Discussion Paper Series

RIEB

Kobe University

DP2019-19

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Xiao FENG
Yongjin WANG
Laixun ZHAO

Revised October 15, 2019

Research Institute for Economics and Business Administration
Kobe University
2-1 Rokkodai, Nada, Kobe 657-8501 JAPAN

Infrastructure Bottlenecks and Dual-Channel Exporters

By

Xiao Feng[a] Yongjin Wang[a] & Laixun Zhao[b]

[a] Nankai University [b]Kobe University

This version: Oct. 15, 2019

Abstract: This paper investigates how infrastructure bottlenecks affect the firm's export mode. We find that under such bottlenecks, the most efficient firms become the so-called "dual-channel exporters", which export only a fraction of their products directly, with the remaining products exported via intermediaries. Using linked annual survey of industrial production and transaction-level customs datasets in China, we document that a significant share of firms are dual-channel exporters, which are more productive than the direct and indirect exporters. Our quantitative model suggests that the elimination of exporting capacity constraint arising from infrastructure bottlenecks leads to substantial aggregate productivity growth via improved resource reallocation.

Keywords: Infrastructure Bottlenecks; Dual-Channel Exporters; Productivity; Capacity Constraint; Resource Misallocation

JEL Classification: F10, O18

Please address correspondence to:

Feng: School of Economics, Nankai University, Tianjin 300071, China, fengxiaonku@163.com;

Wang (Co-corresponding author): School of Economics, Nankai University, Tianjin 300071, China, yjw@nankai.edu.cn;

Zhao (Co-Corresponding author): Research Institute for Economics & Business, Kobe University, Kobe 657-8501, Japan, Zhao@rieb.kobe-u.ac.jp.

1. Introduction

Infrastructure bottlenecks, including the lack of large carriers, ports, railways and highways, warehouses and quarantine testing facilities etc., are among the largest inhibitors of exports in many developing countries, like Bangladesh, China and India.[1] As such, firms in these countries face severe export capacity constraint. Also, intermediaries play a very important role for exports in developing economies (Olney, 2015). However, the existing literature on infrastructure has focused exclusively on trade flows and trade volume, and how infrastructure bottlenecks impact the mode of exports is largely unknown. The issue is important because *how* firms export can impact their profits and gains from trade at the national level via several channels. On the cost side, exporting through intermediaries requires a commission (sometimes as high as 10% of profits) and often kickbacks to avoid additional red tape,[2] though some fixed exporting cost may be saved; on the benefit side, it also prevents a firm from reaping the benefits of direct exporting, such as, building brand reputation, learning via exporting and feedbacks (Bai et al., 2017).

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[1] For Bangladesh, see https://www.export.gov/article?id=Bangladesh-Architectural-Construction-and-Engineering-Services, and India, see https://www.dailypioneer.com/2017/columnists/removing-local-old-bottlenecks.html. For China, the lack of ocean carriers is one of the most severe constraints facing exporters. For example, exporting automobiles requires roll-on ships, but there is not even one roll-on ship in China, and hence foreign intermediaries are needed. See http://www.grand-freight.com/cn/news/view_114.html. In addition, there is a lack of port infrastructure: https://www.dailypioneer.com/2017/columnists/removing-local-old-bottlenecks.html.

Furthermore, infrastructure bottlenecks also exist in the U.S., arguably the most developed country. Take crude oil export as an example, only the LOOP (Louisiana Offshore Oil Port) can fully load VLCCs (very large crude carriers) as things stand today, while the rest of America's oil export terminals can only partially load a VLCC. https://www.eia.gov/todayinenergy/detail.php?id=36232. Similarly, grain exports in the U.S. are also severely limited by such bottlenecks, which are costing farmers, shippers and ultimately consumers millions of dollars a year. https://www.seattletimes.com/nation-world/us-grain-exports-limited-by-infrastructure-bottlenecks/.

[2] https://www.chinalawblog.com/2010/06/avoiding_kickbacks_in_china_just_say_no.html.

The present paper moves forward in this direction by examining the impacts of infrastructure bottlenecks on trade, resource misallocation, aggregate productivity and gains from trade. We find that infrastructure bottlenecks can have important implications which are quite different from those of tariff and non-tariff barriers.

Specifically, we first develop a model of heterogeneous firms whose exporting capacities are constrained due to infrastructure bottlenecks, and show theoretically that exporters can be categorized into three types according to productivity: the least productive ones become *indirect exporters* which export through intermediaries, the most productive ones export a fraction of their products by themselves and the remaining part through intermediaries, thus becoming "*dual-channel exporters*", and those with intermediate productivity are *direct exporters* which export on their own.

Intuitively, in the presence of infrastructure bottlenecks, such as inadequate port capacity and unavailability of large carriers, each firm's exporting quantity is severely constrained. Further, the quality of "soft infrastructure", including red tape associated with export license, export rebate approval, customs clearing, etc., can exacerbate the negative impact of the aforementioned "hard infrastructure". For instance, in China, railway carriage and shipping space are controlled by a few State-owned enterprises (SOEs) and managed inefficiently,[3] leading to bribes and corruption and resulting in "double bottlenecks" (i.e., in addition to hard infrastructure bottlenecks) for firms and businesses. Often, the most efficient firms (which usually export larger quantities) have

[3] For Railway carriage, see: http://finance.sina.com.cn/chanjing/gsnews/20141214/141121072032.shtml. For ocean Shipping, see : http://m.sohu.com/n/408865254/?_once_=000022_shareback_wechatfriends_bdbo

to export through intermediaries above a certain limit, and thus they become the so called "dual-channel exporters (DCX hereafter)."

Next, by linking the Chinese customs trade and annual survey of industrial firms' datasets, we document that a significant share of Chinese exporters are DCX firms. Further, consistent with our theoretical model, in our empirical analysis we find that the DCX firms are larger and more productive than the direct and indirect exporters, and that firms in regions with poorer port infrastructure are more likely to become DCX.

Lastly, for the counter-factual analysis, our quantitative exercises suggest that removing these capacity constraints can generate substantial gains in export volume and productivity for developing countries like China, as resources are reallocated from the less productive firms to the most productive ones.

Our study is closely related to the literature on the role of infrastructure in international trade. Duranton et al. (2014) and Duranton (2015) estimate the effects of interstate highways on regional trade in the U.S. and Colombia, respectively. Martincus and Blyde (2013) exploit a natural experiment involving destruction of key infrastructure due to earthquakes in Chile, and find a significant negative impact of the diminished infrastructure on firm exports. While these studies focus on the impact on trade flows, we are interested in how infrastructure bottlenecks shape the firm's choice of export mode and resource misallocation. In this sense, our study is related to Tombe and Zhu (2018), who examine the impact of China's internal labor migration on resource allocation and productivity growth.

This paper also complements the studies that emphasize the role of intermediaries in facilitating trade (Bernard et al., 2010; Ahn et al., 2011; Bernard et al., 2015). Most recently, Bernard et al. (2018) study carry-along trade (CAT): a significant share of the exports from the Belgian manufacturers are not produced by the firm. They use demand complementarities to rationalize their empirical findings. In contrast, the present paper uncovers a novel export mode, i.e., the *dual-channel exporters*, which export some products directly and others through intermediaries.

Finally, the paper is related to the literature on misallocations in developing countries (e.g., Hsieh and Klenow (2009) and Restuccia and Rogerson (2008)). In particular, our paper is closely related to Khandelwal, Schott and Wei (2013), who examine Chinese textile and clothing exports before and after the elimination of export quotas, and find that export quotas are managed inefficiently in China in the sense that the most productive firms are prevented from entering the export market, substantially reducing aggregate productivity. Our results further suggest that infrastructure bottlenecks constrain a firm's ability to export directly, leading to resource misallocation by shifting away resources from the most efficient exporters to the less productive ones and causing welfare losses.

The remaining part of the paper proceeds as follows. Section 2 sets up a theoretical framework; Section 3 describes the data and classification of export modes; Section 4 reports some stylized facts regarding export mode, and conducts empirical analysis and robustness checks; Section 5 extends the theoretical model outlined in Section 2 and undertakes counterfactual exercises; and finally, Section 6 concludes.

2. Model Setup

2.1 Preference

Consumer preferences are represented by the following CES utility function:

$$U = [\int_{\omega\in\Omega} q(\omega)^{\frac{\sigma-1}{\sigma}} d\omega]^{\frac{\sigma}{\sigma-1}}$$

where $q(\omega)$ denotes the consumption for variety ω, and $\sigma > 1$ is the elasticity of substitution between any two varieties. The set Ω measures the mass of available varieties. Utility maximization yields the demand function:

$$q(\omega) = Bp(\omega)^{-\sigma}, B = EP^{\sigma-1} \quad (1)$$

where $P = [\int_{\omega\in\Omega} p(\omega)^{1-\sigma} d\omega]^{\frac{1}{1-\sigma}}$ is the price index, and B measures the real market size. The associated revenue for the producer of variety ω is given as

$$R(\omega) = q(\omega)^{1-1/\sigma} B^{1/\sigma} = Bp(\omega)^{1-\sigma} \quad (2)$$

2.2 Production

The timing for the firms is as follows. In stage 1, a mass of firms M_e enters, pay a fixed entry cost F and then receive information about their innate ability φ, which is assumed to be Pareto distributed with a cumulative probability function of: $G(\varphi) = 1 - (\varphi/b)^{-k};\ \varphi \geq b,\ k > 1$.

