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Using Truck Probe Data to Measure Border Clearance Time: Evidence from Thailand

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Abstract

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Keywords: Probe data, Border time, Thailand

JEL classification: F10, R40

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Using Truck Probe Data to Measure Border Clearance Time: Evidence from Thailand

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Abstract: This study proposes a new approach for measuring border clearance time using truck probe data. Specifically, by using Global Positioning System (GPS) logs of trucks that cross border gates between two bordering countries, we measured the time for crossing the border gates in various ways. To demonstrate how this approach works, we employed probe data in Thailand, which included GPS logs of trucks that crossed Thai border gates to neighboring countries. We found some differences in the time required near the border area among different borders. For example, on the border with Laos, a large part of the time seems to be spent near the border. We also detected sudden increases in the time taken for customs clearance at the border with Malaysia. Furthermore, we empirically investigated how an increase in exports handled at the border changes the border crossing time. We found that it increases the border clearance time mainly because of the congestion in customs clearance and immigration procedure rather than on the nearby roads.

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1. Introduction

In this modern era, which features sophisticated international supply chains, a lengthy export/import process (e.g., customs clearance) results in economic loss. The time required for export/import processing depends on various factors particularly, the efficiency of cargo handling at ports. The process also takes longer if customs personnel inspect cargo

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physically. In addition, traffic jams around borders create further time loss. Narrow, undeveloped, or less-capacity roads leading to the border increase waiting time. These time losses have a significant effect on firms' activities. For example, if the import process is slow and the arrival of imported intermediate inputs takes a long time, the producers' ability to ensure timely production is hampered. Efficient processing at the customs clearance, in addition to a well-developed infrastructure around the border, is a critical factor in firms' international business.

There are some indicators of how much time and cost it takes for border clearance. Doing Business, developed by the World Bank, provides the most comprehensive data on the number of countries and years. It represents the time (and cost) associated with the logistical process of exporting and importing goods. Data were gathered through a questionnaire administered to local freight forwarders, customs brokers, port authorities, and traders. Some studies use actual shipment dates in detailed customs data to measure the length of time in customs clearance (Carballo et al., 2014, 2016; Volpe Martincus et al., 2015; Hayakawa et al., 2017). These data include various dates, such as the dates on which shipments arrived in ports and were released from the container yard. By taking the difference between the two dates, they calculated the processing times, such as customs clearance time or port handling time.

Against this backdrop, we propose a new approach for measuring border time. Our idea is to use truck probe data. The probe data included logs of the global positioning system (GPS) in cars or trucks. By examining such data for trucks that cross border gates between two bordering countries, we can measure the border clearance time for each truck. To demonstrate how this approach works, we employ probe data in Thailand for selected 48-hour slots in several months during 2017-2020, collected by Toyota Tsusho Mobility Informatics Thailand. Using these data, we measured the border clearance time at the Thailand border gates with neighboring contiguous countries (i.e., Laos, Myanmar, and Malaysia) and identified the times taken to enter the radii of 16 km, 8 km, 4 km, and 2 km on the Thai side from those gates. Examining these times, we can discern which point takes more time to pass, near the border gate, or on the road to the gate.

Our method has some advantages over other existing measures. First, unlike the Doing Business measure, our measure is computed from the actual transportation time. Thus, it is free from biases based on differences in survey respondents. However, our measure captures only the time around the customs gate. This does not include the time required to prepare customs clearance documents. Second, compared with the measure computed from customs data, our method has an advantage in terms of feasibility. Access to detailed customs data is not necessarily possible in all countries as such data is often restricted. On the one hand, GPS data can be collected by governments, private companies, or even individuals. On the other hand, in terms of coverage, customs data are much superior to truck probe data because it is almost impossible to track all trucks that cross the border.

Our findings can be summarized as follows: first, we found some differences with the borders in the time required near the border area. For example, on the border with Laos, most of the time seems to be spent near the border. A sudden increase in the time taken for customs clearance was also detected at the border with Malaysia. Second, we found that the crossing hours are relevant concerning road congestion but are not in the customs inspection or documentation processes. Third, these times depend not only on the customs' efficiency but also on the transaction volume and number of passing trucks. Thus, we also examine how trade volumes handled on a border affect these times. In this regard, we found that an increase in exports handled at a border increases the border clearance time mainly due to congestion in customs handling rather than on the road nearby.

