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Trade Efficiency, Cross-Border Integration, and Regional Barriers in Northeast China

Kiril Tochkov

Department of Economics, Texas Christian University, Fort Worth, Texas, USA

ABSTRACT
The Northeast region has struggled to restructure and modernize its economy during China's transformation into a global power, missing the opportunity to benefit from foreign trade and investment. This paper explores the trade patterns of the region's three provinces vis-à-vis their main trading partners over the period 1992-2018. In particular, we quantify the barriers to trade employing a gravity model specification and trace changes across time and regions. Furthermore, we use a stochastic frontier approach to calculate a measure of the trade potential that serves as a benchmark in assessing the trade performance of Northeast China's provinces. The results show that the region exhibits high trade costs that amount to ad-valorem tariffs ranging between 75% and 100%. The analysis also indicates that the region's trade performance is only 40% to 55% of its potential level. The relatively high levels of inefficiency extend even to trade with the rest of China and have increased over time.

KEYWORDS
Trade; trade inefficiency; border effects; regional integration; China

1. Introduction

Trade has become one of the defining features of China's successful transformation into a global manufacturing superpower. The regional dimension of this process has drawn attention to coastal provinces, five of which accounted for 70% of national exports and 60% of imports in 2018. By contrast, many poor landlocked provinces, especially in West and Southwest China, missed out on trade, compelling the central government to launch massive investment programs aimed at stimulating growth and reducing regional disparities. In this context, Northeast China is an anachronism as its share in national trade was less than 4% in 2018 despite being highly industrialized and having access to the coast. This makes the Northeast an intriguing case of a region that apparently is not using its favorable economic and geographical advantages to realize its potential for integration into the global production and trading process.

In the 1950s, the region was celebrated as the cradle of industrial development, ranking as one of the wealthiest parts of China. Its economy relied on an industrial structure dominated by large-scale state-owned enterprises (SOE) engaged in mining and heavy industries. When the focus of government policies shifted to efficiency improvements and modernization during the early decades of market transition, SOEs in the Northeast missed the opportunity to restructure and benefit from the opening of the economy to foreign trade and investment (Chen & Li, 2008). Stagnation, unemployment, and environmental pollution plagued the region. In response, the central government implemented three major drives (in 2003, 2009, and 2016) aimed at revitalizing the "Old Industrial Base" of the Northeast (Chung et al., 2009; Hou et al., 2019; Wang et al.,

CONTACT Kiril Tochkov k.tochkov@tcu.edu Department of Economics, Texas Christian University, TCU Box 298510, Fort Worth, TX, 76129, USA.

2014). A key objective of the strategy has been to boost cross-border trade and investment, especially with neighboring nations.

This paper explores the trade patterns of Northeast China over the past three decades in the belief that the region is not taking full advantage of its geographic location to foster closer ties with neighboring countries. In particular, we investigate two key aspects of the region's trade over the period 1992-2018. First, we study the barriers to trade between Northeast China's three provinces (Heilongjiang, Jilin, and Liaoning) and their main trading partners using a gravity model. The estimated border effects allow us to quantify the trade costs and trace their changes over time. Moreover, these measures of trade impairment are evaluated relative to intranational trade, making it possible to gauge the extent of regional integration.

The second aspect deals with the issue of trade potential. We employ a stochastic frontier approach that defines the potential for trade in Northeast China as a frontier enveloping the observed trade levels. The data points forming the frontier serve as a benchmark for assessing the trade performance of the region, whereby the distance to the frontier can be interpreted as a measure of trade efficiency. Accordingly, we use this methodology to identify the extent of inefficiency in Northeast China's trade relations. In addition, the application of this approach to the ties between the Northeast and the rest of China allows us to study the intranational dimension of trade performance.

A large number of studies have estimated trade costs and border effects, motivated by seminal contributions like McCallum (1995) and Anderson and van Wincoop (2003, 2004). Research on trade potential was initially inspired by the enlargement of the European Union (EU) in the 1990s. Trade flows of candidate states were assessed relative to the trade patterns of existing EU members to estimate possible gains from expanding the common market (Baldwin, 1994; Gros & Gonciarz, 1996; Nilsson, 2000; Papazoglou et al., 2006). Since then, the literature has expanded to cover single nations (India: Kumar & Prabhakar, 2017; Ireland: Brulhart & Kelly, 1999; Kazakhstan: Nurseiit, 2014; Pakistan: Atif et al., 2017) and groups of countries (Arab states: Salim et al., 2011; ASEAN: Chen et al., 2017; CIS: Shepotylo, 2013). However, only a few studies have used trade data at the subnational level to conduct a similar analysis (see, for instance, Tochkov, 2018).

