, precious metals, metals clad with precious metal and articles thereof; imitation jewellery; coin
15	Base metals and articles of base metal
16	Machinery and mechanical appliances; electrical equipment; parts thereof; sound recorders and reproducers, television image and sound recorders and reproducers, and parts and accessories of such articles
17	Vehicles, aircraft, vessels and associated transport equipment
18	Optical, photographic, cinematographic, measuring, checking, precision, medical or surgical instruments and apparatus; clocks and watches; musical instruments;
20	Miscellaneous manufactured articles

Note: Only the major sections relevant to the current paper are shown.

Source: World Customs Organization.

**Table 2: Export Value by Harmonized System Sector, 2000 and 2006**

2000			2006		
HS Sector	Value (\$ billion)	Value Share	HS Sector	Value (\$ billion)	Value Share
16	69.107	0.299	16	400.918	0.422
11	46.015	0.199	11	138.232	0.145
20	16.604	0.072	15	86.257	0.091
15	15.677	0.068	20	54.680	0.058
6	12.541	0.054	6	42.344	0.045
12	11.152	0.048	17	38.001	0.040
5	8.679	0.038	18	36.311	0.038
18	8.588	0.037	7	29.791	0.031
17	8.276	0.036	12	26.137	0.028
7	7.579	0.033	5	21.328	0.022
8	7.009	0.030	13	17.043	0.018
4	5.067	0.022	8	15.276	0.016
13	4.032	0.017	4	14.521	0.015
14	3.347	0.015	9	9.892	0.010
2	2.769	0.012	14	8.968	0.009
9	2.444	0.011	10	6.879	0.007
10	1.777	0.008	2	3.134	0.003
3	0.114	0.000	3	0.388	0.000
21	0.016	0.000	21	0.064	0.000
19	0.011	0.000	19	0.039	0.000

HS = harmonized system.

Source: Authors' calculations.

**Table 3: Export Value by Harmonized System Sector, 2011 and 2017**

2011			2017		
HS Sector	Value (\$ billion)	Value Share	HS Sector	Value (\$ billion)	Value Share
16	799.727	0.422	16	983.643	0.433
11	240.614	0.127	11	258.456	0.114
15	145.021	0.076	15	167.045	0.073
17	109.282	0.058	20	162.073	0.071
20	103.857	0.055	6	114.757	0.050
6	97.116	0.051	17	104.969	0.046
7	66.391	0.035	7	92.018	0.040
18	66.055	0.035	18	77.426	0.034
12	52.466	0.028	12	61.723	0.027
5	36.340	0.019	13	48.685	0.021
13	34.056	0.018	5	39.435	0.017
8	29.955	0.016	8	33.780	0.015
14	27.514	0.015	4	30.124	0.013
4	24.349	0.013	2	25.573	0.011
2	18.772	0.010	10	22.610	0.010
10	16.259	0.009	1	17.635	0.008
1	14.974	0.008	14	17.586	0.008
9	13.161	0.007	9	15.282	0.007
3	0.544	0.000	3	0.843	0.000
19	0.117	0.000	19	0.133	0.000

HS = harmonized system.

Source: Authors' calculations.

**Table 4: Import Value by Harmonized System Sector**

2000		2006		2017				
HS Sector	Value (\$ billion)	Value Share	HS Sector	Value (\$ billion)	Value Share	HS Sector	Value (\$ billion)	Value Share
16	80.573	0.384	16	319.928	0.412	16	626.863	0.353
5	23.649	0.113	5	123.051	0.158	5	377.344	0.213
15	19.673	0.094	15	60.076	0.077	6	132.644	0.075
6	17.773	0.085	18	58.601	0.075	17	108.890	0.061
7	15.675	0.075	6	58.319	0.075	18	101.506	0.057
11	15.625	0.074	7	46.663	0.060	15	95.474	0.054
18	7.741	0.037	17	29.714	0.038	7	88.117	0.050
10	6.307	0.030	11	25.820	0.033	2	61.948	0.035
17	5.925	0.028	10	11.875	0.015	11	31.030	0.017
2	3.641	0.017	2	9.384	0.012	10	27.914	0.016
9	3.336	0.016	9	6.485	0.008	1	23.596	0.013
8	2.997	0.014	8	6.270	0.008	9	23.470	0.013
4	2.163	0.010	14	5.366	0.007	4	22.014	0.012
13	1.705	0.008	4	4.745	0.006	14	14.339	0.008
14	1.015	0.005	13	3.938	0.005	13	9.926	0.006
3	0.966	0.005	3	3.744	0.005	8	9.518	0.005
20	0.871	0.004	20	2.121	0.003	20	8.446	0.005
12	0.395	0.002	12	0.772	0.001	3	8.286	0.005
21	0.007	0.000	21	0.012	0.000	12	3.959	0.002
19	0.004	0.000	19	0.002	0.000	19	0.007	0.000

HS = harmonized system.  
Source: Authors' calculations.

