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Export Capacity Constraints and Distortions

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Abstract: We investigate how export capacity constraints (ECCs) affect resource misallocation and aggregate productivity by distorting the firm's export mode. Using unique datasets in China, we first document a number of observed patterns for the so-called "dual-channel exporters", which export only a fraction of their products directly with the rest via intermediaries. We show that introducing capacity constraints reconciles the theory with the observed patterns in the data. Our quantitative exercise suggests that removal of the ECCs leads to gains of 2.27% in aggregate productivity, 4.97% in total exports and 0.37% in national welfare.

Keywords: Dual-channel exporters; capacity constraint; distortion; resource misallocation

JEL Classification: F10, O18

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Introduction

"*Identification of bottlenecks and barriers is critical, and understanding of how they affect potential traders is an area where Aid for Trade can make a large contribution*."

Anne O. Krueger (2011)

A common phenomenon in developing countries is the prevalence of export capacity constraints (ECCs hereafter), due to the lack of large carriers, ports, railways and highways, warehouses and quarantine testing facilities, etc.[1] Perhaps surprisingly, export constraints even exist in the U.S., arguably the most advanced country,[2] especially during the COVID-19 pandemic. In 2021, the shortage of containers has quadrupled prices on maritime trade routes for several months.[3] Meanwhile, the number of ocean-going vessels waiting to enter Los Angeles and Long Beach, the busiest ports in the world, has repeatedly hit new records. The freight slowdown and port gridlock have led to heavy disruption in the global supply chain.[4]

Despite these urgencies, how ECCs distort the mode of exporting is largely unknown. The issue is important because *how* firms export can impact the gains from trade and national welfare via resource reallocation.

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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.

[2] In oil shipping, 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/.

3 https://www.ft.com/content/40d23da5-c321-4b56-8ec7-551573a7a485.

4 https://ihsmarkit.com/research-analysis/global-supply-chains-face-heavy-disruption-amid-freight-slowdown-Dec20.html.

The present paper represents an attempt in this direction. To begin with, we first uncover a novel export mode, namely the "dual-channel exporters" (DCXs hereafter), which export some products directly and the rest via intermediaries, by using linked annual survey data of industrial production from the Chinese National Bureau of Statistics and transaction level customs data in China. There exist a number of clear patterns observable in the data, which are difficult to resolve even in a heterogeneous firm model with multiple products and multiple destinations, but consistent with our model where the firms' export capacities are constrained.

Second, to establish the causal link between capacity constraints and export modes, we exploit China's "Integration of Free Trade Zone and Port (IFTZP)" policy pilot implemented in 8 coastal cities as a quasi-experiment and examine its impact on the firms' exporting modes. We find that by providing firms with larger warehousing and more efficient customs clearance, this policy has significantly alleviated the exporters' capacity constraints and in turn facilitated direct export participation.

We then show theoretically that in the presence of ECCs, *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, due to factors such as inadequate port capacity and unavailability of large carriers, each firm's export quantity is severely constrained, and the constraints hurt more productive firms more. Further, the quality of "soft infrastructure", including red tape associated with export license/export rebate approval/customs clearing, and corruption involved 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,[5] 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 to export through intermediaries above a certain limit, and thus they become the so called DCXs, a stylized example of that is Geely Automobile, which as one of China's largest automobile exporters, must resort to intermediaries in order to get the roll-on-roll-off ship space.[6]

Finally, for the counter-factual analysis, our quantitative exercises suggest that eliminating the ECCs such as improving port infrastructure or institutional quality allows firms to reap the benefits of direct exporting, from which more productive firms benefit more, and in turn this generates substantial gains in export volume, productivity and welfare, as resources are reallocated from the less productive firms to the most productive ones. Specifically, removal of the ECCs leads to gains of 2.27% in aggregate

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[5] 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.

[6] https://www.autonews.com/article/20050517/REG/505170703/china-car-export-ambitions-hurt-by-ship-shortage.

productivity, 4.97% in total exports, and 0.37% in national welfare (which is roughly equal to 1/5 of those coming from trade liberalization).

The present paper makes novel contributions in a number of aspects. First, it is related to the recent literature on relaxing the assumption of constant marginal cost (MC) (See e.g., Vannoorenberghe, 2012; Blum et al., 2013; Soderbery, 2014; Ahn and McQuoid, 2017; Antràs et al., 2021), which shows that increasing MC causes a natural substitutability between domestic sales and exports. In contrast in this paper, trade distortion and resource reallocation are caused by export-specific capacity constraints.

Second, the paper is closely related to misallocations in developing countries (e.g., Restuccia and Rogerson, 2008; Hsieh and Klenow, 2009). In particular, Khandelwal et al. (2013) examine Chinese textile and clothing export, and find that export quotas are managed inefficiently in the sense that the most productive firms are prevented from entering the export market. Also, some scholars examine how firm-level frictions can dampen or even reverse a country's gains from trade (Ho, 2010; Costa-Scottini, 2018; Bai et al., 2019; Berthou et al., 2020). Our results further suggest that capacity constraint limits 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.