The paper makes several important contributions to the literature. We examine trade potential and efficiency issues at the regional level of a large emerging economy, whereas the overwhelming majority of previous research on the topic is dedicated to trade between nations. Moreover, we apply a stochastic frontier approach to the gravity model of trade, a relatively new empirical strategy that has been gaining traction in recent years (Stack et al., 2018). Comparisons between cross-border and intranational trade enable us to address integration issues relevant for efforts to lower regional disparities prevalent in China. Existing studies on market integration within China have estimated border effects between regions (Xu & Fan, 2012; Zhao & Ni, 2018), while we go a step further and test also for inefficiencies in domestic trade. Lastly, we draw attention to Northeast China, a region facing unique challenges that might be mitigated through expanding trade flows, especially with neighboring countries, given that current levels seem remarkably low.

The structure of the paper is as follows. The next section introduces the methodologies used in the empirical investigation and discusses various estimation strategies. Section 3 presents the data and shows the descriptive statistics. Section 4 reports the results of the estimation, while Section 5 summarizes the findings and draws conclusions.

2. Methodology

The gravity model represents a well-known empirical approach to analyzing trade, which defines the exchange of goods between two countries as a function of their economic size and the physical distance between them. In line with the seminal contribution by Anderson and van Wincoop

(2003), the basic specification can be expressed as:

$$x_{ij} = \frac{y_i y_j}{y^W} \left(\frac{t_{ij}}{P_i P_j} \right)^{1-\sigma} \tag{1}$$

where the left-hand side variable denotes the exports of country i to country j, y is the country's nominal income, y^w is the world income, t denotes the bilateral trade costs, and σ is the elasticity of substitution, which is typically assumed to range between 5 and 10. The price levels (P) represent the average trade barriers of a country vis-à-vis all of its trading partners. Accordingly, impediments to trade have an adverse effect and play a key role in this relationship.

After linearizing Eq. (1) and decomposing trade costs, the gravity equation transforms into:

$$\ln x_{ij} = \ln(y_i y_j) - \ln y^W + (1-\sigma)\ln b(1-\delta_{ij}) + (1-\sigma)\rho \ln d_{ij} + (1-\sigma)\tau_{ij} - (1-\sigma)\ln P_i - (1-\sigma)\ln P_j \tag{2}$$

where δ_{ij} represents the home bias in the form of a categorical variable that takes the value of one for intranational trade, and zero otherwise; d_{ij} is bilateral distance, while τ_{ij} includes all remaining trade costs. Variable b represents the border effect, i.e. the cost of bringing goods across a border, which, broadly defined, may include tariff and non-tariff barriers.

We adapt Eq. (2) to the needs of our empirical investigation by specifying the stochastic model as follows:

$$\ln\left(\frac{x_{ijt}}{y_{it} y_{jt}} \right) = \beta_0 + \alpha_i \lambda_i + \alpha_j \lambda_j + \eta_t + \beta_1 RU + \beta_2 NK + \beta_3 SK + \beta_4 JP + \beta_5 ROW + \varepsilon_{ijt} \tag{3}$$

The dependent variable is the log of exports that have been adjusted for the size of the two involved trade partners to avoid endogeneity issues. The exporter and importer fixed effects (λ_i, λ_j) account for all variables that are typically included in the gravity model, such as bilateral distance, contiguity, common language, shared history, landlockedness, etc. Year-fixed effects (η_t) control for factors that vary across time but not across countries. We are primarily interested in the coefficients of the five dummy variables that take the value of 1 for trade between the three Northeast provinces and their main trading partners (Russia, North Korea, South Korea, Japan, and the Rest of the World), and zero otherwise. The zero in this case represents the control group, defined as the trade between the Northeast and the rest of China. Accordingly, these coefficients represent the border effects measuring bilateral trade costs relative to those involved in intranational trade. The estimates of the border effects can be converted into ad-valorem tariff equivalents to facilitate their interpretation.

Santos Silva and Tenreyro (2006) argue that OLS estimates of log-linearized models like the one in Eq. (3) produce biased estimates in the presence of heteroscedasticity. Although fixed effects control for heteroscedasticity, the log-linearization could still generate misleading results. Santos Silva and Tenreyro (2006) suggest instead estimating the gravity equation in levels (rather than logs) by employing Pseudo Poisson Maximum Likelihood (PPML). This technique has since become a standard approach in the gravity literature to deal with the problem of heteroscedasticity (see, for instance, Lateef et al., 2018).[1] Accordingly, we test the robustness of our results by using both the traditional OLS specification with fixed effects and PPML to estimate Eq. (3).