In stage 2, given its type, each firm decides whether or not to produce by paying the fixed production cost f_d. Then, if a firm decides to export, it must choose the modes of export: either to export directly by paying the fixed cost f_D, or indirectly by paying the fixed cost $f_I < f_D$, because exporting directly typically entails huge sunk cost for setting up its own logistic systems including warehousing, transportation, packaging, customs clearance, freight and logistics hubs. Both modes require an iceberg trade cost: τw for direct exporting and $\gamma\tau w$ for exporting through intermediaries, where $\gamma > 1$. Here as in Ahn et al. (2011), exporting through intermediaries entails a higher variable cost as the intermediaries incur an additional per-unit cost to aggregate orders across clients and prepare the variety for the foreign market. Also, exporting through intermediaries in imperfectly competitive markets could lead to "double marginalization," whose end result is similar to assuming a higher variable cost.

However, in the presence of infrastructure bottlenecks, a firm may be forced to use intermediaries to export even when it is capable of overcoming the fixed cost associated with direct exporting. This is more so for developing countries whose exporting infrastructure in general and port-infrastructure in particular are inadequate when connecting with foreign countries. The presence of such infrastructure bottlenecks implies not only a higher iceberg type cost, but also an exporting capacity constraint that limits a country's exporting quantity and leads to a convex trade cost. In this sense, infrastructure bottlenecks play a similar role as exporting quotas.

The situation could get worse in the presence of poor *soft infrastructure* when exporting opportunity is not based on efficiency but other considerations. First, as is illustrated in Khandelwal, Schott and Wei (2013), exporting quotas in China are managed by inefficient institutions, e.g., the exporting license allocation is not based on productivity. Second, the allocation of transport opportunities is also managed inefficiently in China.[4] As mentioned in the Introduction, because transportation is a scarce resource and is monopolized either by a few SOEs or directly controlled by the government, only a fraction of the connected firms (through “guanxi”) can transport their products using the railway system and ports, leading to bribes and corruption and resulting in “double bottlenecks”.

Given such “double bottlenecks”, we assume that each firm is endowed with a fixed transportation capacity $\overline{q}$ such that if it exports $q > \overline{q}$, the above-capacity quantity ($q_x - \overline{q}$) must be exported through intermediaries. Hence, $\overline{q}$ can also be interpreted as the inverse of the infrastructure bottleneck: less bottleneck, a higher $\overline{q}$. Then the variable costs of exporting associated with each mode are (see also Table 1):

$$VC_x(\varphi, q_x) = \begin{cases} \frac{w}{\varphi}\gamma\tau q_x & \text{Indirect exporters} \\ \frac{w}{\varphi}\tau q_x & \text{Direct exporters} \\ \frac{w}{\varphi}\tau\overline{q} + \frac{\gamma}{\varphi}w\tau(q_x - \overline{q}) & \text{DCX} \end{cases} \tag{3}$$

where q_x is the quantity of exports that reach the foreign consumers, $\tau > 1$ is the iceberg trade cost of direct export such that for each unit arriving at the foreign country τ units must be shipped, and $\gamma\tau$ is the iceberg trade cost of indirect export.

Table 1. Export mode and trade costs

Export mode	variable cost	Fixed cost
Indirect	$w\gamma\tau$	wf_I
Direct	$w\tau$	wf_D
Dual-channel	$w\tau$ *for* $q \le \overline{q}$; $w\gamma\tau$ *for* $q > \overline{q}$	wf_D

[4] A typical example is railway transport which is monopolized by the Ministry of Railways and has been in a state of shortage for a long time, which creates conditions for corruption. For example, the rent of transporting 100 million tons of coal from Ordos to Tianjin port is 25.5 billion Yuan. The coal dealers go as far as using 20 billion Yuan for bribes (above the regulated rail transport cost) to get the train and transport the coal to Tianjin. As a result, they keep only 5.5 billion as profits. See: http://business.sohu.com/20120611/n345255649.shtml.

Note: $\gamma > 1$ and $f_I < f_D$.

Finally in stage 3, firms choose the quantity to maximize profits, and consumption takes place afterwards. We solve this problem by backward induction.

2.3 Profits

If production is for domestic sales, the profit function can be written as

$$\pi_H(\varphi) = \max_q B^{\frac{1}{\sigma}} q^{1-\frac{1}{\sigma}} - \frac{w}{\varphi} q - wf_d$$

Profit maximization enables us to rewrite:

$$\pi_H(\varphi) = \frac{1}{\sigma} B(\frac{\sigma}{\sigma-1}\frac{w}{\varphi})^{1-\sigma} - wf_d \tag{4a}$$

As usual, there exists a productivity cutoff φ_H^* satisfying $\pi_H(\varphi_H^*) = 0$, such that a firm with productivity below which exits; equivalently,

$$\frac{1}{\sigma} R(\varphi_H^*) = wf_d,\ R(\varphi_H^*) \equiv B(\frac{\sigma}{\sigma-1}\frac{w}{\varphi_H^*})^{1-\sigma}$$

Next, for an indirect exporter, the profit is given by

$$\pi_I(\varphi) = \max_q B^{\frac{1}{\sigma}} q^{1-\frac{1}{\sigma}} - \frac{\gamma w \tau}{\varphi} q - wf_I = \frac{1}{\sigma} B[(\frac{\sigma}{\sigma-1})\frac{\gamma w \tau}{\varphi}]^{1-\sigma} - wf_I \tag{4b}$$

Finally, for a direct exporter, the profit is

$$\pi_D(\varphi) = \max_q B^{\frac{1}{\sigma}} q^{1-\frac{1}{\sigma}} - \frac{w}{\varphi}\tau q - wf_D = \frac{1}{\sigma} B[(\frac{\sigma}{\sigma-1})\frac{w}{\varphi}\tau]^{1-\sigma} - wf_D \tag{4c}$$

2.4 Sorting of firms

2.4.1 Benchmark: no export capacity constraint

We start our analysis from the benchmark of no exporting capacity constraint. A firm chooses whether to export directly or via intermediaries. Then, there exists two productivity cutoffs φ_I^* and φ_D^*, such that firms with $\varphi \in [\varphi_I^*, \varphi_D^*]$ export via intermediaries, while more efficient ones with $\varphi \in [\varphi_D^*, \infty)$ export directly, where

$$\begin{aligned}
&\frac{1}{\sigma}B[(\frac{\sigma}{\sigma-1})\frac{\gamma}{\varphi_I^*}w\tau]^{1-\sigma} = wf_I \\
&\frac{1}{\sigma}B[(\frac{\sigma}{\sigma-1})\frac{w\tau}{\varphi_D^*}]^{1-\sigma}(1-\gamma^{1-\sigma}) = w(f_D - f_I)
\end{aligned} \tag{5}$$

Combing eqs. (4a)-(4c) and (5), we obtain

$$(\frac{\varphi_I^*}{\varphi_H^*})^{\sigma-1} = (\gamma\tau)^{\sigma-1}\frac{f_I}{f_d}, \ (\frac{\varphi_D^*}{\varphi_I^*})^{\sigma-1} = \frac{\frac{f_D}{f_I}-1}{\gamma^{\sigma-1}-1} \tag{6}$$

We assume $\tau^{\sigma-1}\frac{f_I}{f_d} > 1$ and $\frac{f_D}{f_I} > \gamma^{\sigma-1}$; that is, the selling cost is higher in the foreign market than in the domestic market, and the fixed cost is higher for direct exporting than indirect exporting. Then, it is straightforward that the most efficient firms choose to export directly, firms of intermediate productivity export through intermediaries, while firms with lower productivity sell domestically only.

2.4.2 Export capacity constraint

Next, on top of the benchmark, we examine how infrastructure bottlenecks distort a firm's export mode. Due to the infrastructure bottlenecks, each firm can only export directly its own product up to an upper bound $\bar{q}$. Hence, the most efficient firms have to export its above-capacity quantity through intermediaries, and become the "*dual-channel exporters*".

The profit function of a typical DCX firm is given by

$$\pi_{DCX} = \max_{q_2} B^{\frac{1}{\sigma}}(\bar{q}+q_2)^{\frac{\sigma-1}{\sigma}} - \frac{w\gamma\tau}{\varphi}q_2 - \frac{w\tau}{\varphi}\bar{q} - f_D, \ \ s.t. \ q_2 \geq 0 \tag{7}$$

Profit maximization gives:

$$\pi_{DCX} = \frac{1}{\sigma} B(\frac{w\gamma\tau}{\rho\varphi})^{1-\sigma} + \frac{(\gamma-1)w\tau}{\varphi}\overline{q} - f_D \quad (7')$$

The export capacity constraint leads to a "jump" in the firm's marginal cost curve which occurs at the constrained output $\overline{q}$. Specifically, for a firm with productivity φ the marginal cost equals $\frac{w\tau}{\varphi}$ if $q \leq \overline{q}$, and equals $\frac{\gamma w\tau}{\varphi}$ if otherwise.