Third, this paper contributes to the studies that emphasize the role of intermediaries in facilitating trade (Bernard et al., 2010; Ahn et al., 2011; Bernard et al., 2015; Bai et al., 2017). In particular, Bernard et al. (2018) use demand complementarities to rationalize carry-along trade: a significant share of the exports from the Belgian manufacturers are not produced by the firms themselves. In contrast, we uncover a novel export mode, i.e., the *dual-channel exporters*.

Finally, the paper speaks to the literature exploring the impact of infrastructure on 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) examine the destruction of key infrastructure due to earthquakes in Chile, and find a significant negative impact on firm exports. Ishikawa and Tarui (2018) analyze the backhauling problem in shipping. While these studies focus on the impact on trade flows, we are interested in how capacity constraint and other infrastructure bottlenecks shape the firm's choice of export mode and resource misallocation.

2. Data and Measurement of Variables

2.1 Data sets

We exploit two main datasets to identify firms' export modes: the production-based, 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).

2.1.1 The production dataset

The ASIF dataset (henceforth *production dataset*) contains production data of Chinese manufacturing firms from 1998 to 2007, in which all SOEs and "above-scale" non-SOEs with annual sales exceeding RMB 5 million are included. Following Cai et al. (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 category. 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).

2.1.2 The transaction level trade data

The second dataset is the product-level trade transaction data from China's General Administration of Customs (henceforth *trade dataset*). It records a variety of information for each trading firm's product list, including price, quantity and value at the HS 8-digit level. We exclude processing-trade firms from our baseline 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, and thus they are much less subject to the influence of ECCs.

Finally, matching the above two datasets following the approach in Yu (2015) (see Appendix A), 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.

2.1.3 Classification of exporting modes

The definition of DCX is crucial for both the empirical analysis and the theoretical model. In practice, direct export means that a firm sends its invoice directly, maintains close contacts with customers and undertakes its own marketing and sales. Sales through a foreign branch are also direct exports. On the other hand, indirect export means a firm sells its products to a trade intermediary in its own country, who then exports. Specifically, it is the intermediary that coordinates the shipping logistics, organizes payment and arranges marketing for export. The crucial difference between direct and indirect exporting is that direct exporters have to grapple with and overcome identifying a market to penetrate, finding customers, navigating foreign market regulations, dealing with customs, understanding tax implications, conducting due diligence, managing foreign exchange risks, delivering goods—just to name a few.

We define DCX by comparing the firm-level export values observed in the production dataset and the trade dataset. A firm can export either directly by itself or indirectly through trading companies/intermediaries, which can be divided into three subsamples according to export modes. Specifically, a firm is classified as a DCX if it satisfies two criteria: first, it reports positive export values in the two datasets; second, the value of exports is much larger in the production dataset than in the trade dataset, i.e., *export in trade dataset* $<$ *export in production dataset* $\times(1-\eta)$, where $\eta<1$ is a parameter indicating measurement error. A firm is classified as an indirect exporter if it reports a positive export value in the production dataset but is not documented in the trade dataset; and a firm is tagged as a direct exporter if it is neither a DCX nor an indirect exporter (see Table 1). We set η=0.10 in the main text, and have tried alternative values, such as η=0, or more restricted definitions of η=0.25, 0.40. Further, since the total export volume reported in the trade dataset (exclude intermediaries) is 1.84% higher than that in the production dataset, we also set η=-0.0184. As shown in Appendix F, all the conclusions (both empirical and quantitative) are similar.

Table 1. Classification of export modes

Exporting mode	Definition
Indirect	export in production dataset >0, export in trade dataset =0
Direct	export in production dataset >0, export in trade dataset >0, export in trade dataset > export in production dataset $\times$ (1-η)
DCX	export in production dataset >0, export in trade dataset >0, export in trade dataset < export in production dataset $\times$ (1-η)

A natural concern is that the discrepancy of export values in the two datasets could arise from measurement error, η, as the self-reported export value in the production dataset is measured using factory price, while that in the trade dataset is F.O.B., which is higher than the factory price. If it were this case, one should always observe the following pattern: *export in production dataset* < *export in trade dataset*; then, our standard of classification would provide a lower bound for the share of DCXs even when setting $\eta = 0$. However, in the actual dataset, we observe that about 25.38% of the firms exhibits *export in production dataset* > *export in trade dataset*, which can hardly be resolved via the discrepancy between F.O.B and the factory price.