Similarly, some previous studies used GPS data to identify the transport time. Lubulwa et al. (2011) identified the times at port terminal entry and exit to compute truck turnaround times. Bartholdi et al. (2019) also suggested a method to measure truck service times at container terminals using GPS. Truck probe GPS data are also used to measure road quality in terms of speed and congestion (Zhao et al., 2013). Some studies measured the truck turnaround time at the port terminal by employing camera images (Lam et al., 2007; Tsai et al., 2012). Although these studies mainly targeted port terminals, we focus on time around the border gate for land transportation.

Some studies have examined the effects of trade facilitation, such as customs efficiency, on trade. Country-level studies on the effects of customs clearance time on trade include those by Djankov et al. (2010), Freund and Rocha (2011), and Portugal-Perez and Wilson (2012). By estimating gravity equations, these studies found a significant effect of customs clearance time on trade values using data obtained from World Bank's Doing Business. Some studies have examined the relationship between customs clearance time and firm-level exports (Dollar et al. 2006; Li and Wilson 2009; Shepherd 2013; Carballo et al. 2014, 2016; Fernandes et al. 2015; Volpe Martincus et al. 2015). In contrast to these studies, we examine the opposite effect, that is, the effect of border-level trade volume on truck-level customs clearance time. In this sense, our study complements Hillberry and Zhang (2015), who empirically showed that customs clearance time depends particularly on customs governance.

The remainder of this paper is organized as follows: Section 2 explains the methodology. Section 3 presents our empirical results. Finally, Section 4 concludes the paper.

2. Methodology

This section introduces the data used for the measurement of border crossing times. We then explain our empirical framework to examine the relationship between border time and border congestion.

2.1. Probe Data

This study used probe data or high-frequency location information of moving vehicles to evaluate the cross-border time of trucks. We acquired probe data from the largest provider in Thailand, whose data covered approximately 10,000 taxis and 130,000 trucks as of 2018. According to the Department of Land Transport, approximately 339,144 non-personal-use trucks were registered in Thailand by the end of 2019. Our data provider covers approximately one-third of the commercial truck population in Thailand. Because the size of all data for one day is dozens of gigabytes, the whole data from 2016 to 2020 would be several petabytes (1 petabyte = 1 million gigabytes), which is beyond our processing capacity and budget. For demonstration purposes, we focus only on vehicles that appear near customs houses, where all border-crossing trucks need to stop. We acquired one set of probe data for consecutive 48 hours of all vehicles that appeared within a 10-km radius from regional custom houses on selected Sundays, Mondays, Wednesdays, and Thursdays in each odd month between May 2016 and November 2020.

The information included in our data is the follows:

IMEI: Unique number for each GPS device
Latitude: North-south geographic coordinates
Longitude: East-west geographic coordinates
Speed: Speed measured by GPS
Timestamp: GPS epoch time stamped in seconds since 1970 UTC.
Acceleration: Acceleration measured by GPS
Error: Information on the margin of error
Direction: Direction measured by GPS
Data source: Identification of primary data provider
Meter: Signal from taxi meter

First, the data were cleaned. We used a meter signal to filter out the taxis. Although the dataset might still have contained taxis or other passenger vehicles without meter equipment, it was the best approach given the information in the dataset. We excluded data points outside Thailand and adjacent countries because the speed derived from such distant locations would be unrealistically well over several hundred kilometers per second. Such erroneous location information is likely to be due to weak GPS signals. Vehicles that did not appear on the other side of the border were excluded. This exclusion substantially reduces the size of our sample, as most trucks that arrived near the border did not cross the border. The trucks that returned without crossing the border included trucks that delivered goods to Thailand's border cities, or transferred goods to other trucks or different transport modes, such as small ships, for cross-border deliveries. We excluded the trucks outside Thailand at the start of each 48-hour period because our focus was on the cross-border time on the Thai side.

Second, we interpolated observations. The driving distance of vehicles moving at a speed of 60 km/hour was approximately 34 meters in 2 seconds on flat terrain. The frequency of the GPS data varies from approximately one to several seconds in the dataset. The interval between the timestamps can also be large when the GPS signal is weak. If the interval between timestamps is large, identifying the time that a truck enters or leaves an area of interest becomes less accurate. For example, suppose that a truck arrived at the area of the customs house at 8:00 a.m., but GPS data were not available from 7:59 and 8:05 a.m. because of a weak signal, the arrival time was identified as 8:05 a.m., which was five minutes behind the actual time. To address this issue, we applied interpolation to generate location data for each second by assuming that the truck traveled at a constant speed during the period when GPS was not working correctly.