Figure 1. Output choice of DCX firms

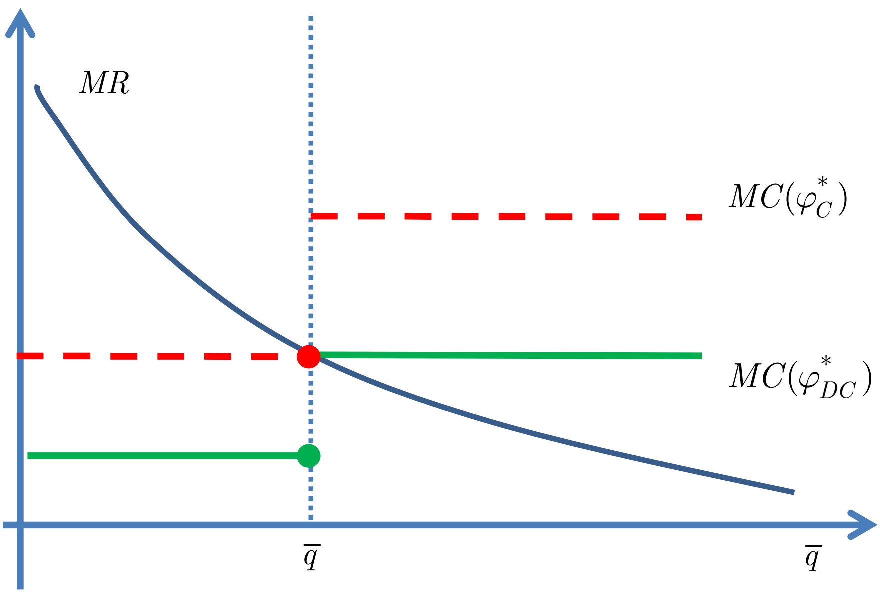


Figure 1 illustrates how the firm decides its optimal export quantity in the presence of the export capacity constraint, in which the horizontal axis represents the firm's output and the vertical axis represents the marginal revenue and marginal cost. There exist two cutoff productivities φ_C^* and φ_{DC}^*, with $\varphi_C^* < \varphi_{DC}^*$, such that the optimal outputs for both the firm with $\varphi = \varphi_C^*$ and $MC(\varphi) = \frac{w\tau}{\varphi}$ and the firm with $\varphi = \varphi_{DC}^*$ and $MC(\varphi) = \frac{\gamma w\tau}{\varphi}$ are just equal to $\overline{q}$, where

$$B(\frac{\rho\varphi_{DC}^*}{w\gamma\tau})^\sigma = \overline{q} \quad \text{and} \quad \varphi_{DC}^* = \gamma\varphi_C^* \tag{8}$$

As a result, firms with productivity $\varphi \in [\varphi_C^*, \varphi_{DC}^*]$ produce $\overline{q}$ and export directly. For those with $\varphi \in [\varphi_{DC}^*, \infty)$, the optimal output is larger than $\overline{q}$ even at the higher marginal cost, so they become DCX.

As is evident, direct exporters exist only if $\varphi_{DC}^* > \varphi_D^*$, satisfying

$$(\frac{\varphi_{DC}^*}{\varphi_D^*})^\sigma = \frac{\overline{q}^*}{\varphi_D^*}, \quad \overline{q}^* \equiv \frac{\tau(1-\gamma^{1-\sigma})\gamma^\sigma}{(\sigma-1)(f_D - f_I)}\overline{q} \tag{9}$$

We restrict parameters such that both the direct exporters and DCX exist. Then we have

Proposition 1 (firm sorting): *The most efficient firms with productivity* $\varphi \in (\varphi_{DC}^*, \infty)$ *are the dual-channel exporters, those with* $\varphi \in (\varphi_D^*, \varphi_{DC}^*)$ *export directly, those with* $\varphi \in (\varphi_I^*, \varphi_D^*)$ *export via intermediaries, and the least productive firms with productivity* $\varphi < \varphi_H^*$ *exit the export market.*

Further, from eq. (8), one sees that φ_{DC}^* is increasing in the export capacity constraint $\overline{q}$. Hence we obtain:

Proposition 2 (share of DCX): *The share of the dual-channel exporters is increasing in the infrastructure bottlenecks.*

2.5 General equilibrium

Free entry requires the fixed entry cost to equal the expected value of entry,

(i) if $\varphi_I^* < \varphi_D^* < \varphi_C^* < \varphi_{DC}^*$, there are three types of exporters: the indirect exporters, direct exporters and DCX, and the free entry condition is given by

$$
\begin{aligned}
F = &\int_{\varphi_H^*}^{\infty} \pi_H(\varphi) dG(\varphi) + \int_{\varphi_I^*}^{\varphi_D^*} \pi_I(\varphi) dG(\varphi) + \int_{\varphi_D^*}^{\varphi_C^*} \pi_D(\varphi) dG(\varphi) \\
&+ \int_{\varphi_C^*}^{\varphi_{DC}^*} \pi_D(\overline{q},\varphi) dG(\varphi) + \int_{\varphi_{DC}^*}^{\infty} \pi_{DC}(\varphi) dG(\varphi)
\end{aligned} \tag{10a}
$$

(ii) if $\varphi_I^* < \varphi_C^* < \varphi_D^* < \varphi_{DC}^*$ or $\varphi_C^* < \varphi_I^* < \varphi_D^* < \varphi_{DC}^*$, again there are three types of exporters with the direct exporters exporting the constrained quantity, and the free entry condition is given by

$$
\begin{aligned}
F = &\int_{\varphi_H^*}^{\infty} \pi_H(\varphi) dG(\varphi) + \int_{\varphi_I^*}^{\varphi_D^*} \pi_I(\varphi) dG(\varphi) \\
&+ \int_{\varphi_D^*}^{\varphi_{DC}^*} \pi_D(\overline{q},\varphi) dG(\varphi) + \int_{\varphi_{DC}^*}^{\infty} \pi_{DC}(\varphi) dG(\varphi)
\end{aligned} \tag{10b}
$$

(iii) if $\varphi_I^* < \varphi_C^* < \varphi_{DC}^* < \varphi_D^*$, $\varphi_C^* < \varphi_I^* < \varphi_{DC}^* < \varphi_D^*$ or $\varphi_C^* < \varphi_{DC}^* < \varphi_I^* < \varphi_D^*$, then there are only two types of exporters: the indirect exporters and DCX, and the free entry condition is given by

$$
F = \int_{\varphi_H^*}^{\infty} \pi_H(\varphi) dG(\varphi) + \int_{\varphi_I^*}^{\varphi_D^*} \pi_I(\varphi) dG(\varphi) + \int_{\varphi_D^*}^{\infty} \pi_{DC}(\varphi) dG(\varphi) \tag{10c}
$$

where the profit functions are specified in eqs. (4a), (4b), (4c) and (7'), respectively, and $\pi_D(\overline{q},\varphi) = B^{\frac{1}{\sigma}} \overline{q}^{\frac{\sigma-1}{\sigma}} - \frac{w\tau}{\varphi}\overline{q} - wf_D$.

3. Data and measurement of variables

3.1 Data sets

We exploit two main datasets to identify the firm's export modes: the Annual Survey of Industrial Firms (ASIF) complied by the National Bureau of Statistics (NBS) of China and the transaction level trade data obtained from China's General Administration of Customs (CGAC).

3.1.1 The production dataset

The ASIF dataset contains production data of Chinese manufacturing firms from 1998 to 2007. All SOEs and "above-scale" non-SOEs with annual sales exceeding RMB 5 million are included in the dataset. Following Cai and Liu (2009), we clean the sample and omit outliers by using the following criteria. First, observations missing key financial variables (such as total assets, net value of fixed assets, sales and gross value of the firm's output and productivity) are excluded. Second, we drop firms with fewer than eight workers as they fall under a different legal regime, following Brandt et al. (2012). Third, observations with exports exceeding total sales or with total asset lower than net value of fixed assets are also dropped. To deal with changes in the Chinese Industry Classification (CIC) codes in 2003, we merge some industries to obtain a consistent classification over the entire sample period as in Brandt et al. (2012).

3.1.2 The transaction level trade data

The second dataset we use is the extremely disaggregated product-level trade transaction data obtained from CGAC. It records a variety of information for each trading firm's product list, including price, quantity and value at the HS 8-digit level. The CGAC dataset also reports if a firm undertakes processing trade or ordinary trade at the transaction level. We exclude processing-trade firms from our analysis, and focus on only the observations of ordinary exporters, as processing firms in China do not need to search for buyers and also receive special treatment on tariffs and customs clearing.

Both the NBS and the CGAC datasets provide firm-level export information, however, the latter only records information on the firm's direct exports, and firms which export through intermediaries report positive export values in the NBS dataset but are not recorded in the CGAC dataset. Combining the NBS and the CGAC datasets together allows us to compute each firm's share of direct export and that through intermediaries. We therefore combine the NBS and the CGAC datasets to identify each firm's export mode (see Section 3.1.3).

Following Yu (2015), we adopt two methods to match the two datasets. First, we identify each firm's Chinese name and year. That is, if a firm has an exact Chinese name in both datasets in a particular year, it should be the same firm. Second, to increase the number of qualified matching firms, we use another matching technique to serve as a supplement; namely, we rely on two other common variables to identify the firms: postal code and the last seven digits of the firm's phone number. As a result, we obtain 310931 matched firms which are about 44.52% of the exporters and account for 81.40% of total export value in the firm-level production data, and they are 61.74% of China's total exports during 2000–2006.

3.1.3 Classification of exporting modes (see Tables 1 and 2)

A firm can export either directly by itself or indirectly through trading companies/intermediaries. We classify a firm as a dual-channel exporter (DCX) if it satisfies the following criteria: first, it reports positive export values in both the NBS and CGAC datasets; second, the value of exports is much larger in the NBS dataset than in the CGAC dataset such that export_custom < export_NBS *($1-\eta$); a firm is classified as an indirect exporter if it reports a positive export in the NBS data but is not documented in the CGAC dataset; a firm is tagged as a direct exporter if it is neither a dual-channel exporter nor an indirect exporter. We have tried alternative values of η, and the results are similar, so we set η=0.1 in the main text.

One might be concerned that the discrepancy between the export values reported in NBS and CGAC is due to measurement errors. To alleviate this concern, we infer the intermediary's export value share of the NBS dataset and compare it with that of the CGAC dataset. More specifically, the intermediary's export value share of the NBS dataset equals

$$(\frac{X_{NBS}-X_{CGAC}^{m}}{X_{CGAC}-X_{CGAC}^{um}})=(\frac{X_{NBS}-X_{CGAC}^{m}}{X_{CGAC}^{tc}+X_{CGAC}^{m}})=28.44\%,$$

where X_{NBS} and X_{CGAC} indicate the total export value computed with the NBS and CGAC datasets, respectively; X_{CGAC}^{m} is the export value of the matched firms in the CGAC dataset, measuring the direct exporter's exporting value in the NBS dataset; X_{CGAC}^{tc} and X_{CGAC}^{um} are the export values of the trading companies and the unmatched manufacturing firms in the CGAC dataset, respectively. Thus, the numerator and the denominator measure respectively the export values of the intermediaries and direct exports in the NBS dataset. This ratio is 28.44%, which is quite close to 26.2%--the number computed using the CGAC dataset.