**Table 5: Export Value from Yunnan Province to Thailand by Harmonized System Sector**

2000		2011		2017				
HS Sector	Value (\$ billion)	Value Share	HS Sector	Value (\$ billion)	Value Share	HS Sector	Value (\$ billion)	Value Share
6	0.015	0.680	2	0.255	0.635	2	0.609	0.750
15	0.004	0.172	6	0.074	0.183	6	0.085	0.105
16	0.002	0.075	4	0.022	0.055	4	0.053	0.065
11	0.001	0.029	14	0.017	0.042	15	0.021	0.026
4	0.001	0.027	16	0.011	0.027	17	0.015	0.019
13	0.000	0.004	15	0.007	0.018	16	0.015	0.019
9	0.000	0.003	7	0.005	0.012	10	0.005	0.006
14	0.000	0.003	11	0.003	0.009	5	0.003	0.004
18	0.000	0.002	20	0.002	0.006	20	0.002	0.002
2	0.000	0.002	17	0.001	0.003	11	0.001	0.001

HS = harmonized system.  
Source: Authors' calculations.

**Table 6: Import Value of Yunnan Province from Thailand by Harmonized System Sector**

2000			2017		
HS Sector	Value (\$ billion)	Value Share	HS Sector	Value (\$ billion)	Value Share
2	0.001	0.295	2	0.140	0.649
6	0.000	0.151	18	0.043	0.199
4	0.000	0.146	1	0.011	0.052
11	0.000	0.122	7	0.007	0.033
7	0.000	0.120	4	0.005	0.025
15	0.000	0.112	20	0.005	0.022
16	0.000	0.030	13	0.002	0.008
18	0.000	0.017	3	0.001	0.006
10	0.000	0.006	9	0.001	0.004
12	0.000	0.000	5	0.000	0.001

HS = harmonized system.

Source: Authors' calculations.

**Table 7: Export Value from Yunnan Province to Thailand by Port**

2000		2011				2017			
Port	Value (\$ billion)	Value Share	Port	Value (\$ billion)	Value Share	Port	Value (\$ billion)	Value Share	
Huangpu	52	0.007	Kunming	0.264	0.658	Kunming	0.454	0.559	
Zhanjiang	67	0.007	Nanning	0.047	0.118	Shenzhen	0.233	0.287	
Nanning	72	0.006	Shenzhen	0.035	0.088	Nanning	0.080	0.098	
Kunming	86	0.001	Hangzhou	0.016	0.040	Hangzhou	0.009	0.011	
Shanghai	22	0.001	Huangpu	0.015	0.037	Huangpu	0.008	0.010	
Guangzhou	51	0.001	Zhanjiang	0.011	0.027	Nanjing	0.007	0.009	
Dalian	09	0.000	Qingdao	0.008	0.019	Zhanjiang	0.007	0.008	
Shenzhen	53	0.000	Nanjing	0.002	0.004	Tianjin	0.004	0.004	
Tianjin	02	0.000	Shanghai	0.001	0.004	Shenyang	0.004	0.004	
Fuzhou	35	0.000	Tianjin	0.001	0.002	Xiamen	0.002	0.003	

Note: only the top 10 ports in terms of export value are shown.

Source: Authors' calculations.



**Table 8: Export Value from Yunnan Province to Thailand by Transportation Method**

Transportation	2000			2011			2017		
	Value (\$ billion)	Value Share	Transportation	Value	Value Share	Transportation	Value	Value Share	Transportation
Water	0.022	0.978	Water	0.208	0.519	Water	0.422	0.520	
Road	0.000	0.011	Road	0.175	0.437	Road	0.389	0.479	
Airway	0.000	0.009	Airway	0.018	0.044	Airway	0.000	0.001	

Source: Authors' calculations.

**Table 9: Nighttime Lights Regression in Level**

	$\ln(NTL_{it} + 1)$	t-value	$\Delta \ln(NTL_{it} + 1)$	t-value
$TreatInt_i \times AfterCons_t$	0.486	4.487	1.411	4.555
Lagged County Attributes	No		Yes	
No. Obs	494		198	
Adj. $R^2$	0.974		0.966	

Note: Year and county fixed effects are controlled.

Source: Authors' calculations.

**Table 10: Building Share Regression**

	$BShare_{it}$	t-value	$BShare_{it}$	t-value
$TreatInt_i \times AfterCons_t$	0.056	3.067	0.023	1.534
Lagged County Attributes	No		Yes	
No. Obs	176		32	
Adj. $R^2$	0.726		0.826	

Source: Authors' calculations.

**Table 11: Nighttime Lights Regression**

	$\Delta \ln(NTL_{it} + 1)$	t-value	$\Delta \ln(NTL_{it} + 1)$	t-value
$TreatInt_i$	0.029	0.550	0.054	2.016
No. Obs	78		390	
Adj. $R^2$	-0.004		0.225	
Period	1994 to 1997		1998 to 2012	

Source: Authors' calculations.

**Table 12: Building Share Regression**

	$\Delta BShare_{it}$	t-value	$\Delta BShare_{it}$	t-value
<i>TreatInt<sub>i</sub></i>	0.004	1.360	0.022	2.296
No. Obs	44		88	
Adj. $R^2$	0.022		0.072	
Period	1987 to 1995		2000 to 2019	

Source: Authors' calculations.