Third, although we aim to study cross-border time, its computation is not straightforward. Because the border is a line, the time needed for a moving truck to cross it is approximately the same. The cross-border time that we are interested in includes the time needed before crossing the border, that is, the time for customs clearance. At some borders, congestion may occur much before custom checkpoints. The actual distance between the points of congestion and border crossing is also dependent on the profile of the road. We propose the following method for analyzing cross-border time: first, we identify a cross-border crossing point for each truck by overlaying its GPS track with a high-resolution border line obtained from the World Bank.[1] We created circular buffers of 2, 4, 8, and 16 km from that point and then extracted the time when each truck entered each buffer.

Figure 1 illustrates the distribution of the number of trucks that crossed each border at a certain time of the day for all obtained data. Time (hh) denotes cross-border time in 24-hour format. The number of trucks crossing borders is denoted by n. Sadao had the highest number (3,771) of border-crossing trucks, a major border gate between southern Thailand and Malaysia. The cross-border time at Sadao spans the widest period between 5 am and 8 pm, with the peak at approximately 10 am. Three friendship bridges between Thailand and Laos, Muang Nong Khai, Muang Mukdahan, and Muang Nakhon Phanom, had 581, 492, and 483 trucks, respectively. The crossings at these bridges were mostly between 8 am and 4 pm. The fifth-largest border crossing was Mea Sot, bordering Myanmar, with 453 trucks. Crossing at Mea Sot was mostly between 7 am and 4 pm. In our empirical analysis, to ensure a sufficient number of observations, we focused on trucks crossing borders in Mae Sot, Muang Nong Khai, Muang Mukdahan, and Sadao between January 2017 and November 2020.

[1] The information of border gates in free and even commercial online map is not always up to date. Furthermore, vehicles do not always cross border through official border gates. In this study, we generated border crossing points from GSP data themselves to capture border-crossing operation in reality.

=== Figure 1 ===

2.2. Congestion Effects

We empirically examine the effects of border congestion on border crossing time. An ideal measure of congestion is the total number of vehicles existing around the border gates. However, our probe data are obtained from a private company and do not cover all vehicles that passed through the gates. Official data collected by governments are not available for the total number of vehicles. Thus, as a proxy for this number, we use monthly data on total exports from Thailand through each border.

Specifically, we estimate the following equation:

$$\ln Time(\mathrm{X})_{ibt} = \alpha \ln Exports_{bt} + \delta_h + \delta_b + \delta_t + \epsilon_{ibt}. \quad (1)$$

$Time(\mathrm{X})_{ibt}$ is the border-crossing time from X km by truck i at border b on date t. X is 2 km, 4 km, 8 km, or 16 km. $Exports_{bt}$ is Thailand's total exports through border b for the month corresponding to date t. We expect a positive coefficient for this variable, which indicates that an increase in exports handled at a border increases the time taken to pass through the border. By estimating this equation for each point, we can determine the area most affected by the congestion. We controlled for border and date fixed effects. The former type of fixed effects controls for geographical differences in each buffer across borders, while the latter type captures the effects of macro shocks, such as the COVID-19 pandemic. Furthermore, we introduced fixed effects on the hour when truck i enters point X km (δ_h) in the case where border gates may not be crowded in the early morning. ϵ_{ibt} is an error term.

There are some sources of endogeneity bias in Equation (1), namely, reverse causality. Commercial vehicles can avoid passing through crowded gates, thereby exports through the gate may be reduced. In this case, when we estimate Equation (1) using the ordinary least squares (OLS) method, the error term is negatively associated with our main explanatory variable, *Exports*. As a result, its estimate suffers from downward bias and is underestimated. In addition, there might be unobservable border-date level elements that affect both exports and time across borders, yielding an omitted variable bias. Furthermore, our export variable indicates the value of export transactions rather than the number of vehicles, and the entire month rather than the corresponding date. Thus, it includes measurement error and creates an attenuation bias toward zero.

To address these endogeneity issues, we employ the instrumental variable (IV) method. Specifically, as an instrument, we use a log of monthly imports from the world in the country where each border belongs (denoted by ln *Imports from ROW*). For example, suppose there is a border gate in Mae Sot, which is the border between Thailand and Myanmar. Our main explanatory variable for this case is monthly exports from Thailand through Mae Sot. To instrument this variable, we used Myanmar's imports from the world (except for those from ASEAN) in the corresponding month. This instrument represents Myanmar's total import demand, which is closely related to Thailand's exports to Myanmar. On the other hand, Myanmar's import demand will affect the driving time around Mae Sot by changing imports from Thailand, and will not have a direct association with driving time.