To gain more detailed insights about the border effects for each country/province and their changes over time, we employ a different methodology developed by Novy (2013), which allows the calculation (rather than estimation) of bilateral trade costs in a given year. In line with this approach, trade costs between countries i and j can be expressed as:

$$\tau_{ij} = \left(\frac{x_{ii}x_{jj}}{x_{ij}x_{ji}}\right)^{1/(2(\sigma-1))} - 1 \tag{4}$$

Eq. (4) uses a similar logic as the border effect variables in Eq. (3), calculating the ratio of intranational trade in each country to cross-border trade between them. The key benefit is obtaining a measure of bilateral trade costs for a given year and pair of trade partners. At the same time, the computation of intranational trade for various countries presents a challenge, discussed in the next section.

In the second step of the analysis, we explore how impediments to trade affect performance relative to the trade potential. In particular, we estimate the extent of trade efficiency using a gravity model incorporated into a stochastic frontier framework. The basic idea of the stochastic frontier approach, first developed by Aigner et al. (1977), is to generate a frontier that envelopes the data. Observations on the frontier are defined as efficient because they correspond to the maximum output produced with a given set of inputs. Any distance from the frontier is thus treated as inefficiency. In other words, the frontier serves as the benchmark for evaluating the performance of a given entity. This methodology was first applied to the gravity model of trade by Kalirajan (1999) and the literature has grown in recent years (see, for instance, recent contributions, such as Kumar & Prabhakar, 2017; Stack et al., 2018). The stochastic frontier specification is given by:

$$\begin{gathered} \ln\left(\frac{x_{ijt}}{y_{it}y_{jt}}\right) = \beta_0 + \eta_t + \sum_{k=1}^{m}\beta_k Z_{ijk} + \varepsilon_{ijt} \\ \varepsilon_{ijt} = \upsilon_{ijt} - u_{ijt} \end{gathered} \tag{5}$$

where Z_{ijk} stands for the usual gravity variables such as bilateral distance, contiguity, home bias, and landlockedness. The model looks similar to Eq. (3), except that the focus is now on the error term, which is decomposed into υ_{ijt} and u_{ijt}. The former is a random disturbance with a normal distribution and a mean of zero, while the latter is a non-negative one-sided error term assumed to have a half-normal distribution.[2] u_{ijt} measures the deviation of size-adjusted bilateral trade from its potential level at the frontier and is thus interpreted as the extent of trade inefficiency for a given pair of trade partners. Eq. (5) is estimated using Maximum Likelihood (ML) and a generalized likelihood ratio (LR) test is employed with the null hypothesis of no one-sided error term, which under the half-normal distribution assumption amounts to testing whether the variance of u_{ijt} is zero (Kumbhakar et al., 2015). If we fail to reject the null hypothesis, the model in Eq. (5) basically reverts to the specification in Eq. (3). Furthermore, we also estimate a version of Eq. (5) with country/region-pair fixed effects to control for heterogeneity. For this purpose, we apply the "true fixed-effects" panel stochastic frontier model by Greene (2005), which manages to separate time-invariant heterogeneity from time-varying inefficiency.

3. Data

Bilateral trade flows of the three Northeast provinces are reported by the Customs Administration of China for the period 1992-2018.[3] The sample of 30 major trading partners of Northeast China consists mostly of countries in East and Southeast Asia, Western Europe, and North America. They account for more than 80% of exports and imports of the region as well as for China as a whole. Bilateral distance is measured as the great-circle distance in kilometers between the largest agglomerations of each trade partner.

In addition to foreign trading partners, we also include the rest of China as an entity that excludes the Northeast in terms of GDP and international trade. Following the literature, we calculate the region's trade with the rest of China as the gross provincial value of goods production net of consumption and total gross exports to foreign countries.[4] In other words, trade with the

Table 1. Descriptive statistics of trade flows (million USD).

	Heilongjiang		Liaoning		Jilin	
	Exports	Imports	Exports	Imports	Exports	Imports
Russia	73,642	129,497	13,388	20,504	5,860	2,502
	(40.9)	(63.4)	(1.7)	(2.7)	(9.6)	(1.4)
North Korea	3,194	159	17,332	10,568	5,020	3,171
	(1.8)	(0.1)	(2.1)	(1.4)	(8.2)	(1.8)
South Korea	7,713	3,141	75,671	60,253	5,778	3,009
	(4.3)	(1.5)	(9.3)	(8.0)	(9.5)	(1.7)
Japan	6,586	4,870	171,589	98,196	6,410	22,892
	(3.7)	(2.4)	(21.2)	(13.0)	(10.5)	(13.1)
Rest of Asia	20,161	4,124	130,624	32,695	7,813	3,922
	(11.2)	(2.0)	(16.1)	(4.3)	(12.8)	(2.3)
North America	13,519	13,107	99,966	52,513	6,106	6,010
	(7.5)	(6.4)	(12.3)	(7.0)	(10.0)	(3.4)
Europe	14,469	11,289	90,986	97,299	9,104	90,432
	(8.1)	(5.5)	(11.2)	(12.9)	(14.9)	(51.8)
Rest of world	6.136	10,078	24,858	75,953	2,939	6,271
	(3.4)	(4.9)	(3.1)	(10.1)	(4.8)	(3.6)
Total	179,944	204,332	810,980	754,350	60,982	174,601