**Table 13: Export Level Regression**

	$\Delta \ln Expo_{it}$	t-value	$\Delta \ln Expo_{it}$	t-value
<i>TreatInt<sub>i</sub></i>	6.119	2.439	3.695	1.474
No. Obs	288		288	
Adj. $R^2$	0.050		0.074	
Trans	Road		Maritime	

Source: Authors' calculations.

**Table 14: Gravity Equation Estimates**

	$\ln (X_{idjsrt} + 1)$	t-value	$\ln (X_{idjsrt} + 1)$	t-value
$\ln (Dist_{idt} + 1)$	-0.261	-158.605	-0.151	-90.679
$\ln Dist_{dj}$	-0.320	-31.096	-0.285	-28.299
Year	2000		2011	
No. Obs	1913098		1913098	
Adj. $R^2$	0.184		0.094	

Source: Authors' calculations.

**Table 15: Gravity Equation Estimates across Sectors, 2000**

	(1)	(2)	(3)	(4)	(5)	(6)
sector	$\ln Dist_{idt}$	t-value	$\tau_{id}$	$\ln Dist_{dj}$	t-value	$\tau_{dj}$
6	-0.179	-31.923	1.261	-0.312	-9.125	1.973
7	-0.297	-52.243	1.475	-0.326	-8.022	2.056
11	-0.277	-62.128	1.432	-0.350	-14.419	2.153
12	-0.278	-37.031	1.436	-0.476	-9.232	2.880
13	-0.269	-45.501	1.438	-0.344	-8.553	2.138
15	-0.245	-58.443	1.373	-0.284	-10.273	1.868
16	-0.384	-80.597	1.665	-0.234	-7.193	1.677
17	-0.246	-27.213	1.368	-0.329	-4.778	2.073
18	-0.314	-46.790	1.486	-0.205	-4.638	1.571
20	-0.367	-62.660	1.624	-0.438	-10.968	2.649

Source: Authors' calculations.

**Table 16: Gravity Equation Estimates across Sectors, 2011**

	(1)	(2)	(3)	(4)	(5)	(6)
sector	$\ln (Dist_{idt} + 1)$	t-value	$\tau_{id}$	$\ln Dist_{dj}$	t-value	$\tau_{dj}$
6	-0.143	-25.228	1.192	-0.345	-10.414	2.123
7	-0.246	-43.519	1.358	-0.397	-10.165	2.409
11	-0.125	-28.844	1.164	-0.548	-24.043	3.329
12	-0.141	-18.922	1.187	-0.407	-8.207	2.473
13	-0.097	-15.609	1.131	-0.369	-9.026	2.258
15	-0.121	-28.070	1.159	-0.221	-8.050	1.626
16	-0.436	-102.896	1.743	-0.539	-19.224	3.289
17	-0.268	-30.026	1.386	-0.441	-6.718	2.654
18	-0.252	-38.488	1.350	-0.364	-8.737	2.236
20	-0.264	-46.287	1.391	-0.346	-9.139	2.154

Source: Authors' calculations.

**Table 17: Gravity Equation Estimates**

	$\ln(X_{idjsrt} + 1)$	t-value	$\ln(X_{idjsrt} + 1)$	t-value
$\ln(Dist_{idt} + 1)$	-0.282	-19.083	-0.041	-2.403
$\ln Dist_{dj}$	-2.264	-5.049	-2.602	-5.344
Year	2000		2011	
No. Obs	21055		21055	
Adj. $R^2$	0.218		0.094	

Source: Authors' calculations.

**Table 18: Total Exports and Inlandness**

	$\ln(X_{it} + 1)$	t-value	$\ln(X_{it} + 1)$	t-value	$\ln(X_{it} + 1)$	t-value	$\ln(X_{it} + 1)$	t-value
$\ln(Inland_i + 1)$	-1.666	-11.211	-1.083	-11.802	-0.923	-10.730	-0.984	-9.118
Year	2000		2006		2011		2017	
No. Obs	474		474		474		474	
Adj. $R^2$	0.209		0.226		0.194		0.148	