The data issues are as follows: the dependent variable is constructed based on the method proposed in the previous subsection. The data on exports are obtained from the Department of Foreign Trade of Thailand[2], while the instrument is constructed using data from the Global Trade Atlas. In this regression analysis, we restricted our sample borders to Mae Sot, Muang Nong Khai, and Sadao, thereby excluding observations for Mukdahan. Because exports from Thailand through Mukdahan go to Laos, Vietnam, and China, the magnitude of these exports is largely affected by changes in the demand in Vietnam and China. Thus, our instrument does not work for observations in Mukdahan. Finally, the top and bottom 1% of the observations in $Time(16)$ were dropped as outliers.

3. Empirical Results

This section first presents an overview of the major stop points for the trucks. We then show our computation results for border times and present our estimation results for Equation (1).

3.1. Overview of Stop Points

Before our analyses, we examine where cross-border trucks tend to stop, that is, when their speed likely becomes zero, by checking the GPS data. We focus on four borders, Mae Sot, Muang Nong Khai, Muang Mukdahan, and Sadao, in 2019 and 2020. Because there are two days of data in each odd month, we examine truck stop points for a total of 24 days. Note that stopping here may mean actual parking or standing still because of traffic congestion.

In Mae Sot, a relatively larger number of non-moving trucks are observed along many roads more than 30 km away from the border crossing compared to the other three borders. The number of trucks stopping on the roads increase within the range of 16–8 km but decrease within the range of 8–4 km. The latter decrease could be because this area has a city center with more roads and is less likely to create traffic jams. The number of trucks stopping on the road again increases within a 4 to 2 km range for trucks headed to the first and second friendship bridges through different routes.[3] Within a 2 km distance from the

[2] The export data are not available by products though the effect of exports on congestion at a border may be different across the main products handled at that border.

[3] As mentioned in Section 3.3, two bridges exist in the border of Mae Sot.

border, trucks stopped the most around the customs offices and immigration offices toward both friendship bridges.

Most cross-border trucks headed to Muang Nong Khai do not stop before entering the 16 km buffer. Note that the number of cross-border trucks handled by Muang Nong Khai is slightly higher than that handled by Mae Sot in our data (581 vs. 453, Figure 1). The number of stops at locations further than 16 km from the border crossing is significantly small compared to those at Mae Sot. Within the range of 16–8 km from the border, the largest stops were observed at a junction toward the border crossing. Within the range of 8–4 km, more trucks stop at several locations near the quarantine center, train station, and factories' parking lots; specifically, outside the roads. Within the range of 4–2 km, the largest number of stops is observed around the customs office. The last major stops on the roads are at the immigration office within 2 km of the border crossing, where the immigration procedure occurs.

The situation in Muang Mukdahan is similar to that in Muang Nong Khai. The number of trucks that stop on the roads is generally small. A substantially large number of stops within the range of 8–4 km from the border are observed at two non-road locations, one around the village office and the other around the provincial office. Within the range of 4–2 km, the largest stops are observed at the customs and immigration offices located adjacent to one another.[4] The number of stops around the customs office is several times larger than that of Muang Nong Khai, while the total number of cross-border trucks in the sample period is approximately the same. In contrast, we find few stops in the 2 km buffer.

Last, we look at Sadao, which handled the largest number of border-crossing trucks among the four borders. Many trucks stop beyond 16 km from the border gates. The situation looks similar to that of Mae Sot at first glance, but most stops are clearly outside the roads. Within a range of 16–4 km, trucks stopped at large gasoline stations and accommodations. The number of trucks stopping on the road increases substantially from 4 km toward the border. A large number of stops are observed around the customs office within the range of 4–2 km. The last major stop location is observed at the immigration office immediately before the border gate, but the extent is smaller than that around the customs office.

3.2. Distribution of Border Times

Figure 2 depicts the distribution of the time spent driving from each point to the border gate for the sample trucks. This shows the distributions of the observations in 2019. We can observe a large variation in the required times across vehicles. In Mae Sot, bordering Myanmar, a relatively large variation between points can also be found, although the distribution is right-skewed as the point moves away from the border. In particular, the

[4] The existence of these offices in the range of 4–2 km, not within the 2 km from the border, is another reason for excluding Mukdahan from our regression analyses.

distribution for 2 km is flatter, implying that the required time from the 2 km point to the border varies more widely across trucks. Such variations may be attributed to the existence and efficiency of customs inspections. In contrast, in Muang Nong Khai and Muang Mukdahan, both of which border Laos, the differences among 4, 8, and 16 km look trivial, implying that it does not take much time from the 16–4 km points. The case of Sadao, which borders Malaysia, shows similar patterns to the two previous borders.