Note: Cumulative trade flows over the period 1992-2018 (in the case of Jilin: 2006-2018). Share (%) of total cumulative trade in parenthesis.

rest of China is defined as the value of goods that have been produced though not consumed in the province or exported to other countries. For this reason, we designate these flows as intranational rather than intraregional trade and use them as the control group in the estimation of border effects in Eq. (3) and in the numerator of Eq. (4). For the foreign trading partners, intranational trade is computed as the difference between the gross value of goods production and total exports. Finding data on gross output for the 30 nations is a challenge. For more than half of the sample, the corresponding values are obtained from the OECD's Structural Analysis (STAN) database. For the remaining countries (mostly developing or emerging economies), we use the Industrial Production Index reported by the IMF and compute the gross value of output in the base year as the sum of the gross domestic product of the relevant sectors (agriculture, mining, manufacturing, construction) and the imports of intermediate goods and raw materials.[5]

The descriptive statistics on trade flows of the three provinces in Table 1 show that Liaoning ranks at the top in Northeast China with cumulative exports exceeding $800 billion and imports over $750 billion for the years 1992-2018. The province is located along the coast and has major port facilities, allowing it to maintain active trade with nearby South Korea and Japan, which account for more than 30% of exports and 20% of imports. Landlocked Heilongjiang is highly dependent on trade with Russia with which it shares a long border. The northern neighbor accounts for more than 40% of Heilongjiang's exports and 63% of imports. Russia, North and South Korea, and Japan absorb each approximately 10% of Jilin's exports but imports come primarily from Europe (52%) and Japan (13%).

4. Results

4.1. Border effects

The first objective is to examine the barriers to trade between Northeast China and its main trading partners. The estimates of various gravity specifications in Table 2 are all statistically significant and the standard control variables have the expected signs across models. Distance has a negative effect and its magnitude is close to unity. Contiguity boosts trade, while landlockedness impairs it. The dummy variables denoting trade costs carry a negative sign, indicating the presence of a home bias, i.e. cross-border trade is lower than trade with the rest of China. North

Table 2. Gravity model estimates.

	Fixed Effects OLS			PPML		
	(1)	(2)	(3)	(1)	(2)	(3)
RU	−0.769	−3.103	−1.819	−2.133	−4.114	−3.386
	(0.267)	(0.263)	(0.149)	(0.165)	(0.162)	(0.173)
NK	−0.788	−0.845	−1.646	−1.307	−1.327	−0.265
	(0.263)	(0.264)	(0.153)	(0.162)	(0.163)	(0.173)
SK	−1.623	−1.772	−2.794	−3.434	−3.500	−3.543
	(0.321)	(0.323)	(0.165)	(0.195)	(0.199)	(0.173)
JP	−2.016	−2.167	−2.849	−3.548	−3.604	−4.327
	(0.317)	(0.292)	(0.161)	(0.195)	(0.195)	(0.173)
ROW	−1.475	−1.629	−1.297	−2.494	−2.533	−4.913
	(0.294)	(0.292)	(0.149)	(0.181)	(0.180)	(0.173)
$DIST_{ij}$	−0.981	−0.979		−0.827	−0.839	
	(0.056)	(0.056)		(0.034)	(0.034)	
$CONT_{ij}$	1.873	1.724		0.934	0.875	
	(0.204)	(0.205)		(0.125)	(0.126)	
$LANDL_{ij}$	−0.493	−0.498		−0.280	−0.286	
	(0.055)	(0.055)		(0.034)	(0.034)	
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
EX/IM FE	No	No	Yes	No	No	Yes
Obs.	3988	3988	3988	4087	4087	4087
R^2	0.38	0.38	0.73	0.67	0.68	0.76

Note: Standard errors are in parentheses. All coefficients are significant at the 1% level. Models (1) and (2) use a different distance measure for Russia. Dependent variable is the size-adjusted trade for the PPML and its natural log in the case of OLS.

Korea emerges as the neighbor with the lowest barriers to trade, followed by Russia. South Korea is ranked third, while Japan exhibits the highest border effects in Northeast Asia.