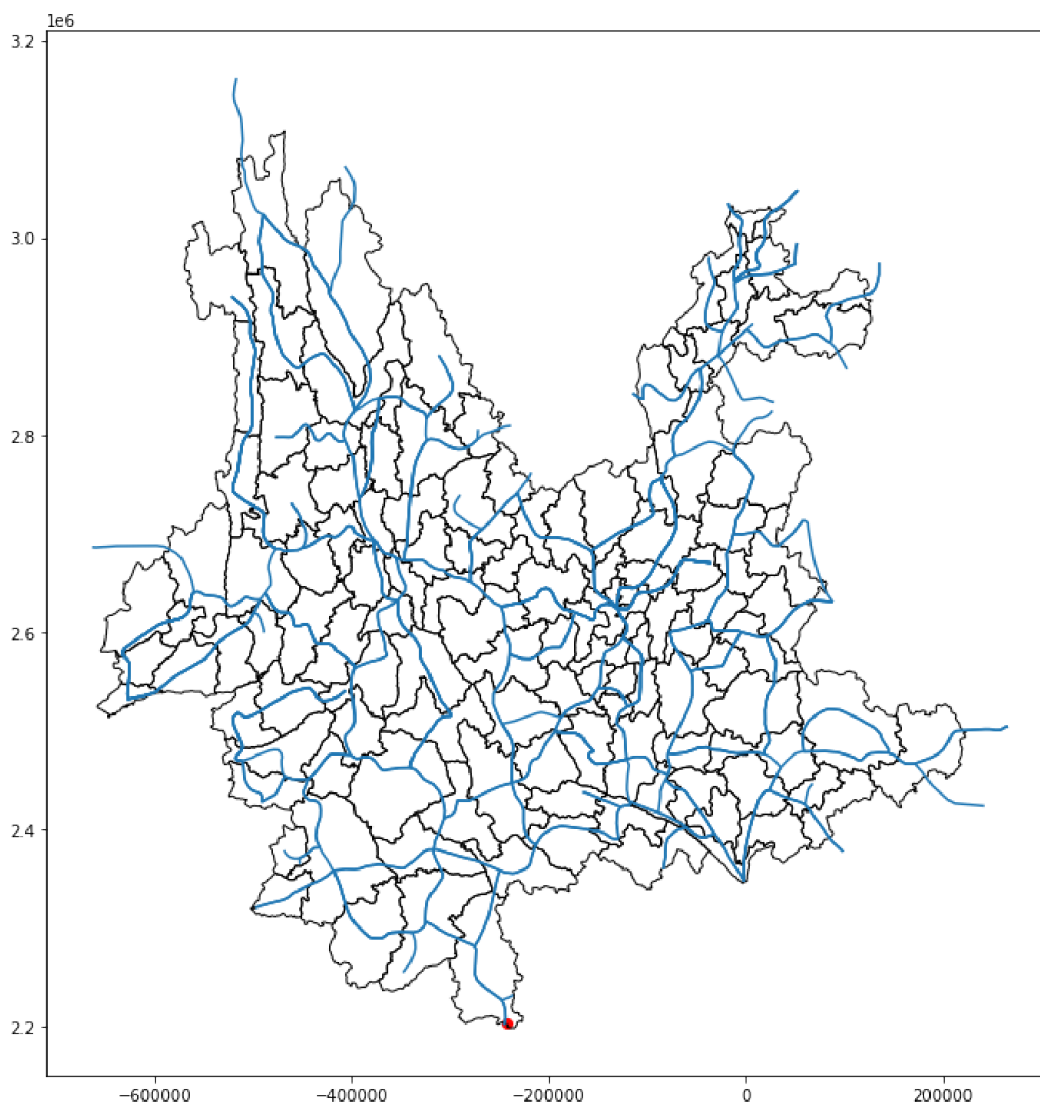
Source: Authors' calculations.

**Table 19: Port Access and Economic Development**

	$\ln(GDP_{it})$	t-value
$\ln(PA_{it})$	0.677	38.255
FE	Province	
No. Obs	62	
Adj. $R^2$	0.980	

FE = fixed effects, GDP = gross domestic product.  
Source: Authors' calculations.

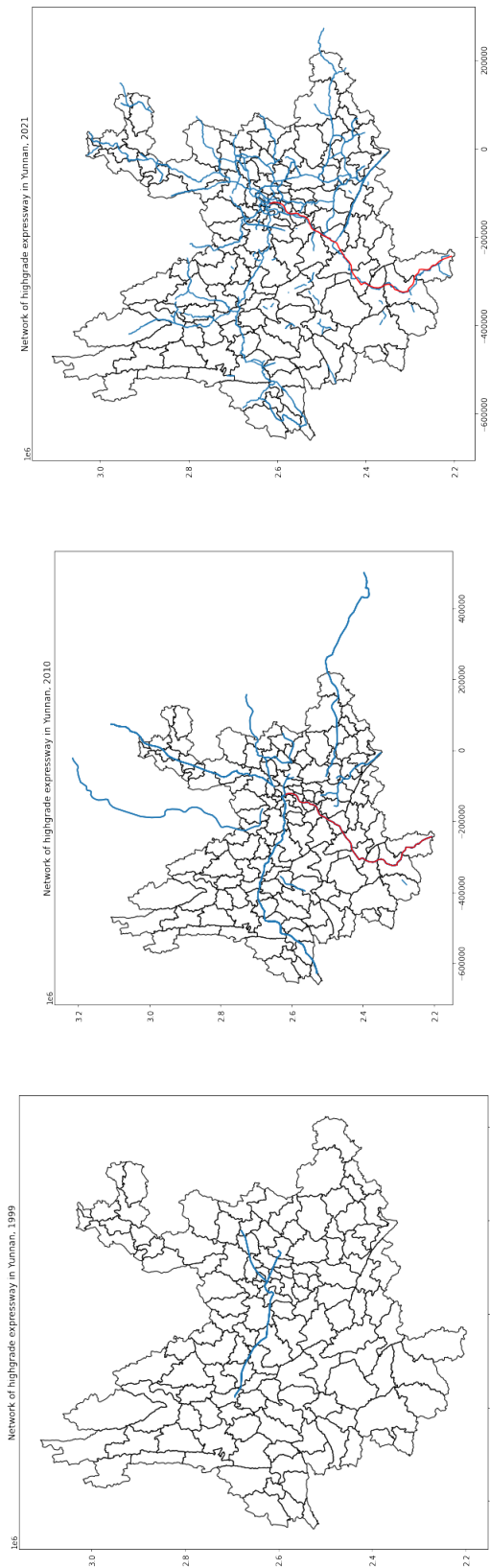
**Figure 1: Network of National Highways in Yunnan Province, 1999**