Table 1. Classification of export modes

Exporting mode	**Definition**
Indirect	export_ NBS >0, export_custom =0
Direct	export_NBS >0, export_custom >0, export_custom >export_NBS *(1-η)
DCX	export_NBS >0, export_custom >0, export_custom <export_NBS *(1-η)

Note: export_NBS and export_custom refer to the export value reported in the NBS and CGAC datasets, respectively.

Table 2. Classification of firms

Firms in the NBS dataset		**Firms in the CGAC dataset**	
unmatched	Indirect exporters		
matched	Direct exporters	Direct exporters	matched
	DCX exporters	DCX exporters	
		Unmatched manufactures	Unmatched, exporting mode unknown
		Trade companies	intermediaries

3.2 TFP estimation

In our baseline regression, we estimate the firm level TFP as in Brandt et al. (2017), who estimate the production function using the ACF approach proposed by Ackerberg et al., (2015). To check the robustness of the results, we also try alternative measures of TFP as proposed by Olley and Pakes (1996) and Levinsohn and Petrin (2003).

4. Evidence

In this section, we examine the data and establish the following stylized facts: (i) exporters in China are more likely to be located in coastal regions; (ii) a significant share of the exporting firms are DCX; (iii) indirect exports account for a significant share of the total exports, and the export volume of the intermediaries is more volatile than that of the direct exporters; (iv) the average productivity of the DCX firms is higher than the direct and indirect exporters; (v) a firm is more likely to become DCX rather than a direct exporter in regions with poorer port infrastructure. Observe that all of these facts are consistent with our theoretical model.

4.1 Distribution of exporters and non-exporters across regions

Table 3 reports the share of firms located in the coastal regions and landlocked regions for the exporters and non-exporters. Our theoretical model implies that the exporters would concentrate in the coastal regions where export capacity is less constrained. From Table 3, it is clear that the distribution of exporting firms is unevenly skewed to the coastal regions, with the share of firms there being 95% for the exporters and 84.23% for the non-exporters during our sample period of 2000-2006.

Table 3. Distribution of exporters across regions

Share	Firms	Landlocked	Coastal
2000-2006	Non-exporters	15.77%	84.23%
	Exporters	**5%**	**95%**
2000-2003	Non-exporters	18.6%	81.4%
	Exporters	**5.66%**	**94.34%**
2004-2006	Non-exporters	13.54%	86.46%
	Exporters	**4.5%**	**95.5%**

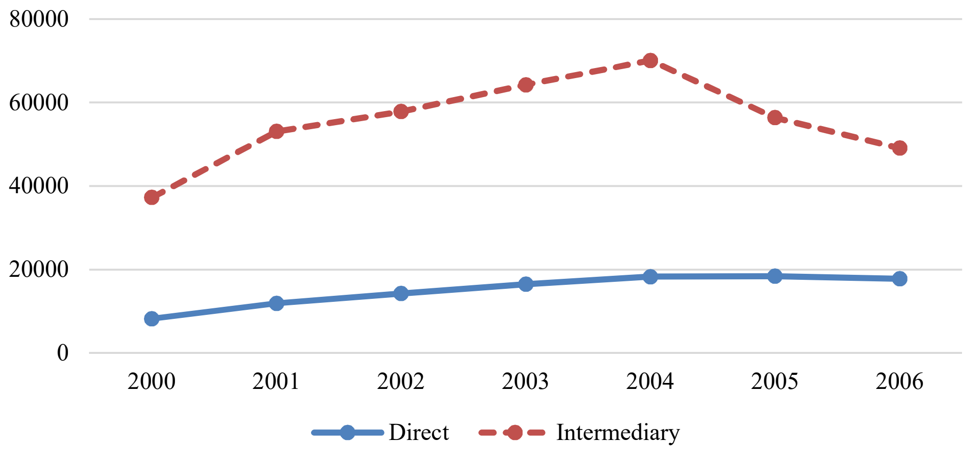
4.2 Share of firms across export modes

To compare with the literature (e.g., Ahn et al., 2011), we split the firms in the customs data into two categories: the direct exporters and trade intermediaries, where the set of intermediary firms is identified based on Chinese characters that have the English-equivalent meaning of “importer”, “exporter”, and/or “trading” in the firm’s name. Note that the above identification methods could underestimate the number of intermediaries, as the carry-along exporters are also tabbed as direct exporters.

Consistent with the literature, trade intermediaries account for 32.07 percent of the total exports for ordinary exporters.

Figure 2 depicts the real exporting value of the continuous ordinary exporters of different exporting modes over 2000-2006. As is evident, the export value of the intermediaries is more volatility than that of the direct exporters, consistent with our "export capacity constraint" hypothesis.

Figure 2. Export value over exporting types

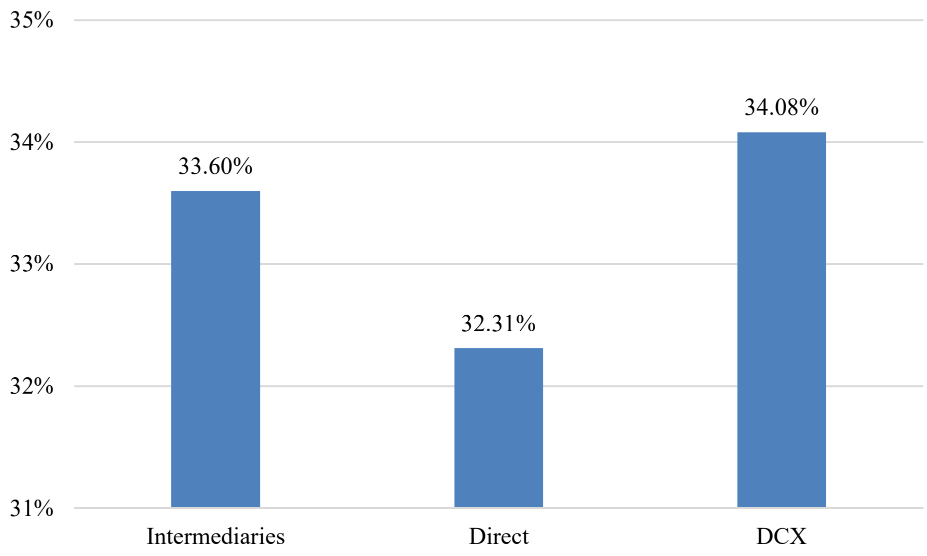


4.3 Share of firms across export modes

We can further classify the exporting firms into three modes according to Tables 1 and 2, and document the share of exporters across modes.[5] As is illustrated in Figure 3, the share of DCX and direct exporters in the custom dataset are 34.08% and 32.31%, respectively. Note that the share of the intermediaries is the lower bound of the indirect exporters, as each intermediary exports for more than one manufacturing firm.

Figure 3. Share of firms across export modes

[5] For the unmatched firms in the custom data, we assume the share of the DCX firms to be identical with the figure in the matched sample.



4.2 Comparing firm productivity across export modes: baseline regression

In this subsection, we regress firm productivity on the export mode dummies, where we choose the indirect exporters as the benchmark and include two dummies in the regression equations, namely, Direct and DCX. As in the first column of Table 4, the DCX firms are 1.6% and 0.9% more efficient than the indirect and direct exporters, respectively. This finding squares well with our theoretical explanation.

Table 4. Firm productivity across export modes: baseline regression

	(1)	(2)	(3)
Direct	0.005***	0.004***	0.005***
	(0.001)	(0.001)	(0.001)
DCX	0.016***	0.014***	0.014***
	(0.001)	(0.001)	(0.001)
Firm controls		Y	Y
Year FE	Y	Y	Y

Industry FE+ Province FE	Y	Y	
*Industry FE*Province FE*			Y
N	258,155	258,155	258,126
R-squared	0.413	0.414	0.429

Note: (1) Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1; (2) η=0.1 in the baseline regression.

4.3 Robustness checks

4.3.1 Redefining DCX

In Table 4, we have used $\eta = 0.1$ and defined firms as DCX if their export value reported in the CGAC dataset is 10% less than that reported in the NBS dataset. To alleviate the concern of measurement error, we now experiment with alternative values of η and the results are shown in Table 5. Specifically, we let $\eta = 0.25$ and $\eta = 0.4$ respectively, and repeat the exercises in Table 4. We find a significantly positive coefficient on the variable DCX, and the magnitude is very close to the estimates in Table 4, thus the finding that DCX firms are more productive than other exporters is robust to measurement errors.

Table 5. Robustness check I: redefining DCX

	(1)	(2)	(3)	(4)	(5)	(6)
	η=0.25			η=0.40		
Direct	0.005***	0.004***	0.005***	0.005***	0.004***	0.005***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
DCX	0.016***	0.014***	0.014***	0.017***	0.015***	0.014***

	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Firm controls		Y	Y		Y	Y
Year FE	Y	Y	Y	Y	Y	Y
Industry FE+ Province FE	Y	Y		Y	Y	
*Industry FE*Province FE*			Y			Y
N	249,677	249,677	249,645	239,863	239,863	239,831
R-squared	0.412	0.412	0.428	0.410	0.411	0.427

Note: Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1.

4.3.2 Alternative measures of TFP

Our second group of robustness checks considers alternative measurements of TFP. First, when computing TFP, we use two different price indices as in Brandt et al. (2017). Specifically, for the period 1998-2003, firms are required to report both the nominal and real prices. We then compute the mean firm-level price changes at each 4-digit industry. Our first price index excludes as outliers the observations for which the price change differs by more than 1/2 of the standard deviation from the mean (about 15–25% of observations), while our second price index excludes outliers that see a price change that is at least one standard deviation away from the mean change (dropping 8% of observations). In columns 1-2 of Table 6, we measure TFP using the ACF method with the second price index. In columns 3-4 and 5-6, we report our estimates using the Olley-Pakes and Levinsohn-Petrin methods, respectively, which are robust to alternative measures of TFP.