=== Figure 2 ===

Figure 3 depicts the time-series changes in the median values of time according to the distance from the border and months. There are several interesting findings. First, in Mae Sot, the median times for the 8 and 16 km buffers seem to decrease over time. Another interesting finding is that in November 2020, the median time increased for all points except for the 2 km buffer. Time from the 4–2 km points is found to increase remarkably, because the time difference between the 4, 8, and 16 km buffers is minimal. Second, in Nong Khai, the required time for all buffers, except for the 2 km buffer, fluctuates over time but indicates almost the same time among the three buffers of 4, 8, and 16 km. The latter implies that it does not take much time from 16–4 km points. It is also found to take minimal time from the 2 km point to the border, that is, at the immigration office. As a result, most of the time within 16 km is spent in the 4–2 km interval points, where the customs office exists.

=== Figure 3 ===

Third, the longest time spent from the 16 km point to the border in Mukdahan is the time spent from the 4–km points, where customs and immigration procedures are carried out. Fourth, in Sadao, except for 2017, the median time for all intervals is stable over time. Nevertheless, jumps can be seen in some months. Since such jumps are observed for all four lines, they occurred from the 2 km point to the border. Thus, these jumps may be related to tightening border controls, especially during immigration. Finally, the scale of the vertical axis differs among the four borders. Overall, the median time to the border was the shortest in Sadao, followed by Mukdahan, Nong Khai, and Mae Sot. This finding is interesting because we focus on the time required only in Thailand. Nevertheless, we can find apparent differences in the border-crossing times among borders, perhaps because of the differences in the efficiency of custom offices and nearby road conditions.

Figure 4 shows the median time among the half-yearly observations according to the hours recorded for passing at each point. For example, in the figure for 4 km, "0:00-8:59" indicates the median time from 4 km point to the border by vehicles passing the 4 km point before 9 am. To ensure a sufficient number of observations for each period, we focus on the observations for Sadao. There were no considerable differences according to passing hours within 2 km, except for the first half of 2017. Thus, the time required for immigration, inspection, or documentation was the same regardless of the hours of the day. In the other intervals, the time seems shortest when passing in the early morning, that is, before 9 am, and longest when passing in the early afternoon, that is, from 12 pm to 3 pm. This difference is related to road congestion.

=== Figure 4 ===

3.3. Estimation Results

We examine the effects of exports on border time using Equation (1). Table 1 presents the OLS results. The coefficients for exports are significantly positive at 2 and 16 km. Specifically, a 1% increase in exports increases the time from the 2 km point by 1.2% and that from the 16 km point by 0.3%. Although the significantly negative result for 4 km is puzzling, we can say that the increase in exports has the largest impact near the border area.

=== Table 1 ===

The results by the IV method are presented in Table 2. The test statistics for under-identification (Kleibergen-Paap rk *LM* statistic) and weak identification (Kleibergen-Paap rk Wald *F* statistic) show reasonably high values, while the high value in the former test indicates that the rank condition is satisfied and that the equations are identified. The high value in the latter test suggests that our IV estimates are unlikely to suffer from bias due to weak instruments. The significantly negative coefficient for our instrument (denoted by ln Imports from ROW) in the first-stage regression may indicate the substitution relation between neighboring countries' imports from Thailand and those from the rest of the world. In the second-stage regression, we see a significantly positive coefficient for only 2 km. Its magnitude increases greatly compared to the results produced by the OLS method, implying that our OLS estimate suffers from a downward bias. Specifically, a 1% increase in exports increased the time from 2 km to the border by 3.7%.

=== Table 2 ===

Finally, in Table 3, we add another dummy variable that takes a value of one for observations in Mae Sot after October 2019 and a value of zero otherwise (*Border dummy*). During that month, the border between Mae Sot and Myanmar introduced two trade facilitation measures. One was to open the Second Thailand-Myanmar Friendship Bridge. Although the first bridge existed on this border, its capacity for vehicle crossing was limited. After opening the second bridge, passenger cars and pedestrians use the first bridge, whereas trucks and buses use the second bridge. Another measure is that the Cross-Border Transport Agreement entered into force on this border, allowing approved trucks to cross the border, therefore, transporters need not change trucks. Table 3 lists the estimation results. Again, the coefficient for exports was significantly positive for only 2 km. In addition, its magnitude decreases as the distance from the border increases, although it is insignificant. *The border dummy* had significantly negative coefficients for both 2 and 16 km. For example, the two trade facilitation measures significantly reduced the time from 2 km to the border by 94% (= exp(−2.813)−1), which is economically large.