2.2 Total factor productivity estimation

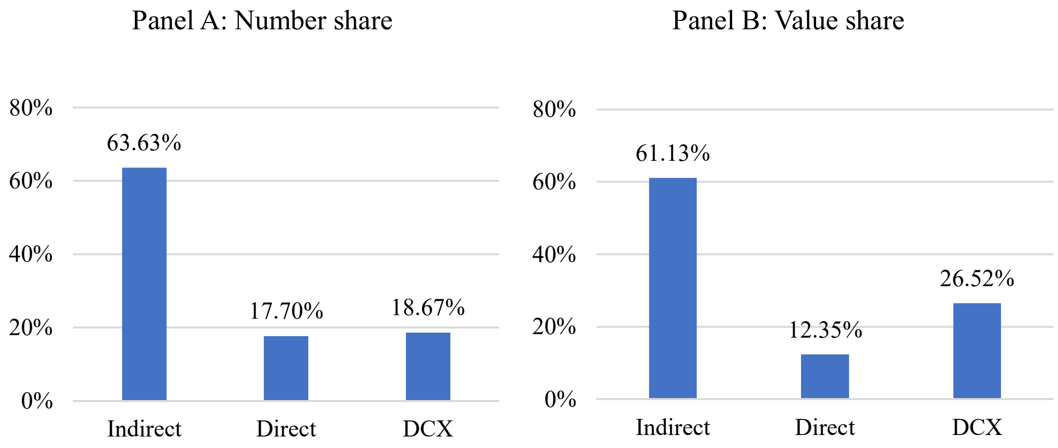
We estimate the firm-level total factor productivity (TFP) as in Ackerberg et al., (2015) and Brandt et al. (2017). For robustness checks, we also try alternative measures of TFP as proposed by Olley and Pakes (1996) and Levinsohn and Petrin (2003). Table B1 in the Appendix summarizes the key variables employed in the empirical analysis.

3. Stylized Facts from the Data

In this section, we first examine the data and establish the following stylized facts: (i) A significant share of the exporters are DCXs; (ii) DCXs on average export more than direct exporters; (iii)The average productivity of the DCXs is higher than that of the direct and indirect exporters; (iv) The productivity premium of DCXs is higher for non-private firms and industries where firms are not sensitive to ECCs than other firms; (v) The share of DCXs is higher in regions with weak port infrastructure; (vi) The productivity advantage of DCXs is higher in regions with better port infrastructure; (vii) Within DCXs, the share of direct exports is decreasing in export value. As will be demonstrated clearly soon, the ECC hypothesis we propose can account for all the above 7 facts, while alternative stories might explain only one or several of them.

Then, we provide direct evidence for the existence of ECCs with four examples. Finally, we further demonstrate the linkage between the presence of such a constraint and the DCX status of a firm, using a triple difference (DDD) method.

Figure 1. Share of firms across export modes



3.1 Share of firms across export modes

We classify the exporters in the production dataset into three modes according to the methods in Table 1, and document the share of exporters across modes. As is illustrated in Figure 1, when η=0.10, the share of direct and DCX exporters in the production dataset are 17.70% and 18.67%, with corresponding export volumes being 12.35% and 26.52%. We have also tried alternative values of η which show similar results (see Figure F1-F4 in the Appendix).[7]

One might argue that the existence of DCXs is industry-specific, for example, Geely Automobile usually faces more ECCs than electric kettle exporters and hence more likely to be an DCX. As shown in Figure C1 in the Appendix, even though the DCX share in each 2-digit industry varies substantially, the existence of DCXs seems to be rather pervasive: the industries with higher DCXs shares are medical &

[7] Another way of identifying the intermediary firms is based on Chinese-language characters that have the English-equivalent meaning of "importer", "exporter", and/or "trading" in the firm's name (see Ahn et al., 2011). This identification method could underestimate the number of intermediaries, as the carry-along exporters are tabbed as direct exporters too. It also underestimates the share of the indirect exporters, since each intermediary exports for more than one manufacturing firm.

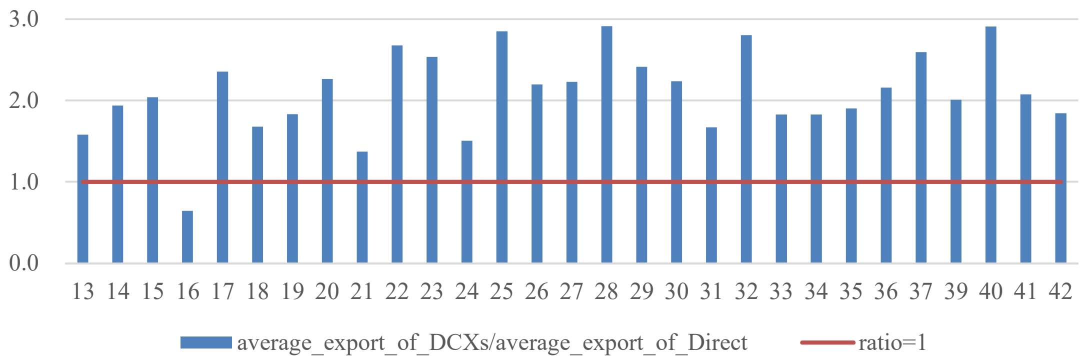
pharmaceutical products (26.27%), instruments, meters, cultural & office equipment (22.30%), ordinary machinery (22.24%), while the industries with lower DCXs shares are papermaking & paper products (9.32%) and tobacco (1.71%).