We test the robustness of the results for Russia by using the distance to Moscow in Model (1) and to Vladivostok in Model (2). Given the geographical size of Russia and the importance of proximity for the cross-border exchange of goods, we explore the possibility that the trade barriers with the Russian Far East, the federal district across the border from Northeast China, might be lower than with far-away Moscow. Our results show the opposite with border effects increasing dramatically in magnitude when the shorter distance to Vladivostok is included. Accordingly, the border between the Russian and Chinese frontier regions represents a major impairment to trade that leads to inefficiencies and missed potential.

In Model (3) of Table 2, we include the full set of fixed effects to control for unobserved cross-sectional variation. In general, this leads to an increase in the coefficients' magnitude, meaning that in the first two specifications we have underestimated the barriers to trade by omitting some important factors. Furthermore, the estimation method seems to matter as well. Compared to the fixed-effects OLS, PPML produces markedly larger coefficients for the border effects without changing the ranking among trading partners. Given PPML's desirable properties regarding heteroscedasticity and zero trade flows, we proceed by converting its estimates into ad-valorem tariff equivalents for a more intuitive interpretation.

The resulting numbers in the left panel of Table 3 confirm the patterns we detected earlier and augment the analysis by providing additional estimates for two subperiods of equal length. North Korea's border effects amount to an add-valorem tariff equivalent of just 5% above the intranational level in China for the entire sample period. In the years after 2005, the number turns even negative (albeit not statistically significant), indicating that it was less costly for the Northeast to trade with North Korea than with the rest of China. Barriers to trade with Russia amount to around 76%, although there seems to have been a modest decline after the mid-2000s. By contrast, South Korea and Japan have witnessed a rise in border costs from already high levels, exceeding 100% in the case of Japan.

To gain additional insights, we turn to the index by Novy (2013) that allows us to calculate the tariff equivalent of the border effect for every year and trade partner of each of the three

Table 3. Border effects (tariff equivalents in %).

	Gravity estimation			Novy (2013) index		
	(1992-2018)	(1992-2004)	(2005-2018)	Heilongjiang	Liaoning	Jilin
RU	75.83	78.60	65.67	73.87	170.74	197.53
				(14.93)	(84.19)	(21.87)
NK	4.52	11.87	−0.83	311.34	129.96	144.11
				(126.19)	(25.78)	(47.37)
SK	80.49	72.17	78.31	228.20	138.80	230.11
				(38.25)	(21.99)	(10.06)
JP	105.68	103.30	106.16	255.20	132.21	201.85
				(19.70)	(14.64)	(10.15)
ROW	126.79	124.79	107.06	281.30	143.15	239.71
				(31.51)	(18.22)	(24.93)

Note: Border effects for the gravity specification are based on the PPML estimation with time, exporter, and importer fixed effects. Elasticity of substitution is set at 7. Novy (2013) index is an average over the sample period with standard deviation in parenthesis.

Northeast provinces. A summary of the findings in the right panel of Table 3 reveals big differences in the magnitude of the border effects when compared to the gravity estimates. This is not surprising, given that Novy's (2013) index is not the result of an empirical estimation, despite its strong theoretical foundations. At the same time, the general patterns in Table 3 concur broadly with the conclusions from the gravity specification. North Korea still has the lowest barriers to trade but only Liaoning and Jilin benefit from it, while Heilongjiang faces tariff equivalents of more than 300%. The two provinces share a border with North Korea, which is one of its major channels for cross-border exchange of goods left, especially in the face of Western sanction that China has also agreed to implement. Furthermore, both provinces have strong cultural ties, and thus lower transaction costs, with their impoverished neighbor thanks, in part, to the presence of significant Korean minorities in the border regions.

With regards to Russia, Heilongjiang records by far the lowest trade hurdles in the Northeast, which are close in magnitude to the gravity estimate (75%). The province shares a long border with Russia and has a network of direct transportation links (e.g., a branch of the Trans-Siberian Railway), along with historical and cultural ties (Hsu & Soong, 2014). Liaoning's trade costs with Japan and South Korea are significantly lower because its ports facilitate the transportation of goods to both island nations.[6] By contrast, Heilongjiang and Jilin are landlocked, compelling them to use either Russian or Liaoning ports. Accordingly, their tariff equivalents for South Korea and Japan are of very similar magnitude.

Figure 1 illustrates the changes in border effects across time. Trade costs with Japan have been increasing continuously since the early 2000s, after an initial decline over the 1990s. The barriers to trade with North Korea have remained relatively constant for Liaoning and Jilin, although some upticks in the last years of the sample period indicate that the tightening of sanctions might have had an impact. In the case of Russia, there is a single drop in border effects in 2014, which might have been caused by the Ukrainian crisis and the subsequent Western sanctions that compelled the Russian government to seek closer ties with China. However, this appears to have been a rather short-lived effect as trade costs returned to their previous levels relatively quickly, except in Liaoning where they have remained lower than in earlier decades. Moreover, Liaoning experienced a slower increase in trade hurdles with South Korea since the 2000s, compared to Heilongjiang where the surge has been dramatic.