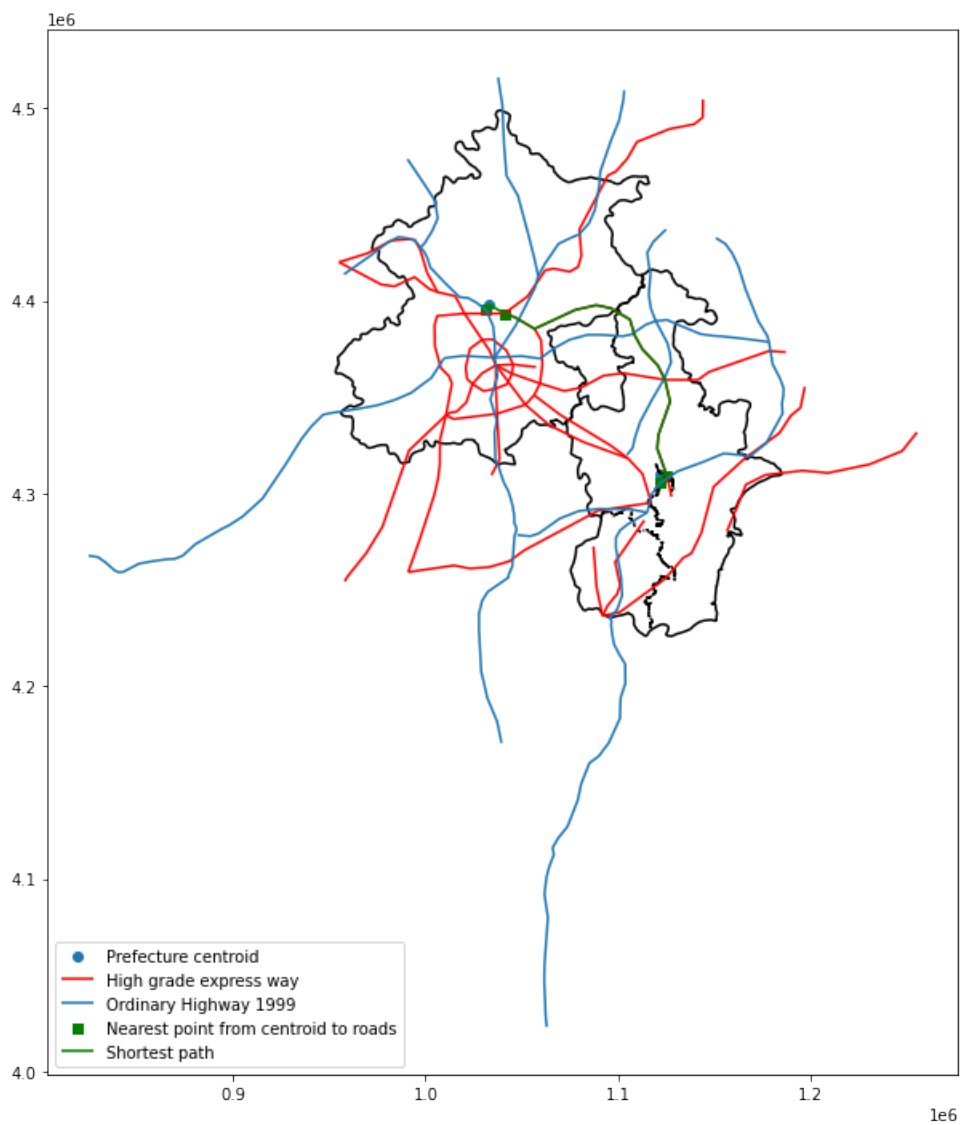
Source: Baum-Snow et al. (2017); Authors' calculations.