We thus establish our first stylized fact:

Fact 1: *DCXs account for a significant share in both the number of exporters and total export value.*

3.2 *Average export volume across export modes*

Figure 2. Average export volume of DCXs/Direct for two-digit CIC industries (η=0.10)



Next, we compare the export volume of different export modes within the same product category. Figure 2 displays the ratio of firm-level average export volume for DCXs and direct exporters within a 2-digit industry. Since only 18.67% of the firms export by DCXs but they collectively exported 26.52% of the China total in 2000-2006, it is not surprising to see that the export volume of DCXs is higher than that of direct exporters (except CIC 16, tobacco products), leading to:

Fact 2: *DCXs on average export more than direct exporters.*

3.3 Firm productivity across export modes

3.3.1 Baseline regression

To compare the productivity gaps among firms with different export modes, we consider the following specification:

$$tfp_{ft} = \alpha_1 Direct_{ft} + \alpha_2 DCX_{ft} + \alpha_3 \mathbf{X}_{ft} + \mathbf{D} + \varepsilon_{ft} \tag{1}$$

where subscripts f and t indicate firm and year, respectively, and tfp represents firm-level productivity. We choose indirect exporters as the benchmark and then set two dummies in the regression, namely, *Direct* and *DCX*. To isolate the effect of firm characteristics X_{ft}, we further control for size (*lnl*), age (*lnage*) and ownerships (*SOE*, *private* or *foreign*). Also, variables of time, industry-province fixed effect $\mathbf{D}$ are included to control for any common shocks. Finally, ε_{ft} is an error term. We cluster standard errors at the firm level to address potential serial correlation.

We start with a simple OLS regression that only includes year and industry-province fixed effects (FE) in Column (1) and add firm controls in Column (2) of Table 2a. The estimation results show that the DCXs are 1.3% and 0.9% more efficient than the indirect and direct exporters, respectively. Next, we restrict the sample to the direct exporters and DCXs, and regress firm productivity on the *DCX* dummy in Columns (3)-(4). Again, DCXs show significantly higher productivity than direct exporters.

In Table 2b, we replace industry-province FEs with *firm* FEs to control for time-invariant firm-level characteristics that might trigger changes in export status. As shown in Columns (1)-(4), the average productivity of the DCXs is higher than that of the direct and indirect exporters.[8] In Column (5), we add export value-weighted *market size* and *distance* to eliminate the influence of demand-side factors. Since the destinations and the characteristics of the indirect export part of DCXs are unknown, we assume that the product category of this part is the same as that of the direct part, and replace the former's destination characteristics with that of the trade intermediaries at the six-digit Harmonized System products (HS6) level. Take *market size* as an example, we have: *market size* of DCXs= export value-weighted of *market size* of the direct part + indirect export share × average *market size* of the intermediaries corresponding to the product category of the direct export part.

Table 2a. Firm productivity across export modes: baseline regression

Dependent variable: tfp	(1)	(2)	(3)	(4)
	Indirect+Direct+DCX		Direct+DCX	
Direct	0.006***	0.002**		
	(0.001)	(0.001)		
DCX	0.016***	0.013***	0.012***	0.012***
	(0.001)	(0.001)	(0.001)	(0.001)
Firm controls		Y		Y
Year FE	Y	Y	Y	Y
Industry-Province FE	Y	Y	Y	Y
Observations	257,216	257,059	92,851	92,815
R-squared	0.487	0.488	0.538	0.539

Note: (1) Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1; (2) η =0.10 in the baseline regression.

One might doubt whether the product categories of the indirect export part of DCXs are the same as that of the direct part. To address this concern, we combine the data from China Industrial Firms *product and output* database and restrict the DCX sample to single-product firms. The regression results are shown in Column (6).

[8] Because only a small share of firms switches from indirect to direct export (see Table D1), it implies that there is not much within firm variation in the variable Direct, leading the firm FE estimates to be less reliable.

Evidently, we find a similar estimate in this reduced sample, implying that our results remain robust even under these additional controls.

Table 2b. Firm productivity across export modes: baseline regression

Dependent variable: tfp	(1)	(2)	(3)	(4)	(5)	(6)
	Indirect+Direct+DCX		Direct+DCX			
Direct	-0.004**	-0.003				
	(0.002)	(0.002)				
DCX	0.004***	0.005***	0.011***	0.011***	0.010***	0.007*
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.004)
lngdp					0.002	0.000
					(0.001)	(0.002)
lndistance					0.002	0.002
					(0.003)	(0.006)
Firm controls		Y		Y	Y	Y
Year FE+Firm FE	Y	Y	Y	Y	Y	Y
Observations	202,419	202,268	76,681	76,651	76,557	16,874
R-squared	0.725	0.725	0.738	0.738	0.738	0.769

Note: (1) Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1; (2) η =0.10 in the baseline regression.

3.2.2 Alternative explanations

A candidate explanation for why the most productive firms choose to become DCXs could be that they produce multiple products, i.e., 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 exclude the multi-product firms from DCXs in Columns (1)-(2) of Table 3, and find that DCXs are still significantly more productive than firms of other modes.