4.2. Trade efficiency

Now that we have explored the trade barriers for Northeast China we turn our attention to the aspect of trade efficiency. For this purpose, we use again the gravity specification but in a

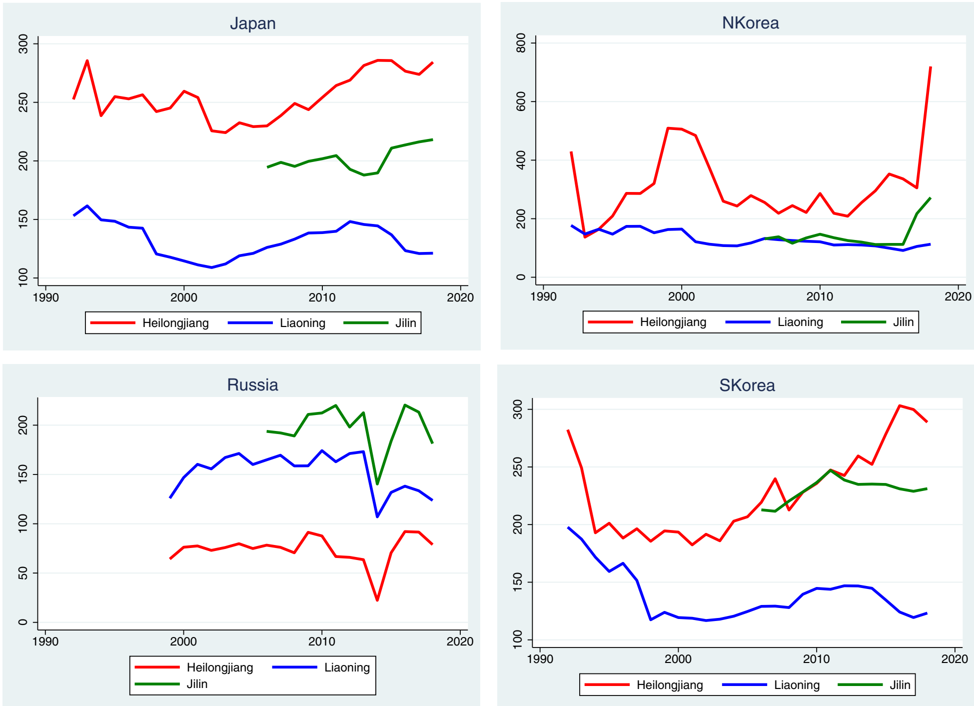

Figure 1. Border effects of Northeast China with its main trade partners (tariff equivalents in %

Table 4. Stochastic frontier estimates.

	(1)	(2)	(3)
HOME	1.384	1.409	1.151
	(0.189)	(0.192)	(0.263)
$DIST_{ij}$	−0.997	−1.006	
	(0.025)	(0.024)	
$CONT_{ij}$	1.747	1.695	
	(0.087)	(0.084)	
$LANDL_{ij}$	−0.951	−1.021	
	(0.046)	(0.045)	
Trade efficiency	0.40	0.54	0.44
	(0.20)	(0.19)	(0.29)
Time FE	Yes	Yes	Yes
EX/IM FE	No	No	Yes
Obs.	5608	5608	5608
LR test	p<.000	$p < 0.000$	

Note: Standard errors are in parentheses. All coefficients are significant at the 1% level. The distribution of the inefficiency term is half-normal in Model (1) and (3) and exponential in Model (2). Dependent variable is the log of the size-adjusted trade.

stochastic frontier framework, which establishes the benchmark for the efficiency evaluation. The results in Table 4 are in line with the estimates in Table 2 and have the expected signs. The home bias variable, which replaced the border effect dummies is positive and significant, confirming again that intranational trade is larger than trade with foreign countries. The likelihood-ratio (LR) test rejects the null hypothesis that the variance of the inefficiency term is zero, which strengthens the case of adopting the stochastic frontier approach. We further test the robustness of the results by assuming two different distributions for the inefficiency term. In Model (1) and (3) we impose a half-normal distribution, while in Model (2) we opt for the exponential distribution. The estimates are largely robust across the three specifications, although the average trade

Table 5. Trade efficiency (in %).