Table 6. Robustness check II: alternative measures of TFP

	(1)	(2)	(3)	(4)	(5)	(6)
	tfp_acf2		tfp_op		tfp_lp	
Direct	0.004***	0.005***	0.002*	0.002*	0.006***	0.006***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
DCX	0.014***	0.014***	0.015***	0.015***	0.016***	0.015***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Firm controls	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y
Industry FE+ Province FE	Y		Y		Y	
Industry FE* Province FE		Y		Y		Y
N	258,139	258,109	258,411	258,385	258,582	258,553
R-squared	0.427	0.442	0.547	0.559	0.389	0.405

Note:(1) Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1; (2) η=0.1.

4.3.3 Changing sample periods

In order to fulfill its WTO commitments, China revised the "Foreign Trade Law" and implemented it on July 1, 2004. In this revision, foreign trade management rights were changed from the approval system to the registration system, and the requirements for business qualifications were deleted. Prior to 2004, not all firms were allowed to choose their exporting modes, and in fact some firms had to export through intermediaries. Thus, our results could be obscured by the fact that only some firms had export rights prior to 2004. To alleviate this concern, here we divide our whole sample into two sub-periods, 2000-2003 and 2004-2006, and report the results in Table 7.

As expected, the pattern that DCX firms are significantly more productive than firms of other modes only holds for the period after 2004. Moreover, the productivity gap between DCX and other exporters is even larger during 2004-2006, respectively 9% -13% and 14%-17% more productive than the direct and indirect exporters.

Table 7. Robustness check III: before and after 2004

	(1)	(2)	(3)	(4)	(5)	(6)
	2000-2003			2004-2006		
Direct	0.014***	0.012***	0.011***	0.003**	0.002*	0.003**
	(0.002)	(0.002)	(0.002)	(0.001)	(0.001)	(0.001)
DCX	0.014***	0.012***	0.011***	0.017***	0.014***	0.014***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Firm controls		Y	Y		Y	Y
Year FE	Y	Y	Y	Y	Y	Y
Industry FE+ Province FE	Y	Y		Y	Y	
Industry FE Province FE*			Y			Y
N	108,381	108,381	108,347	149,774	149,772	149,738
R-squared	0.359	0.360	0.379	0.485	0.486	0.502

Note:(1) Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1; (2) η=0.1.

4.4 Port infrastructure and export mode

As is predicted in the theoretical model laid out in section 2, infrastructure bottlenecks are the key in generating the dual-channel exporters. In this subsection, we test whether firms, especially the more productive ones, in regions with poorer/better port infrastructure are more likely to become DCX rather than direct exporters. Specifically, we regress DCX_{it} on measures of port infrastructure, firm productivity and other firm controls. We set $DCX_{it} = 1$ if a firm is a dual-channel exporter, and $DCX_{it} = 0$ for direct exporters.

Note that in the regressions below, we deliberately exclude the indirect exporters from our sample for two reasons: first, as predicted by our theoretical model, only the (potential) direct exporters in the unconstrained model choose to become DCX; second, a better infrastructure has two effects on the firm's export modes. On the one hand, it increases the probability of being a direct exporter, on the other hand it reduces the probability of being an indirect exporter. As a result, if we allow $DCX_{it} = 0$ to include both the direct and indirect exporters, the estimating coefficient of DCX_{it} on the quality of infrastructure bottlenecks would be insignificant as the aforementioned two opposing effects cancel out each other.[6]

4.4.1 Customs and export mode: baseline results

In Table 8, we measure a city's port infrastructure by the indicator variable $custom_{it}$, which equals 1 if the city has a custom and 0 otherwise. We expect cities with

[6] We thank Qing Liu and Yi Lu for suggestions on this point.

customs to have a better port infrastructure because most of these cities are located along the coast, and hence face less geographical trade barriers. We also expect firms in these cities to be more connected with custom officials, suggesting a better soft infrastructure for these firms. As is illustrated in Table 8, firms located in cities with customs are less likely to be DCX, and the more productive firms are more likely to become DCX, consistent with our theoretical predictions.

Table 8. Customs and exporting mode: baseline regression

DCX	(1)	(2)	(3)
Custom	-0.039**	-0.029**	-0.025*
	(0.015)	(0.014)	(0.014)
tfp_acf		0.098***	0.097***
		(0.020)	(0.020)
age		0.024***	0.028***
		(0.005)	(0.005)
lnl		0.063***	0.062***
		(0.003)	(0.004)
soe		0.071***	0.065***
		(0.009)	(0.009)
Year FE	Y	Y	Y
Industry FE+ Province FE	Y	Y	
Industry FE Province FE*			Y

Observations	102,138	93,715	92,815
R-squared	0.093	0.121	0.193

Note:(1) Robust standard errors in parentheses, *** $p<0.01$, ** $p<0.05$, * $p<0.1$; (2) $\eta=0.1$.

4.4.2 Customs and export mode: redefining DCX

As mentioned previously, our estimates might be obscured by measurement errors, for instance, statistical errors could result in a firm reporting less or more export volume in China's CGAC data. To alleviate this concern, we adopt more conservative definitions of DCX, and define a firm as DCX if its export volume reported in the CGAC dataset is either 25% or 40% lower than that reported in the NBS data. As is evident from Table 9, the facts that firms located in cities without customs and the more productive firms are more likely to become DCX still hold for these conservative definitions of DCX.

Table 9. Robustness check I: redefining DCX

DCX	(1)	(2)	(3)	(4)	(5)	(6)
	$\eta=0.25$			$\eta=0.40$		
Custom	-0.042**	-0.031*	-0.026*	-0.042**	-0.030*	-0.025*
	(0.017)	(0.016)	(0.015)	(0.017)	(0.016)	(0.015)
tfp_acf		0.098***	0.098***		0.093***	0.091***
		(0.022)	(0.022)		(0.023)	(0.024)
Firm controls		Y	Y		Y	Y
Year FE	Y	Y	Y	Y	Y	Y

Industry FE+ Province FE	Y	Y		Y	Y	
Industry FE Province FE*			Y			Y
Observations	92,877	85,240	84,283	86,393	79,246	78,260
R-squared	0.117	0.148	0.229	0.128	0.160	0.246

Note: Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1.

4.4.2 Customs and export mode: controlling for confounding factors

The previous results may also be obscured by heterogeneity in export intensity across firms although our theoretical model predicts a constant export intensity under constant elasticity of substitution. For instance, the most efficient firms could coincidently be the firms with lower export intensity when they face higher trade costs. To correct for this bias, in columns (1)-(2) of Table 10, we control for the firm's export intensity, and the baseline results still hold.

An alternative explanation for why the most productive firms choose to become DCX could be that they produce multiple products; that is, the most productive firms produce more non-core products which enable them to export their core products directly, and non-core products through intermediaries. To test this competing hypothesis, we drop the multi-product firms from the regressions in columns (3)-(4) of Table 10, and the impacts of port infrastructure become even stronger in terms of both statistical significance and economic magnitude.

A certain fraction of firms in China serves only the exporting market, and is known as pure exporters, which could also confound our results. We therefore drop the pure exporters, and again find the results robust.

Table 10. Robustness check II: Controlling for confounding factors

DCX	(1)	(2)	(3)	(4)	(5)	(6)
	Control for export intensity		Single product DCX		Drop pure exporters	
Custom	-0.025*	-0.024*	-0.035***	-0.033***	-0.032***	-0.032***
	(0.014)	(0.013)	(0.008)	(0.008)	(0.009)	(0.009)
tfp_acf	0.124***	0.120***	0.054***	0.049***	0.045***	0.041***
	(0.020)	(0.020)	(0.014)	(0.014)	(0.012)	(0.013)
Export_intensity	0.352***	0.362***	0.191***	0.195***	0.189***	0.193***
	(0.019)	(0.020)	(0.016)	(0.019)	(0.015)	(0.017)
Firm controls	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y
Industry FE+ Province FE	Y		Y		Y	
Industry FE Province FE*		Y		Y		Y
Observations	93,715	92,815	57,363	56,349	49,178	48,164
R-squared	0.168	0.236	0.297	0.383	0.284	0.375

Note: Robust standard errors in parentheses, *** $p<0.01$, ** $p<0.05$, * $p<0.1$; (2) $\eta=0.1$.

4.4.3 Customs and export mode: alternative measures of infrastructure

In previous regressions, we have measured port infrastructure with a dummy variable for if a city has a custom. This measure is imperfect because the port infrastructure in cities with customs can also exhibit significant heterogeneity. In Table 11, we use two other variables to measure a city's port infrastructure: one is the days of export customs clearing, and the other is the share of firm staff specialized in handling governmental relationships. These two measures are computed using the Investment Climate Survey 2005 conducted by the World Bank across 120 cities in China. In the questionnaire, firm managers are required to answer the following two questions: "How many days did the export customs clearance take on average in 2004 for your company?" and "Does your company have specialized staff to handle governmental relationships (for example, a government relations office)? If yes, how many staff?" We have the above two measures only in 120 cities, so we use them as robustness checks, and the results are reported in Table 10. Firms located in cities with a longer time of customs clearing or poorer institution quality are more likely to be DCX.