Table 3. Alternative explanations

Dependent variable: tfp	(1)	(2)	(3)	(4)
	Single product exporters		Main destinations are East/Southeast Asian countries	
Direct	0.006***	0.003***	0.005**	0.002
	(0.001)	(0.001)	(0.002)	(0.002)
DCX	0.010***	0.007***	0.019***	0.015***
	(0.002)	(0.002)	(0.002)	(0.002)

Firm controls		Y		Y
Year FE	Y	Y	Y	Y
Industry-Province FE	Y	Y	Y	Y
Observations	220,804	220,665	72,923	72,875
R-squared	0.481	0.482	0.539	0.541

Note: (1) Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1; (2) η =0.10 in the baseline regression; (3) Columns (1)-(2) drop the multi-product firms from DCXs.

Alternatively, one could argue that the export mode is destination-specific. In other words, DCXs might be explained by firms that directly export to relatively easy-to-enter markets, and simultaneously, indirectly export to more remote markets which require higher entry costs. To rule out this possibility, in the baseline results (see Table 2b), *market size* and *distance* are added, so as to eliminate the influence of destination-specific characteristics. In addition, we restrict our sample to the industries where the exporters' main destinations are East/Southeast Asian countries (share of export to these areas in industry level > 50%), since they are relatively close to China and thus the role of specialized or experienced intermediaries is less important. As shown in Columns (3)-(4) of Table 3, the productivity gap between DCXs and direct exporters is still significantly positive, implying that destination-specific characteristics is not a competing reason for the existence of DCXs, and yielding:

Fact 3: *DCXs are relatively more productive than other exporters, which holds true even after controlling for firm scope and exporting destinations*.

3.2.3 Robustness checks

Redefining DCX. In Table 2a, we have used $\eta = 0.10$ and defined firms as DCXs if their export value reported in the trade dataset is 10% less than that reported in the production dataset. To alleviate the concern of measurement error, we now experiment with alternative values of η and the results are shown in Appendix Table D2. Specifically, we let η=-0.0184, 0, 0.25 and 0.40, respectively, and repeat the exercises in Table 2a. We find a significantly positive coefficient on the variable *DCX*, and the magnitude is very close to the estimates in Table 2a, thus the finding that DCXs are more productive than other exporters is robust to measurement errors.

Alternative measures of TFP. Our second group of robustness checks considers alternative measures 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 D3, we measure TFP using the ACF method with the second price index. Columns (3)-(4) and (5)-(6) use the Olley-Pakes and Levinsohn-Petrin methods, respectively, which are robust to alternative measures of TFP. Further, since our TFP measure is based on revenue rather than prices and output, we control for firm level markups and run the regression again on the single-product firms, enabling the control for export price (see Table D4). Our results remain valid for all the robustness checks.

Adding firms with a small share of exports being processing trade. A unique feature of the Chinese trade regime is that some firms are allowed to import materials free of tariffs but required to export their entire output, i.e., processing trade. As discussed earlier, we have excluded processing-trade firms from our analysis in the baseline regression since they are much less subject to the influence of ECCs. In table D5 of the Appendix, we conduct robustness check by adding firms with a small share of processing exports ($\alpha \leq 25\%$ and $\alpha \leq 50\%$). The results indicate that DCXs are still more productive than other exporters.

Isolating the impacts of trade restrictions. During the sample period (2000-2006), China was still subject to different trade restrictions (such as export license and quota), which restricted the extensive and intensive margins of direct exports and might lead to the existence of DCX. To alleviate these concerns, we exclude the products subject to export licenses in the sample period according to the "2002 Export License Administration Commodity Catalog".[9] As in Table D6, we find a similar estimate in this reduced sample, in terms of statistical significance and magnitude, implying that our findings are not driven by trade restrictions.

3.4 Heterogeneity analysis

In this subsection, we propose an explanation for DCXs based on ECCs. As shall be demonstrated in the theoretical model in Section 4, loosening the constraints leads

[9] See http://www.mofcom.gov.cn/aarticle/bi/200402/20040200176990.html.

to a large productivity advantage for the DCXs. To test our model, we exploit the variations of ECCs across firms, industries, ownerships and regions.

First, one might argue that the severity of export constraints is industry-specific. To deal with this, we first identify the set of export capacity sensitive industries based on Chinese characters that have the English-equivalent meaning of "CIC2 industry name + export capacity restriction" / "CIC2 industry name + shortage of shipping resources" / "CIC2 + shipping barrier" / "CIC2 + export transportation blocked" and/or "CIC2 industry name + infrastructure bottlenecks" in relevant news reports and customs websites, etc. The search results show that petroleum processing & coking (CIC25), smelting & pressing of ferrous/non-ferrous metals (CIC32/33), general machinery manufacturing (CIC35), special equipment manufacturing (CIC36), transport equipment manufacturing (CIC37) and electrical machinery & equipment manufacturing (CIC39) are more vulnerable to export constraints than other industries: due to their relatively bulky volume, almost all exporters in the above 7 industries are facing bottlenecks in warehousing, VLCC (very large crude carrier) and roll-on-roll-off ships, which greatly restricts the scale of direct exports.[10] Therefore, we expect the above 7 industries to be more sensitive to export constraints and to exhibit a smaller productivity advantage for the DCXs.