=== Table 3 ===

4. Concluding Remarks

This study proposed a new approach for measuring the border crossing time using truck probe data. Using GPS logs for trucks that cross the border gates between two bordering countries, we measured the time required to cross border gates in various ways. To demonstrate how this approach works, we employed the probe data of trucks that crossed the border gates from Thailand to neighboring countries. We found some differences in the time required near the border area among the borders. For example, on the border with Laos, most of the time seems to be spent near the border. We also found a sudden increase in the time for customs clearance at the border with Malaysia. Furthermore, we empirically investigated how an increase in exports handled at a border changed the border crossing time. We found that it increased the border clearance time mainly due to congestion in the customs clearance and immigration process rather than on the nearby roads.

References

Alessandria, G., Kaboski, J.P., and Midrigan, V. (2010). Inventories, Lumpy Trade, and Large Devaluations, *American Economic Review*, vol. 100(5), pp. 2304–2339.

Bartholdi, J.J., Lasso, A., Ratliff, H.D., and Oliver, Y. (2019). Using GPS to Measure Truck Service Times in a Container Terminal, *Maritime Economics and Logistics*, vol. 21(1), pp. 146–155.

Carballo, J., Graziano, A., Schaur, G., and Martincus, C. (2016a). The Heterogeneous Costs of Port-of-Entry Delays, Mimeograph.

Carballo, J., Graziano, A., Schaur, G., and Martincus, C. (2016b). Endogenous Border Time: Ports, Customs, Storage?, Mimeograph.

Djankov, S., Freund, C., and Pham, C.S. (2010). Trading on Time, *Review of Economics and Statistics*, vol. 92(1), pp. 166–173.

Dollar, D., Hallward-Driemeier, M., and Mengistae, T. (2006). Investment Climate and International Integration, *World Development*, vol. 34(9), pp. 1498–1516.

Fernandes, A., Hillberry, R., and Alcantara, A. (2015). Trade Effects of Customs Reform: Evidence From Albania, Policy Research Working Paper 7210, The World Bank.

Freund, N. and Rocha, N. (2011). What Constrains Africa's Exports?, *World Bank Economic Review*, vol. 25(3), pp. 361–386.

Hayakawa, K., Laksanapanyakul, N., and Yoshimi, T. (2019). How Does Import Processing Time Impact Export Patterns?, *The World Economy*, vol. 42(7), pp. 2070–2088.

Hillberry, R. and Zhang, X. (2015). Policy and Performance in Customs: Evaluating the Trade Facilitation Agreement, Policy Research Working Paper 7211, The World Bank.

Hummels, D.L. and Schaur, G. (2013). Time as a Trade Barrier, *American Economic Review*, vol. 103(7), pp. 2935–2959.

Lam, S.F., Park, J., and Pruitt, C. (2007). An Accurate Monitoring of Truck Waiting and Flow Times at a Terminal in the Los Angeles/Long Beach Ports, Final Report METRANS Project, Ar. 05-01.

Li, Y. and Wilson, J. (2009). Trade Facilitation and Expanding the Benefits of Trade: Evidence From Firm Level Data, Asia-Pacific Research and Training Network on Trade, Working Paper Series, Number 71.

Lubulwa, G., Malarz, A., and Wang, S. (2014). An Investigation of Best Practice Landside Efficiency at Australian Container Ports, *ATRF*, vol. 2011 **-** 34th Australasian Transport Research Forum.

Portugal-Perez, A. and Wilson, J.S. (2012). Export Performance and Trade Facilitation Reform: Hard and Soft Infrastructure, *World Development*, vol. 40(7), pp. 1295–1307.

Shepherd, B. (2013). Trade Times, Importing and Exporting: Firm-Level Evidence, *Applied Economics Letters*, vol. 20(9), pp. 879–883.

Tsai, Y., Dusanter, T., Wu, Y., Ai, C., and Caïtucoli, Q. (2012). Automatic Truck Processing Time Extraction at Marine Container Terminal Gates Using Low-Frame-Rate Images, *Journal of Intelligent Transportation Systems*, vol. 16(4), pp. 211–225.

Volpe Martincus, C., Carballo, J., and Graziano, A. (2015). Customs, *Journal of International Economics*, vol. 96(1), pp. 119–137.

Zhao, W., McCormack, E., Dailey, D.J., and Scharnhorst, E. (2013). Using Truck Probe GPS Data to Identify and Rank Roadway Bottlenecks, *Journal of Transportation Engineering*, vol. 139(1), pp. 1–7.