Table 11. Robust Check III: Alternative measures of infrastructure

DCX	(1)	(2)	(3)	(4)	(5)	(6)
Custom_clearance	0.013***	0.010**	0.010*			
	(0.005)	(0.004)	(0.005)			
Employment_gov				17.429***	12.318*	86.790***
				(5.212)	(6.457)	(24.235)

tfp_acf		0.086***	0.090***		0.083***	0.089***
		(0.021)	(0.023)		(0.021)	(0.022)
Firm controls		Y	Y		Y	Y
Year FE	Y	Y	Y	Y	Y	Y
Industry FE+ Province FE	Y	Y		Y	Y	
Industry FE Province FE*			Y			Y
Observations	86,255	79,311	78,450	78,516	72,195	71,292
R-squared	0.098	0.126	0.197	0.122	0.153	0.232

Note:(1) Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1; (2) η=0.1.

4.4.4 Customs and exporting mode: interaction of infrastructure and firm productivity

Here we test whether the most productive firms are more likely to become DCX in cities with better infrastructure, by introducing an interaction term of firm productivity and customs (*Custom *tfp*), and the results are reported in Table 12. The regression coefficient on the interaction term Custom **tfp* is negatively significant, suggesting that in cities with customs the most productive firms are less likely to become DCX as infrastructure bottlenecks are less severe there.

Table 12. Interaction of Infrastructure and Firm Productivity

DCX	(1)	(2)	(3)
*Custom *tfp*	-0.098***	-0.102***	-0.103***

	(0.031)	(0.031)	(0.032)
Custom	0.028	0.042	0.046*
	(0.028)	(0.027)	(0.026)
tfp_acf	0.149***	0.148***	0.146***
	(0.030)	(0.029)	(0.030)
age		0.025***	0.028***
		(0.005)	(0.005)
lnl		0.062***	0.062***
		(0.003)	(0.004)
Soe		0.071***	0.065***
		(0.008)	(0.009)
Year FE	Y	Y	Y
Industry FE+ Province FE	Y	Y	
Industry FE Province FE*			Y
Observations	93,752	93,715	92,815
R-squared	0.094	0.121	0.194

Note: Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1; (2) η=0.1.

5. Quantitative Analysis

This section estimates the quantitative effects of export capacity constraints on export volume and productivity. To this end, we first extend the model laid out in

Section 2 to two countries, the home country 1 and foreign country 2, which can be thought of China and the rest of the world (ROW) respectively.

5.1 Theoretical framework

In each country, there are L_i units of labor, and we normalize the wage and labor supply of country 1 to one. We adopt the standard assumption for country 2 in the sense that there is neither exporting capacity constraint nor trade intermediaries as in Melitz (2003) (see Table 13 for details).

Table 13. Export mode and trade costs

Export mode	Variable cost	Fixed cost
Country 1		
Indirect	$w_1\gamma\tau$	$w_1 f_{12I}$
Direct	$w_1\tau$	$w_1 f_{12D}$
Dual-channel	$w_1\tau$ *for* $q \le \overline{q}$; $w_1\gamma\tau$ *for* $q > \overline{q}$	$w_1 f_{12D}$
Country 2		
Direct	$w_2\tau$	$w_2 f_{21}$

Note: $\gamma > 1$ and $f_{12I} < f_{12D}$.

Denote f_{ii} as the fixed cost of production for country i, f_{ijI} the fixed cost of exporting through intermediaries and f_{ijD} the fixed cost of direct exporting from country i to country j. As before, we assume the iceberg trade cost of exporting directly and indirectly to be $w_i\gamma\tau$ and $w_i\tau$, respectively. To ensure the existence of indirect exporters for country 1, we focus on the case of $\frac{f_{12D}}{f_{12I}} > \gamma^{\sigma-1}$.

Then the productivity cutoffs can be written as

$$
\begin{aligned}
w_2 f_{22} &= \frac{r_{22}(\varphi_{22}^{*})}{\sigma} = \frac{1}{\sigma} B_2 (\frac{w_2}{\rho \varphi_{22}^{*}})^{1-\sigma} \\
w_2 f_{21} &= \frac{r_{21}(\varphi_{21}^{*})}{\sigma} = \frac{1}{\sigma} B_1 (\frac{w_2 \tau}{\rho \varphi_{21}^{*}})^{1-\sigma} \\
w_1 f_{11} &= \frac{r_{11}(\varphi_{11}^{*})}{\sigma} = \frac{1}{\sigma} B_1 (\frac{w_1}{\rho \varphi_{11}^{*}})^{1-\sigma} \\
w_1 f_{12I} &= \frac{r_{12}(\varphi_{12I}^{*})}{\sigma} = \frac{1}{\sigma} B_2 (\frac{w_1 \gamma \tau}{\rho \varphi_{12I}^{*}})^{1-\sigma} \\
w_1 (f_{12D} - f_{12I}) &= \frac{1}{\sigma} B_2 (\frac{w_1 \gamma \tau}{\rho \varphi_{12D}^{*}})^{1-\sigma} (\gamma^{\sigma-1} - 1) \\
\overline{q} &= B_2 (\frac{w_1 \gamma \tau}{\rho \varphi_{12DC}^{*}})^{-\sigma} \\
\varphi_{12DC}^{*} &= \gamma \varphi_{12C}^{*}
\end{aligned}
\tag{11}
$$

where $B_i = w_i L_i P_i^{\sigma-1}, i = 1,2$, and firms with $\varphi \in [\varphi_{12I}^{*}, \varphi_{12D}^{*}]$ export through intermediaries, those with $\varphi \in [\varphi_{12D}^{*}, \varphi_{12C}^{*}]$ export directly, those with $\varphi \in [\varphi_{12C}^{*}, \varphi_{12DC}^{*}]$ export at the constrained output $\overline{q}$, and those with $\varphi \in [\varphi_{12DC}^{*}, \infty)$ become DCX. Evidently, the share of firms exporting at the constrained quantity is increasing in the relative variable cost of indirect exporting, γ .

From eqs. (11), we further obtain

$$
\begin{aligned}
\varphi_{21}^{*} &= \varphi_{11}^{*} \tau (\frac{f_{21}}{f_{11}})^{\frac{1}{\sigma-1}} (\frac{w_2}{w_1})^{\frac{\sigma}{\sigma-1}} \\
\varphi_{12I}^{*} &= \varphi_{22}^{*} \gamma \tau (\frac{f_{12I}}{f_{22}})^{\frac{1}{\sigma-1}} (\frac{w_1}{w_2})^{\frac{\sigma}{\sigma-1}} \\
\varphi_{12D}^{*} &= \varphi_{22}^{*} \tau \left[\frac{f_{12D} - f_{12I}}{(1-\gamma^{1-\sigma}) f_{22}} \right]^{\frac{1}{\sigma-1}} (\frac{w_1}{w_2})^{\frac{\sigma}{\sigma-1}} \\
\varphi_{12C}^{*} &= \varphi_{22}^{*\frac{\sigma-1}{\sigma}} [\frac{\overline{q}}{(\sigma-1) f_{22}}]^{\frac{1}{\sigma}} (\frac{w_1 \tau}{w_2}) \\
\varphi_{12DC}^{*} &= \varphi_{22}^{*\frac{\sigma-1}{\sigma}} [\frac{\overline{q}}{(\sigma-1) f_{22}}]^{\frac{1}{\sigma}} (\frac{w_1 \gamma \tau}{w_2})
\end{aligned}
\tag{12}
$$

Free entry requires the fixed entry cost equal the expected value of entry. The free entry condition for country 2 is standard, given by

$$
w_2 F_2 = \int_{\varphi_{22}^{*}}^{\infty} \pi_{22}(\varphi) dG_2(\varphi) + \int_{\varphi_{21}^{*}}^{\infty} \pi_{21}(\varphi) dG_2(\varphi) \tag{13a}
$$

For country 1,

(i) if $\varphi_{12I}^{*} < \varphi_{12D}^{*} < \varphi_{12C}^{*} < \varphi_{12DC}^{*}$, there are three types of exporters, the indirect exporters, direct exporters and DCX, and the free entry condition is given by

$$\begin{aligned} w_1 F_1 = & \int_{\varphi_{11}^{*}}^{\infty} \pi_{11}(\varphi) dG_1(\varphi) + \int_{\varphi_{12I}^{*}}^{\varphi_{12D}^{*}} \pi_{12I}(\varphi) dG_1(\varphi) + \int_{\varphi_{12D}^{*}}^{\varphi_{12C}^{*}} \pi_{12D}(\varphi) dG_1(\varphi) \\ & + \int_{\varphi_{12C}^{*}}^{\varphi_{12DC}^{*}} \pi_{12D}(\overline{q}, \varphi) dG_1(\varphi) + \int_{\varphi_{12DC}^{*}}^{\infty} \pi_{12DC}(\varphi) dG_1(\varphi) \end{aligned} \tag{13b}$$

(ii) if $\varphi_{12I}^{*} < \varphi_{12C}^{*} < \varphi_{12D}^{*} < \varphi_{12DC}^{*}$ or $\varphi_{12C}^{*} < \varphi_{12I}^{*} < \varphi_{12D}^{*} < \varphi_{12DC}^{*}$, again there are three types of exporters with the direct exporters exporting the constrained quantity, and the free entry condition is given by

$$\begin{aligned} w_1 F_1 = & \int_{\varphi_{11}^{*}}^{\infty} \pi_{11}(\varphi) dG_1(\varphi) + \int_{\varphi_{12I}^{*}}^{\varphi_{12D}^{*}} \pi_{12I}(\varphi) dG_1(\varphi) \\ & + \int_{\varphi_{12D}^{*}}^{\varphi_{12DC}^{*}} \pi_{12D}(\overline{q}, \varphi) dG_1(\varphi) + \int_{\varphi_{12DC}^{*}}^{\infty} \pi_{12DC}(\varphi) dG_1(\varphi) \end{aligned} \tag{13c}$$