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**Figure 2: Network of High Quality Expressways in Yunnan Province–1999, 2010, and 2021**

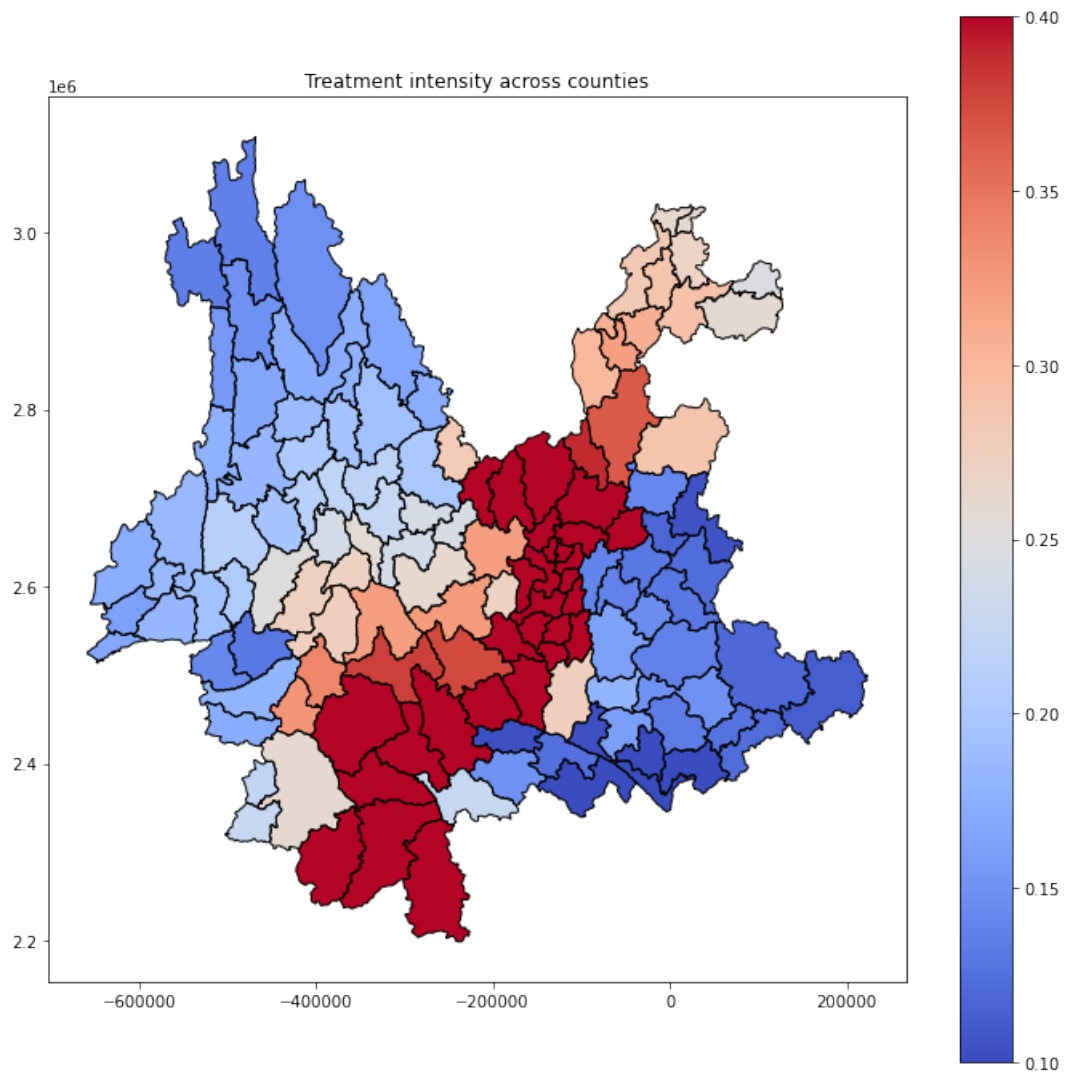


Source: Baum-Snow et al. (2017); National Catalogue Service For Geographic Information; Authors' calculations.

**Figure 3: Example of Shortest Distance Calculation**

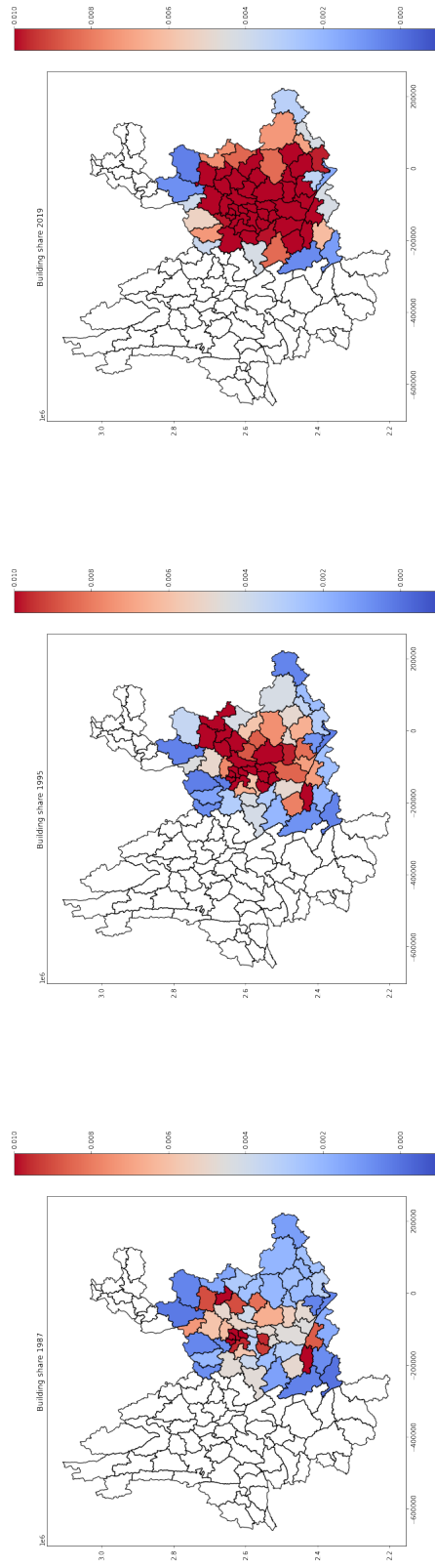
Source: Baum-Snow et al. (2017); Authors' calculations.