Table 1. Estimation Results by the OLS Method

	2 km	4 km	8 km	16 km
ln Exports	1.175***	-0.458**	0.158	0.335*
	[0.234]	[0.195]	[0.199]	[0.183]
Number of obs	4,350	4,350	4,350	4,350
Adjusted R-squared	0.383	0.111	0.104	0.12

Notes: This table reports the estimation results obtained using the OLS method. ***, **, and * indicate 1%, 5%, and 10% levels of statistical significance, respectively. Robust standard errors are reported in the parentheses. In all specifications, we control for the border gate, date, and passing hour fixed effects.

Table 2. Estimation Results by the IV Method

	2 km	4 km	8 km	16 km
Second-stage				
ln Exports	3.746***	1.276	0.034	0.149
	[1.098]	[0.914]	[0.867]	[0.783]
First-stage				
ln Imports from ROW	-0.266***	-0.266***	-0.266***	-0.266***
	[0.029]	[0.029]	[0.029]	[0.029]
Number of obs	4,350	4,350	4,350	4,350
Underidentification test	63.1	63.1	63.1	63.1
Weak identification test	83.8	83.8	83.8	83.8

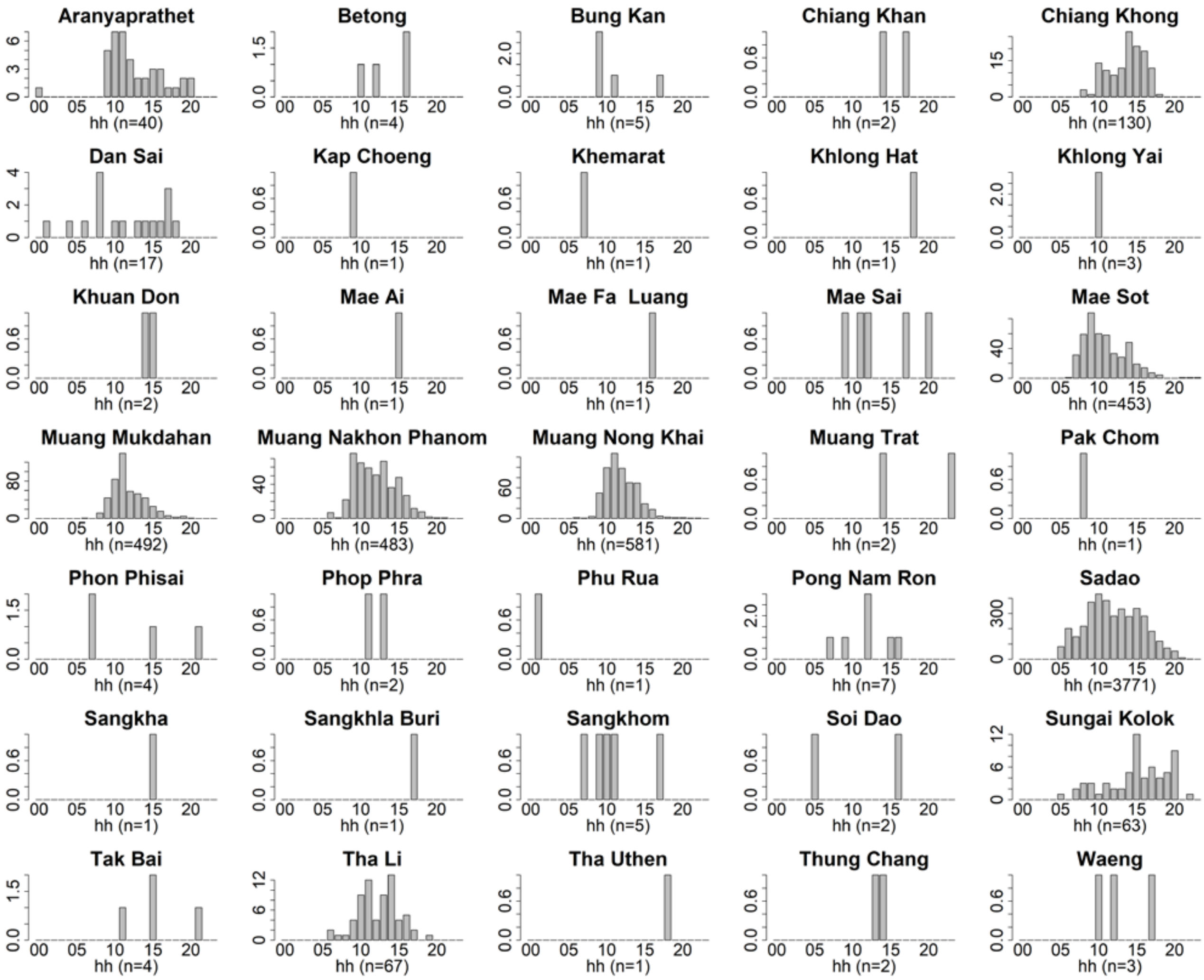
Notes: This table reports the estimation results obtained using the IV method. ***, **, and * indicate 1%, 5%, and 10% levels of statistical significance, respectively. Robust standard errors are reported in the parentheses. In all specifications, we control for the border gate, date, and passing hour fixed effects. Under-identification and weak identification tests indicate the Kleibergen-Paap rk *LM* statistic and the Kleibergen-Paap rk Wald *F* statistic, respectively.