(iii) if $\varphi_{12I}^{*} < \varphi_{12C}^{*} < \varphi_{12DC}^{*} < \varphi_{12D}^{*}$, $\varphi_{12C}^{*} < \varphi_{12I}^{*} < \varphi_{12DC}^{*} < \varphi_{12D}^{*}$ or $\varphi_{12C}^{*} < \varphi_{12DC}^{*} < \varphi_{12I}^{*} < \varphi_{12D}^{*}$, then there are only two types of exporters, the indirect exporters and DCX, and the free entry condition is given by

$$w_1 F_1 = \int_{\varphi_{11}^{*}}^{\infty} \pi_{11}(\varphi) dG_1(\varphi) + \int_{\varphi_{12I}^{*}}^{\varphi_{12D}^{*}} \pi_{12I}(\varphi) dG_1(\varphi) + \int_{\varphi_{12D}^{*}}^{\infty} \pi_{12DC}(\varphi) dG_1(\varphi) \tag{13d}$$

where $G_i(\varphi) = 1 - (\varphi / b_i)^{-k}, k > \sigma - 1$ and

$$
\begin{aligned}
&\pi_{22}(\varphi) = \frac{1}{\sigma}B_2(\frac{w_2}{\rho\varphi})^{1-\sigma} - w_2 f_{22}\\
&\pi_{21}(\varphi) = \frac{1}{\sigma}B_1(\frac{w_2\tau}{\rho\varphi})^{1-\sigma} - w_2 f_{21}\\
&\pi_{11}(\varphi) = \frac{1}{\sigma}B_1(\frac{w_1}{\rho\varphi})^{1-\sigma} - w_1 f_{11}\\
&\pi_{12I}(\varphi) = \frac{1}{\sigma}B_2(\frac{w_1\gamma\tau}{\rho\varphi})^{1-\sigma} - w_1 f_{12I}\\
&\pi_{12D}(\varphi) = \frac{1}{\sigma}B_2(\frac{w_1\tau}{\rho\varphi})^{1-\sigma} - w_1 f_{12D}\\
&\pi_{12D}(\overline{q},\varphi) = B_2^{\frac{1}{\sigma}}\overline{q}^{\frac{\sigma-1}{\sigma}} - \frac{w_1\tau}{\varphi}\overline{q} - w_1 f_{12D}\\
&\pi_{12DC}(\varphi) = \max_q B_2^{\frac{1}{\sigma}}(\overline{q}+q)^{\frac{\sigma-1}{\sigma}} - \frac{w_1\gamma\tau}{\varphi}q - \frac{w_1\tau}{\varphi}\overline{q} - w_1 f_{12D}, s.t.\ q \geq 0\\
&\qquad = \frac{1}{\sigma}B_2(\frac{w_1\gamma\tau}{\rho\varphi})^{1-\sigma} + \frac{w_1(\gamma-1)\tau}{\varphi}\overline{q} - w_1 f_{12D}
\end{aligned}
\tag{14}
$$

Overall, we have seven productivity cutoffs to solve: $\{\varphi_{22}^*, \varphi_{21}^*, \varphi_{11}^*, \varphi_{12I}^*, \varphi_{12D}^*, \varphi_{12C}^*, \varphi_{12DC}^*\}$. By eq. (11), we can express φ_{21}^* as functions of φ_{11}^* and w_2, and φ_{12I}^*, φ_{12D}^*, φ_{12C}^* and φ_{12DC}^* as functions of φ_{22}^* and w_2. Consequently, we obtain φ_{11}^* and φ_{22}^* by solving the free entry conditions for the two countries given w_2. Then φ_{21}^*, φ_{12I}^*, φ_{12D}^*, φ_{12C}^* and φ_{12DC}^* can be derived subsequently.

Combing the labor market clearing condition with the free entry condition, we get the number of entrants for each country:

$$
M_i^e = \frac{\sigma-1}{k\sigma}\frac{L_i}{F_i} \tag{15}
$$

By normalizing country 1's wage to one, we can further solve country 2's wage via the trade balance condition:

$$
w_2 L_2 = L_1 \frac{M_2^e\phi_{21}}{M_2^e\phi_{21} + M_1^e} + w_2 L_2 \frac{M_2^e}{M_2^e + M_1^e\phi_{12}} \quad \text{or} \quad w_2 = \frac{L_1\phi_{21}}{L_2\phi_{21} + L_1} + w_2\frac{L_2}{L_2 + L_1\phi_{12}} \tag{16}
$$

where

$$\phi_{21} = \frac{\int_{\varphi_{21}^*}^{\infty} r_{21}(\varphi) dG_2(\varphi)}{\int_{\varphi_{11}^*}^{\infty} r_{11}(\varphi) dG_1(\varphi)} \tag{17a}$$

For ϕ_{12},

(i) if $\varphi_{12I}^* < \varphi_{12D}^* < \varphi_{12C}^* < \varphi_{12DC}^*$,

$$\phi_{12} = \frac{\left[\begin{array}{l} \int_{\varphi_{12I}^*}^{\varphi_{12D}^*} r_{12I}(\varphi) dG_1(\varphi) + \int_{\varphi_{12D}^*}^{\varphi_{12C}^*} r_{12D}(\varphi) dG_1(\varphi) \\ + \int_{\varphi_{12C}^*}^{\varphi_{12DCX}^*} r_{12D}(\varphi_{12C}^*) dG_1(\varphi) + \int_{\varphi_{12DC}^*}^{\infty} r_{12DC}(\varphi) dG_1(\varphi) \end{array}\right]}{\int_{\varphi_{22}^*}^{\infty} r_{22}(\varphi) dG_2(\varphi)} \tag{17b}$$

(ii) if $\varphi_{12I}^* < \varphi_{12C}^* < \varphi_{12D}^* < \varphi_{12DC}^*$ or $\varphi_{12C}^* < \varphi_{12I}^* < \varphi_{12D}^* < \varphi_{12DC}^*$,

$$\phi_{12} = \frac{\left[\int_{\varphi_{12I}^*}^{\varphi_{12D}^*} r_{12I}(\varphi) dG_1(\varphi) + \int_{\varphi_{12D}^*}^{\varphi_{12DC}^*} r_{12D}(\varphi_{12C}^*) dG_1(\varphi) + \int_{\varphi_{12DC}^*}^{\infty} r_{12DC}(\varphi) dG_1(\varphi)\right]}{\int_{\varphi_{22}^*}^{\infty} r_{22}(\varphi) dG_2(\varphi)} \tag{17c}$$

(iii) if $\varphi_{12I}^* < \varphi_{12C}^* < \varphi_{12DC}^* < \varphi_{12D}^*$, $\varphi_{12C}^* < \varphi_{12I}^* < \varphi_{12DC}^* < \varphi_{12D}^*$ or $\varphi_{12C}^* < \varphi_{12DC}^* < \varphi_{12I}^* < \varphi_{12D}^*$,

$$\phi_{12} = \frac{\left[\int_{\varphi_{12I}^*}^{\varphi_{12D}^*} r_{12I}(\varphi) dG_1(\varphi) + \int_{\varphi_{12D}^*}^{\infty} r_{12DCX}(\varphi) dG_1(\varphi)\right]}{\int_{\varphi_{22}^*}^{\infty} r_{22}(\varphi) dG_2(\varphi)} \tag{17d}$$

with $r_{22}(\varphi) = B_2 \left(\frac{w_2}{\rho\varphi}\right)^{1-\sigma}$, $r_{21}(\varphi) = B_1 \left(\frac{w_2 \tau}{\rho\varphi}\right)^{1-\sigma}$, $r_{11}(\varphi) = B_1 \left(\frac{w_1}{\rho\varphi}\right)^{1-\sigma}$,

$r_{12I}(\varphi) = B_2 \left(\frac{w_1 \gamma \tau}{\rho\varphi}\right)^{1-\sigma}$, $r_{12D}(\varphi) = B_2 \left(\frac{w_1 \tau}{\rho\varphi}\right)^{1-\sigma}$ and $r_{12DC}(\varphi) = B_2 \left(\frac{w_1 \gamma \tau}{\rho\varphi}\right)^{1-\sigma}$.

Clearly, ϕ_{12} and ϕ_{21} are only functions of $\{\varphi_{22}^*, \varphi_{21}^*, \varphi_{11}^*, \varphi_{12I}^*, \varphi_{12D}^*, \varphi_{12C}^*, \varphi_{12DC}^*\}$ and w_2.

5.2 Quantification

5.2. 1 Parameters

This subsection quantifies the impacts of export capacity constraints on aggregate productivity, export and gains from trade, using the model laid out in the previous subsection. We normalize the labor of country one to 1, and foreign labor to 4 to match the labor size of China and ROW. Given that ROW affects China only through the aggregate variables, we assume F_i and f_{ii} to be identical across countries, and set $\sigma = 3$, consistent with the estimates in Bernard et al. (2003).

The fixed cost of domestic production can be recovered from the zero-profit cutoff condition: $f_{ii} = \frac{1}{\sigma - 1} l_{\min}$, where we use the 5% lowest firm labor to proxy $l_{\min}$. To identify the entry cost, we use the equilibrium free entry condition

$$F_i = \frac{1}{\sigma - 1}[1 - G(\varphi_{ii}^*)]\{\mathrm{E}[l(\varphi)] - l_{\min}\}$$

In the data, we use the one period survival rate (0.6495) to measure $[1 - G(\varphi_{ii}^*)]$, and the difference between the mean and lowest 5% labor to measure $\mathrm{E}[l(\varphi)] - l_{\min}$. For the productivity distribution, we assume the shape parameter to be $k = 4$, and the lower bound of the productivity distribution to be $b_1 = b_2 = 0.009$.

The fixed cost of indirect exporting can be calculated by combining the share of the exporting firms $\left[\frac{B_2}{B_1}(\gamma\tau)^{1-\sigma}\frac{f_{11}}{f_{12I}}\right]^{\frac{k}{\sigma-1}}$ and the export-domestic sales ratio of the indirect exporters $\frac{B_2}{B_1}(\gamma\tau)^{1-\sigma}$, from which we obtain $f_{12I} = 0.7316$.