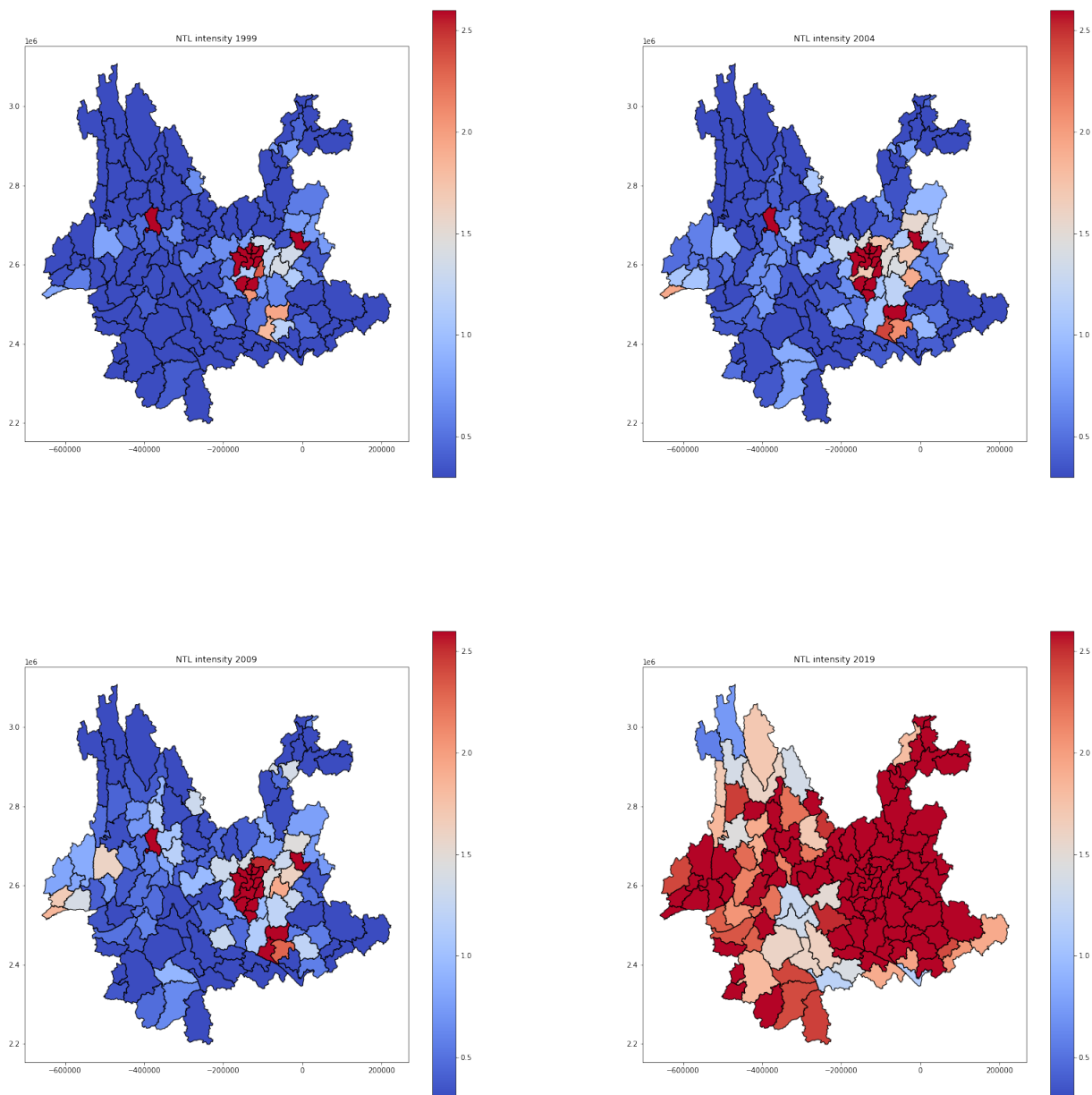
**Figure 4: Treatment Intensity across Counties in Yunnan Province**

Note: The figure plots the treatment intensity  $TreatInt_i$  for different counties in Yunnan Province.  
Source: Authors' calculations.