Table 3. Estimation Results by the IV Method: Trade Facilitation Measures

	2 km	4 km	8 km	16 km
ln Exports	2.922***	1.27	0.074	0.008
	[1.060]	[0.934]	[0.885]	[0.800]
Bridge dummy	-2.813***	-0.021	0.138	-0.479***
	[0.288]	[0.254]	[0.235]	[0.172]
Number of obs	4,350	4,350	4,350	4,350
Underidentification test	60.1	60.1	60.1	60.1
Weak identification test	79.8	79.8	79.8	79.8

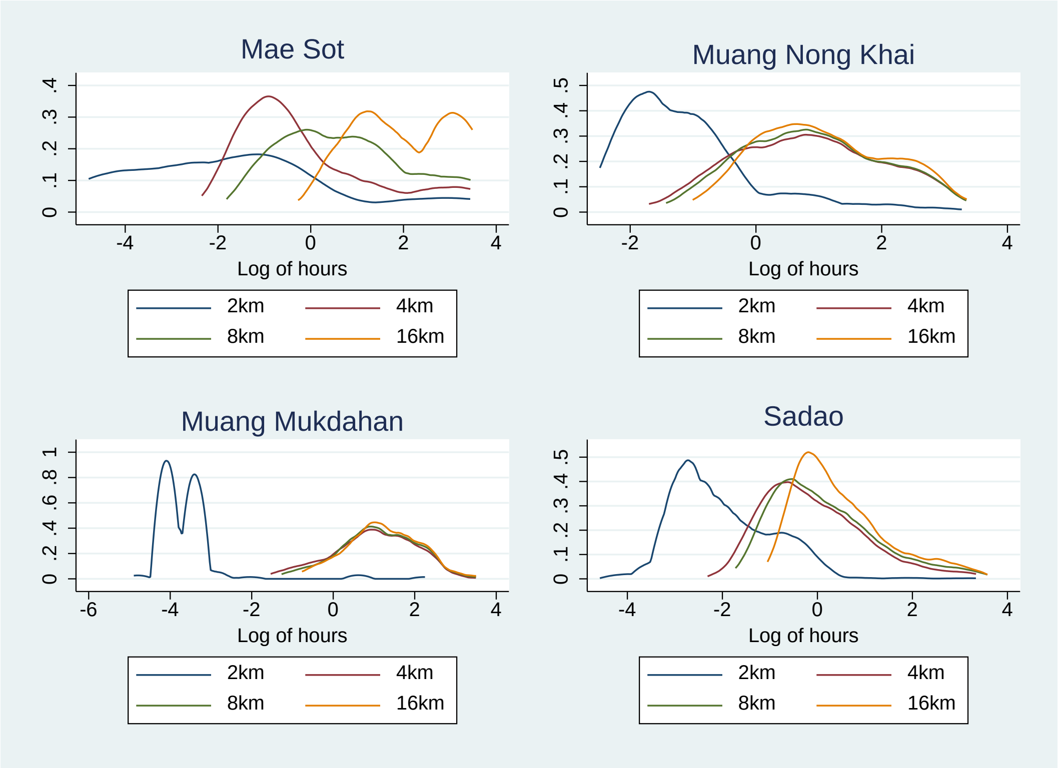
Notes: This table reports the estimation results obtained using the IV method. ***, **, and * indicate 1%, 5%, and 10% levels of statistical significance, respectively. Robust standard errors are reported in the parentheses. In all specifications, we control for the border gate, date, and passing hour fixed effects. Under-identification and weak identification tests indicate the Kleibergen-Paap rk *LM* statistic and the Kleibergen-Paap rk Wald *F* statistic, respectively.

Figure 1. The Distribution of the Number of Trucks Crossing Each Border by Time of Day (May 2016 to November 2020)



Source: Authors' compilation.

Figure 2. Distribution of Hours Required in Each Interval in 2019



Source: Authors' compilation.

Figure 3. Time-series Changes of Median Hours by Distance (Monthly)

Source: Authors' compilation.

Figure 4. Time-series Changes of Median Hours by Entry Time in Sadao (Half-yearly)

Source: Authors' compilation.