[10] See http://www.cinic.org.cn/site951/schj/2016-11-01/839111.shtml, https://news.sina.com.cn/c/2004-06-24/09512894644s.shtml, http://auto.sohu.com/20061211/n246959048.shtml, http://auto.sohu.com/20050109/n223851483.shtml, https://m.pcauto.com.cn/x/18/180987.html, http://auto.sohu.com/20071029/n252928671.shtml and https://www.autohome.com.cn/info/200412/819.html.

Also, the heterogeneity of ECCs exist among firms with different ownership status: SOEs and foreign firms in China usually have a higher export capacity and export directly. In other words, we can expect private firms to have a more severe ECC, and thus the productivity advantage of DCXs over direct exporters should be smaller. We define firms in CIC 25/32/33/35/36/37/39 industries and private firms as subsample that are more sensitive to ECCs. Heterogeneity is confirmed in Table 4, leading to:

Fact 4: *The productivity premium is higher for firms that are not sensitive to ECCs.*

Table 4. The productivity premium of two subsamples

Dependent variable: tfp	(1)	(2)	(3)	(4)
	Z= CIC 25/32/33/35/36/37/39		*Z=private firm*	
DCX×Z	-0.005***	-0.006***	-0.005***	-0.006***
	(0.002)	(0.002)	(0.002)	(0.002)
Direct	0.007***	0.006***	0.007***	0.006***
	(0.002)	(0.002)	(0.002)	(0.002)
DCX	0.017***	0.015***	0.017***	0.015***
	(0.001)	(0.001)	(0.001)	(0.001)
Firm controls		Y		Y
Year FE	Y	Y	Y	Y
Industry-Province FE	Y	Y	Y	Y
Observations	257,216	257,059	257,216	257,059
R-squared	0.487	0.488	0.487	0.488

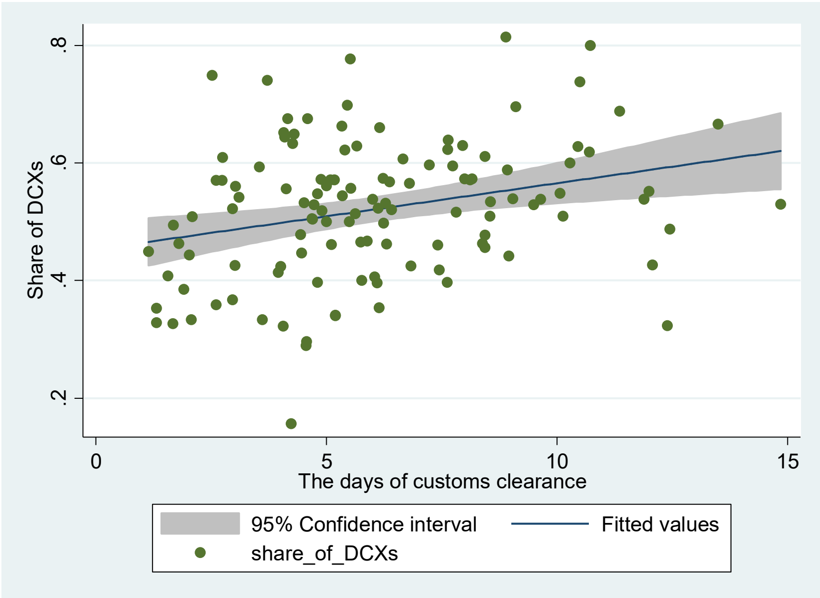
Note: (1) Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1; (2) η=0.1 in the baseline regression.

Likewise, it is also natural to expect the export capacity to be increasing in port infrastructure. Hence, firms located in cities with a poorer port facility and personnel are more likely to be DCXs. In Figure 3, we use the days of customs clearing to proxy for the (inverse of) port infrastructure, and plot its relationship with the share of DCXs. This measure is computed using the Investment Climate Survey 2005 conducted by the World Bank across 120 cities in China, in which firm managers are required to answer the following question: "How many days did the export customs clearance take on average in 2004 for your company?"

Consistent with the theoretical prediction, the share of DCXs is significantly higher for regions with poor port infrastructure (see Figure 3), leading to:

Fact 5: *The share of DCXs is higher in regions with weaker port infrastructure.*

Figure 3. The share of DCXs and (inverse of) infrastructure quality



Further, to test if DCXs in regions with a better port infrastructure has a higher productivity advantage over direct exporters, we introduce an interaction term between days of customs clearance and a DCX dummy in Columns (1)-(2) of Table 5. As a robustness check, we proxy a city's port infrastructure by the indicator $custom_{it}$, which equals 1 if the city has a custom and 0 otherwise. We expect cities with customs to have a better port infrastructure because most of these cities are located along the coast, hence facing less geographical trade barriers. We also expect firms in these cities to be more connected with customs officials, suggesting a better soft infrastructure.