Figure 5: Share of Built-Up Areas in Yunnan Province—1987, 1995, and 2019



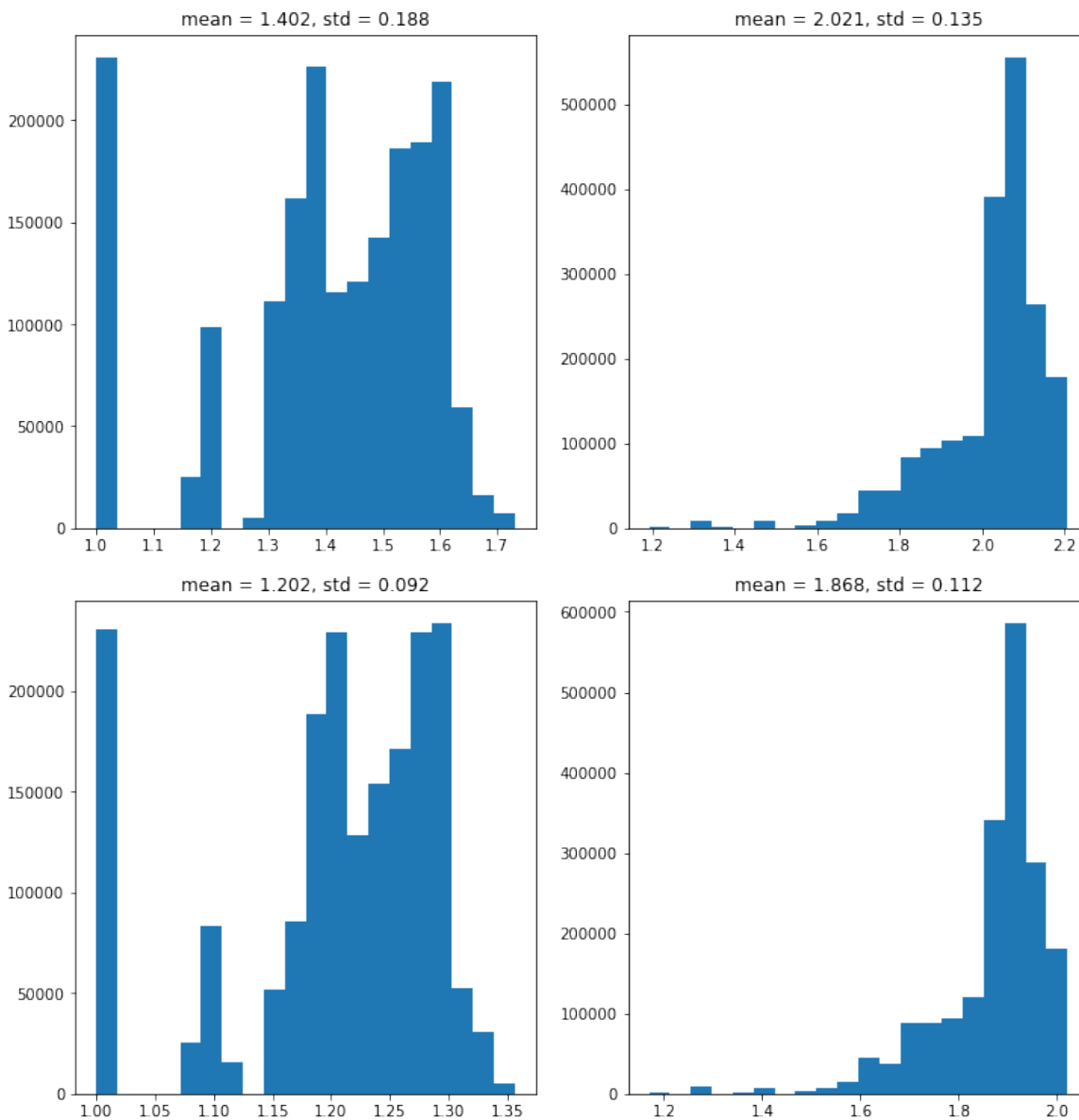
Note: From left to right: year 1987, 1995, 2019.  
Source: Authors' calculations.

**Figure 6: Nighttime Lights in Yunnan Province–1999, 2004, 2009, and 2019**

Note: From upper left to lower right: year 1999, 2004, 2009, 2019. Nighttime lights data are available yearly from 1994 to 2021, but not all years are included due to space limitation.

Source: Authors' calculations.

**Figure 7: Distribution of Trade Costs**



Note: Two figures in the first row plot the distributions for estimated internal trade costs (left panel) and estimated external costs (right panel) in 2000. Two figures in the second row plot the corresponding distributions for the year 2011.

Source: Authors' calculations.

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## **Assessing the Impact of Infrastructure Investments Using Customs Data**

*The Case of the Greater Mekong Subregion Corridor and the People's Republic of China*

This paper presents new evidence of the effects of road construction on both domestic and international trade flows in the People's Republic of China using customs data and information on transport investments in the region. Road construction helped to reduce trade costs significantly from 2000 to 2011. The construction of the Kunming–Bangkok Expressway, in particular, led to local economic growth and higher regional specialization in accordance with comparative advantage, facilitating market integration across borders in the Greater Mekong Subregion.

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