	Period			Region			
	(1992-2018)	(1992-2004)	(2005-2018)	Heilongjiang	Liaoning	Jilin	China
RU	43.02	40.89	44.53	38.03	38.54	34.80	56.44
	(24.73)	(24.21)	(25.09)	(24.81)	(21.18)	(25.61)	(22.83)
NK	40.54	37.39	42.69	17.16	47.28	59.96	46.58
	(30.90)	(32.54)	(29.70)	(29.37)	(25.80)	(31.50)	(19.01)
SK	54.49	65.67	46.57	48.09	50.05	51.09	74.17
	(29.73)	(28.71)	(27.99)	(29.19)	(27.98)	(22.60)	(20.50)
JP	54.79	69.02	44.69	48.03	49.36	56.62	66.09
	(26.39)	(28.10)	(19.72)	(28.13)	(28.80)	(20.38)	(20.60)
CHN	48.83	57.79	43.15	55.09	39.40	59.22	
	(25.08)	(29.92)	(19.82)	(20.06)	(29.05)	(19.96)	
ROW	45.41	39.74	49.29	31.56	41.28	51.27	59.91
	(28.65)	(28.99)	(27.76)	(26.20)	(27.48)	(28.04)	(24.69)

Note: Trade efficiency is calculated from the estimates of the stochastic frontier estimation with the full set of fixed effects (Model (3) in Table 3). The reported numbers are averages over the sample period with standard deviation in parenthesis.

efficiency in Model (2) is somewhat higher. Similarly, we include various combinations of the fixed effects, with Model (3) containing fixed effects not only for the years but also for each exporter-importer pair in the sample.

The average efficiency across the entire sample is between 40% and 54%, depending on the model, suggesting that there is a large amount of trade inefficiency in China's Northeast. It is important to note that we include China's trade with the 30 trading partners of the Northeast in the sample because this allows us to gauge the efficiency of the region's trade against that for the rest of China. The summary of the results by period and by region is presented in Table 5. Overall, trade with Russia and North Korea exhibits the highest levels of inefficiency, ranging between 37% and 45%. South Korea and Japan have a much better record that reaches levels of almost 70% in the first subperiod. Over the past decade, Russia and North Korea experienced a slight improvement, while Japan and South Korea seem to have suffered a major decline. By comparison, trade with the remaining trading partners of China's Northeast (ROW) has surged from 40% to 50%, indicating that over time the region has expanded its relations beyond Northeast Asia. The most interesting result with regards to regional integration is for intranational trade. Our findings suggest that despite the presence of home bias, trade between the Northeast and the rest of China is far from its potential, with inefficiencies actually higher than for some neighboring countries.

The estimates for the individual entities in the right panel of Table 5 show that the rest of China has achieved significantly higher levels of efficiency in international trade than the Northeast region. The only exception is North Korea where Liaoning, and especially Jilin, are closer to the stochastic frontier than China. In general, Jilin appears to be the most efficient of all three provinces with levels between 50% and 60%. Heilongjiang, on the other hand, is least able to take advantage of its trade potential, with levels below 50%. This is particularly surprising for trade with Russia, meaning that despite the relatively low border effects with its northern neighbor, the region has not been able to shorten the distance to the frontier. At the same time, Heilongjiang is better integrated via trade with the rest of China than with the rest of the world. Liaoning exhibits its highest levels of trade efficiency with North Korea, South Korea, and Japan. In that sense, the province is better integrated with its neighbors than with the rest of China.

The high standard deviations of the estimates in Table 5 suggest that efficiency levels vary over time. To explore this aspect in more detail, we illustrate the results for each year and main trading partner of the three provinces and China in Figure 2. Liaoning exhibits some very clear patterns of efficiency deterioration over the sample period, which are mirrored in the rising border effects over the same periods (see Figure 1). In the 1990s, the province was close to the

Figure 2. Trade efficiency of Northeast China and the rest of China (in %)

frontier, with inefficiency levels of less than 20% in some years. The decline begins in the early 2000s and, with the exception of a reversal in the case of North Korea, continues well into the 2010s before stabilizing. Jilin demonstrates very similar tendencies, other than the spike in the case of North Korea being larger. Heilongjiang has a more varied experience that was masked by the averages in Table 5. The decline in trade efficiency vis-à-vis Japan and South Korea is comparable to the other two provinces. The extreme inefficiency with North Korea remains rather constant with the exception of the dramatic spike over the period 2009-2014. The most interesting aspect is the trade efficiency with regards to Russia, which started from levels as low as 10% and rose gradually to reach 100% on the frontier in 2007. Since then it has been steadily deteriorating despite a spike around 2014, returning at the end of the sample period to the same 10% levels where it started in the early 1990s. China reveals a similar pattern in its trade with Russia, with efficiency improving since the early 2000s but reversing after the frontier was reached in 2014. Unlike the spikes seen in provinces vis-à-vis North Korea, China has actually seen a sustained improvement in its trade efficiency with its impoverished neighbor since 2010.