As shown in Table 5, the coefficient on the interaction term between *DCX* and days of customs clearance is significantly negative, while that between *DCX* and customs is significantly positive, both implying:

Fact 6: *The productivity advantage of DCXs is higher in regions with better port infrastructure.*

Table 5. Infrastructure quality and productivity premium of DCXs

Dependent variable: tfp	(1)	(2)	(3)	(4)
	Z= custom_clearance		*Z*=customs	
DCX×Z	-0.002***	-0.002***	0.012***	0.012***
	(0.001)	(0.001)	(0.002)	(0.002)
Direct×Z	-0.000	-0.000	0.019***	0.019***
	(0.001)	(0.001)	(0.002)	(0.002)
Z	-0.001***	-0.001***	-0.009***	-0.009***
	(0.000)	(0.000)	(0.001)	(0.001)
Direct	0.008***	0.006*	-0.002	-0.005***
	(0.003)	(0.003)	(0.001)	(0.001)
DCX	0.027***	0.024***	0.012***	0.009***
	(0.003)	(0.003)	(0.001)	(0.001)
Firm controls		Y		Y
Year FE	Y	Y	Y	Y
Industry-Province FE	Y	Y	Y	Y
Observations	213,526	213,412	257,216	257,059
R-squared	0.487	0.489	0.487	0.488

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

Finally, in Table 6, we find a negative relationship between firm export value and the share of direct exports, just as will be predicted by the theoretical model soon:

Fact 7: *The share of direct exports is decreasing in firm export value among the DCXs.*

While there may be alternative stories for the existence of DCX, Facts 3-7 square well with the ECC explanation proposed in the present paper, but cannot be inferred from alternative explanations based on multiple-products or multiple-destinations.

Table 6. Share of direct exports among DCXs

Dependent variable: direct_share	(1)	(2)
lnexport	-0.039***	-0.042***
	(0.001)	(0.001)
Firm controls		Y
Year FE	Y	Y
Industry-Province FE	Y	Y
Observations	51,209	51,175
R-squared	0.206	0.208

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

3.5 ECC and DCX: establishing the causal link

Infrastructure bottlenecks including the lack of ports, large carriers, warehouses and complex custom clearance procedures are important factors that can decrease the efficiency of international trade and disrupt the global supply chain. In this subsection, we provide direct evidence for the existence of export constraints by (i) providing several stylized examples, (ii) testing the relationship between the capacity constraints and the DCX status of a firm with the DDD method.

3.5.1 Stylized examples

The first example is the completion of Yangshan deep-water port in December, 2005.[11] In the early years, firms in the Yangtze River delta export only via Shanghai Port, whose water depth plus tide height was less than 12 meters. Many shipping companies had delays of 5 hours waiting for the tide, resulting in heavy cargo congestion. This problem was not resolved until the operation of Yangshan port.[12]

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[11] See https://zjnews.zjol.com.cn/05zjnews/system/2005/12/19/006408542.shtml.

[12] Xie Yuanping, the owner of a textile trading company in Zhejiang province, mentioned that shipping cost can be reduced by about $10 per ton, saving $40,000-50,000 a day. See https://zjnews.zjol.com.cn/05zjnews/system/2005/12/19/006408542.shtml.

The second example is that, before 2004, China had no ro-ro vessels, and vehicle exports were fully carried out by Japanese and Korean shipping companies, such as NYK (Japan Post), K'line (Kawasaki steamship) and Mitsui (Merchant Marine Mitsui).[13] Since these shipping companies usually had signed long-term contracts with their home-country automakers, Chinese auto exporters were routinely charged 5-10% higher than those in Japan and Korea and often could not export on time.[14]

The third example is on customs clearance—"territorial declaration, port inspection and release (TEPIR)".[15] Before 2005, there existed two ways of customs clearance for the hinterland regions: exporters first transport the goods directly to the customs ports, then declare, inspect and release; or first declare at local customs, but the declared goods must be transported to ports by customs-supervised vehicles (at high prices). In contrast, under the TEPIR mode, exporters in the hinterland can declare locally instead of at major sea ports, and then choose relatively low-cost vehicles instead of customs-supervised ones for transport to the ports. TEPIR provides two advantages: exporters no longer have to use inadequate customs-supervised vehicles, and after arrival, goods are immediately inspected and released without repeated declaration, which greatly reduces the port stay time and improves the efficiency of customs clearance. In 2005, twelve inland customs in Shandong Province including Linyi, Zaozhuang, Heze, Jining, Tai'an, Liaocheng, Dezhou, Binzhou, Jinan,

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[13] See http://auto.sina.com.cn/news/2004-12-14/092190514.shtml.

[14] "Shang Yugui, the head of Great Wall's (a major exporter of automobiles in China) publicity department, said that due to the lack of ro-ro ships, our cars just cannot be shipped out though we hold a lot of overseas orders." See http://auto.sina.com.cn/news/2004-12-14/092190514.shtml.