A key parameter is γ, the relative iceberg trade cost of indirect to direct exporting, which contains two components: one is the "explicit" commission rate which ranges over 0.5%-5% in the observed contract (Bai et al., 2017);[7] the other part is the "implicit" cost associated with bribery and kickbacks. Although we do not observe both components, the latter one seems to be more important in practice. Because of the strict control of railway and ocean shipping, transportation has been in a state of chronic shortage, which creates environments for corruption. For instance, in the notorious corruption case of Zhijun Liu who is the former Minister of Railways of China, the coal dealers would spend 20 of 25.5 billion yuan as bribes to get "guanxi" (see footnote 4). In another bribery case of Shanghai Wansheng International Freight Agency co., LTD, the total kickbacks amount to 0.4242 million yuan associated with sales of 4.1081 million yuan (including taxes).[8]

In the former case, the firm spends more than 78% of its gross profits to get the train; while in the latter case the firm spends more than 10% of its total revenue to break through the infrastructure bottlenecks. Thus, in our counterfactual exercises, we try alternative values of γ ranging from 1.01 to 1.1.

Having obtained f_{12I} and γ, we can compute the fixed cost of direct exporting from the share of indirect exporters which equals $1-\left(\gamma^{\sigma-1}-1\right)^{\frac{k}{\sigma-1}}(\frac{f_{12D}}{f_{12I}}-1)^{\frac{k}{1-\sigma}}$, giving f_{12D} (see Table 14).

Table 14. Model parameters

Parameter	Definition	Value	Identification
L_1	Labor force in country 1	1	normalization

[7] https://zhidao.baidu.com/question/309184569441265564.html
[8] http://www.cicn.com.cn/zggsb/2015-06/10/cms72533article.shtml

L_2	Labor force in ROW	4	Relative labor size of ROW to China
σ	Elasticity of substitution	3	
f_{11}, f_{22}	Fixed cost of production	0.6931	Lowest 5% of Labor
f_{12I}	Fixed cost of indirect exporting	0.7316	fraction of exporters
f_{12D}, f_{21}	Fixed cost of direct exporting	0.7497-0.9202	Fraction of indirect exporters
F_1, F_2	Entry cost	0.5385	Fraction of firm producing
$\gamma - 1$	Commission rate of the intermediary	0.01-0.1	
b_1, b_2	Lower bound of the productivity draw	0.009	Lower bound of TFP
k	Pareto shape parameter	4	

We calibrate τ and $\bar{q}$ to match the export intensity of the indirect exporters and the share of DCX firms. As is illustrated in Table 15 the discrepancy between the model and data is reasonably small.

Table 15. Data and model moments

	Data	Model
Indirect intensity	0.3934	0.3934
Share of DCX in exporters	0.3408	0.3408

5.2. 2 Counterfactuals

Table 16 reports the loss of productivity and gains from trade due to exporting capacity constraint. In panel A, we assume wage is fully adjustable, while in panel B we assume it is fixed. The latter scenario can be thought of as the short-run effects or the case with a homogeneous good sector to pin down the wage.

As is evident, when $\gamma = 1.1$, eliminating the exporting capacity constraint leads to 2.00%-2.44% gains in aggregate productivity and 7.94%-10.74% in total exports, respectively.

Table 16: Counterfactuals

γ	τ	$\bar{q}$	**Δ%gains from trade**	**Δ%tfp**	**Δ%Export**
Panel A: flexible wage					
1.01	1.9333	0.0273	-5.90%	-1.08%	-2.26%
1.02	1.9171	0.0273	-6.76%	-1.20%	-2.76%
1.03	1.9014	0.0272	-7.60%	-1.30%	-3.30%
1.04	1.8859	0.0272	-8.50%	-1.42%	-3.88%
1.05	1.8708	0.0271	-9.34%	-1.52%	-4.51%
1.06	1.8561	0.0271	-10.17%	-1.62%	-5.11%
1.07	1.8416	0.0271	-11.00%	-1.72%	-5.76%
1.08	1.8275	0.0270	-11.86%	-1.82%	-6.47%
1.09	1.8136	0.0270	-12.69%	-1.91%	-7.19%
1.1	1.8000	0.0269	-13.51%	-2.00%	-7.94%
Panel B: fixed wage					
1.01	1.9297	0.0273	-5.90%	-1.13%	-2.57%
1.02	1.9104	0.0274	-6.76%	-1.28%	-3.36%
1.03	1.8912	0.0274	-7.60%	-1.43%	-4.20%
1.04	1.8724	0.0274	-8.50%	-1.59%	-5.08%
1.05	1.8538	0.0274	-9.34%	-1.74%	-5.96%
1.06	1.8359	0.0274	-10.17%	-1.88%	-6.85%
1.07	1.818	0.0274	-11.00%	-2.02%	-7.79%
1.08	1.8007	0.0274	-11.86%	-2.17%	-8.74%
1.09	1.7834	0.0274	-12.69%	-2.31%	-9.73%
1.1	1.7667	0.0274	-13.51%	-2.44%	-10.74%

Note: Δ% represents percentage change of the variable in interest under exporting capacity constraints.

6. Conclusions

How firms export matters not only for their own profits but also for a country's aggregate resource allocation, productivity and gains from trade. In this paper, we have examined how infrastructure bottlenecks distort the firm's choice of export mode through an augmented heterogeneous firm model. Specifically, our theoretical model predicts that when a firm's exporting capacity is constrained by infrastructure bottlenecks, the most productive firms have to export through intermediaries and become the so-called dual-channel exporters. With linked annual survey of industrial production and transaction level customs datasets in China, we document that a significant share of firms are DCX. Further, DCX firms are more productive compared with direct and indirect exporters, and in line with our theoretical model, this phenomenon is more salient in the landlocked provinces of China.

The contribution of the present paper is twofold: first, we have uncovered a novel export mode, namely the dual-channel exporters, and thus complement the works emphasizing the role of intermediaries in facilitating international trade; second, we demonstrate both theoretically and empirically that the presence of dual-channel exporters can be attributed, at least partly, to the exporting capacity constrained due to poor exporting infrastructures. Our quantitative exercises suggest infrastructure bottlenecks can substantially reduce total exports and the aggregate productivity by shifting resources from the most productive dual-channel exporters to the least productive firms.

***Acknowledgement**: We are grateful to Wei Jin, Qing Liu, Zhiyuan Li, Yi Lu, Guobing Shen, Yongqin Wang, Hongsong Zhang, Xiaodong Zhu as well as seminar participants at Nankai, Fudan, and the institute of the China and World Economy. Wang acknowledges the financial support of the National Natural Science Foundation of China Grant No. 71573141, and Zhao is grateful to the support of JSPS grant No. 19H01484.*

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Appendix: Estimation

Outer loop: Compute the optimal τ and $\overline{q}$ to minimize

$$M = m_1^{\ 2} + m_2^{\ 2}, \ \ m_1 = \widehat{\iota_I} - \iota_I, m_2 = \widehat{s}_{DCX} - s_{DCX},$$

where $\iota_I = \frac{B_2}{B_1}\left(\gamma\tau\right)^{1-\sigma}$ and $\widehat{\iota_I}$ are export-domestic sales ratio of the indirect exporters, and $s_{DCX} = \left(\frac{\varphi^*_{12DC}}{\varphi^*_{12I}}\right)^{-k} = \left(\frac{(\sigma - 1)f_{12I}\varphi_{12I}}{\gamma\tau\overline{q}}\right)^{\frac{k}{\sigma}}$ and $\widehat{s}_{DCX}$ are the share of the dual channel exporters computed from the model and data, respectively.

Inner loop: Given τ and $\overline{q}$, we first compute $\{\varphi^*_{11}, \varphi^*_{22}, w_2\}$ by solving the free entry and labor market clearing condition, then we compute $B_i = w_i L_i P_i^{\sigma-1}, i = 1,2$, the price index, the social welfare $\frac{w_i}{P_i}$ and the weighted productivity,

$$\tilde{\varphi} = \frac{1}{1 - G(\varphi^*_{11})}\left[\begin{array}{l}\int_{\varphi^*_{11}}^{\varphi^*_{12I}} \varphi \frac{r_{11}(\varphi)}{R} dG_1(\varphi) + \int_{\varphi^*_{12I}}^{\varphi^*_{12D}} \varphi \frac{r_{12I}(\varphi)}{R} dG_1(\varphi) + \int_{\varphi^*_{12D}}^{\varphi^*_{12C}} \varphi \frac{r_{12D}(\varphi)}{R} dG_1(\varphi) \\ + \int_{\varphi^*_{12C}}^{\varphi^*_{12DCX}} \varphi \frac{r_{12D}(\varphi^*_{12C})}{R} dG_1(\varphi) + \int_{\varphi^*_{12DCX}}^{\infty} \varphi \frac{r_{12DCX}(\varphi)}{R} dG_1(\varphi)\end{array}\right]$$

And the export volume:

$$X_1 = M_1^e \left[\begin{array}{l}\int_{\varphi^*_{12I}}^{\varphi^*_{12D}} r_{12I}(\varphi) dG_1(\varphi) + \int_{\varphi^*_{12D}}^{\varphi^*_{12C}} r_{12D}(\varphi) dG_1(\varphi) + \int_{\varphi^*_{12C}}^{\varphi^*_{12DCX}} r_{12D}(\varphi^*_{12C}) dG_1(\varphi) \\ + \int_{\varphi^*_{12DCX}}^{\infty} r_{12DCX}(\varphi) dG_1(\varphi)\end{array}\right]$$

where $M_1^e = \frac{\sigma - 1}{k\sigma}\frac{L_1}{F_1}$.