Lastly, we turn our attention to the bottom graph in Figure 2, representing intranational trade. In the early 1990s, the Northeast and the rest of China achieved almost complete efficiency but since then levels have declined, dipping below 20% in recent years. Jilin is somewhat different from the other two provinces in that it was on the efficiency frontier in 2010 before a steeper decline sets in. This pattern probably reflects the industrial decline of Northeast China and, in more recent years, its fostering of closer trade ties with other countries.

5. Conclusion

Northeast China has struggled on the path to reform and modernization, compelling the central government to implement various revitalization strategies in an attempt to boost the region's economy. On the one hand, the Northeast has a favorable geographical location at the crossroads of Northeast Asia. On the other hand, it appears that the region has not been able to tap its potential for trade with its immediate neighbors. This paper aims at exploring trade flows and their potential for cross-border integration in the belief that trade has not been fully utilized to help the Northeast's economy. For this purpose, two major aspects were investigated. The first focused on quantifying and evaluating the barriers to trade with the Northeast's major trading partners. The second assessed the levels of inefficiency in the region's trade.

The results were set in relation to the trade between the Northeast and the rest of China In order to gauge the extent of intranational vs. cross-border integration. Our findings indicate a clear home bias with the costs of foreign trade being significantly higher than within China. The ad-valorem tariff equivalents ranged between 76% for Russia and more than 100% for Japan for the sample as a whole. However, there was significant variability across regions, with Heilongjiang exhibiting the lowest barriers to trade with Russia, and Liaoning with Japan and Korea. North Korea emerges as one the trading partners with lowest border effects. The analysis across time also reveals that trade hurdles have been on the rise across all three provinces vis-à-vis Japan and South Korea.

Trade efficiency is estimated within a stochastic frontier framework, allowing us to define a benchmark for assessing the trade performance of Northeast China. The rest of China is used again for comparison purposes, given that it achieves the highest levels of efficiency in the sample. Overall, our results show that trade efficiency of the region is low, averaging between 40% and 55%. Levels vary across provinces, with Jilin ranked at the top and Heilongjiang at the bottom. We were also able to identify tendencies over time. Trade efficiency vis-à-vis Japan and South Korea has declined, reflecting the rising border effects described earlier. Trade with North Korea experienced a spike in the Northeast's performance in the early 2010 but in other periods it was low or deteriorating. Heilongjiang has achieved a major improvement in its efficiency of trade with Russia, which, in part, is associated with its relatively low border effects. Last but not least, trade with the rest of China has become gradually highly inefficient, suggesting that the integration between the Northeast and the rest of the country is not living up to its potential.

In conclusion, the results seem to confirm the view that Northeast China is not using its capacity to trade efficiently, not only with neighboring countries but with the rest of China as well. The Chinese government should continue expanding and improving cross-border infrastructure in the Northeast. Red tape and onerous bureaucratic procedures should be reduced to speed up the processing of goods at the border and optimize transportation logistics. Moreover, enlarging port capacity along the coast of Liaoning and upgrading the transportation links between the ports and the inland in the Northeast would certainly boost the efficiency of trade.

The Belt and Road Initiative has encouraged local authorities to discuss cross-border cooperation with neighboring countries and to implement various measures that would facilitate the transportation of goods across the region. At the same time, formidable challenges remain, not least because trade efficiency depends on both sides of the deal to achieve results. North Korea remains a fickle trading partner, while Russia focuses on national mega-projects at the expense of measures that would improve trade and regional integration at the local level in the border regions. Moreover, the recent closure of the borders in Northeast Asia amid the coronavirus pandemic will certainly contribute to a surge in border effects and trade inefficiency.

Notes

1. An added advantage of PPML is that it can handle zero trade flows, unlike the log-linearized model.
2. For robustness purposes, we also estimate a specification where the error term follows an exponential distribution.
3. Data on trade by country for Jilin is available only from 2006 onwards.
4. The gross value of output includes agriculture, mining and quarrying, manufacturing, and construction but excludes any services. GDP is not suitable in this case because it is based on value added and contains services.
5. For North Korea, we use total GDP as a proxy due to lack of data. Moreover, when calculating the border effects using Eq. (4), we drop Hong Kong and Singapore from the sample because their values for intranational trade are negative, which is expected given their small size and their position as entrepot and major trading hub, respectively.
6. South Korea is for all trading purposes a quasi-island due to the lack of transportation links across the north of the Korean peninsula.

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Disclosure statement

No potential competing interest was reported by the authors.

Data sharing statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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