[15] See http://www.gov.cn/gzdt/2006-08/10/content_359439.htm.

Zibo, Dongying, and Weifang became the first cities to implement TEPIR with Huangdao Port Customs, and the General Administration of Customs promoted this mode to the whole country in 2006.[16]

The last example is the policy of "Integration of Free Trade Zone and Port (IFTZP)", which can be regarded as an update of the above TEPIR since it moves the step of inspection from the port to the Free Trade Zone (FTZ) and thus effectively alleviates port congestion.[17] The policy aims to extend the function of the FTZ, making it a shipping origin with comprehensive functions such as collection, storage & transportation, packaging, tally, stowage and distribution, etc. Through "seamless docking" between the FTZ and ports, exporters can go through customs declaration and inspection in the FTZ, and apply for release after arriving at the port. This new one-stop service provides larger warehousing which eases port congestion and reduces time and logistics costs. For example, the integration between Chengdu High-tech Comprehensive FTZ and Chengdu Airport customs in 2013 became the first case of IFTZP in the central and western regions. Statistics shows that it has advanced declaration time by more than 4 hours, shortened inspection and release time by 3-5 hours and reduced the cost of each batch of goods by 135-160 yuan.[18]

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[16] See https://www.qingdaonews.com/content/2005-05/20/content_4733153.htm

[17] See https://baike.so.com/doc/4754214-4969639.html.

[18] Under the current situation, saving more than 100 yuan per order is very valuable for enterprises." Liu Zhonglin, manager of Compal Computer Chengdu Co., Ltd., said that each standard container will save about 500-1,000 yuan, and Compal will save about 5 million yuan in one year.

See https://epaper.scdaily.cn/shtml/scrb/20130629/28169.shtml

and https://epaper.scdaily.cn/shtml/scrb/20130629/28170.shtml.

3.5.2 Empirical specification and results

In this subsection, we empirically investigate whether ECC contributes to the prevalence of DCXs, which could be a potential source of resource misallocation. The identification uses the IFTZP implemented in Shanghai, Qingdao, Ningbo, Dalian, Zhangjiagang, Xiamen, Shenzhen and Tianjin during 2003-2004, in which larger port warehousing and higher efficiency of customs clearance was provided in IFTZP cities but not others.

As shown above, the severity of export constraints is industry- and ownership-specific, so we expect the IFTZP policy to significantly reduce the probability of DCX (or increase the probability of direct export) for firms more sensitive to ECCs. To test this hypothesis, we conduct a DDD estimation. Specifically, the first difference comes from the comparison of DCX probability in IFTZP and non-IFTZP cities (with the former consisting of the above 8 cities and thus having lower export capability constraints); the second difference compares the DCX probability in more sensitive and less sensitive firms (with the former including the above 7 industries/private firms and benefiting more from IFTZP); and the last difference is due to the policy implementation in 2003-2004, which divides the sample into pre-treatment and post-treatment periods.

The DDD specification is as follows:

$$DCX_{ft} = \alpha IFTZP_c \times post_t \times ECSF_f + \mathbf{X\beta} + \mathbf{D} + \varepsilon_{ft} \tag{2}$$

where DCX_{ft} represents firm export mode in year *t*; $IFTZP_c$ indicates city *c*'s status, i.e., *IFTZP*=1 if the city is IFTZP and *IFTZP=0* otherwise; $post_t$ indicates the post-treatment period, i.e.,

$$post_t = \begin{cases} 1 \quad if\ year >= 2003,\ for\ Shanghai, \\ 1\ \ if\ year >= 2004,\ for\ other\ IFTZP\ cities, \\ 0 \quad otherwise \end{cases}$$

and $ECSF_f$ is a dummy variable indicating whether the firm is sensitive to ECCs, i.e., $ECSF_f = 1$ if firm belongs to CIC 25/32/33/35/36/37/39 industries or is private-owned, and $ECSF_f = 0$ otherwise. **X** is a comprehensive set of firm-level controls. Note that the firm's lag export mode is also included since prior export experience affects the export mode and the current decision to export (Bai et al., 2017). **D** denotes fixed effects and ε_{ft} is the error term.

Table 7. IFTZP and DCX: main results

Dependent variable: DCX	(1)	(2)	(3)	(4)
	ECSF=1 if CIC2 =25/32/33/35/36/37/39 industries		*ECSF*=1 if firm is private	
IFTZP ×post2004×ECSF	-0.041**	-0.039***	-0.075***	-0.070***
	(0.016)	(0.015)	(0.019)	(0.016)
IFTZP ×post2004	-0.000	-0.009	-0.001	-0.011
	(0.024)	(0.025)	(0.020)	(0.020)
L. mode=Domestic	-0.035***	-0.045***	-0.042***	-0.046***
	(0.010)	(0.010)	(0.010)	(0.010)
L. mode =Indirect	0.221***	0.199***	0.214***	0.198***
	(0.009)	(0.008)	(0.008)	(0.008)
L. mode =Direct	-0.150***	-0.165***	-0.148***	-0.165***
	(0.010)	(0.011)	(0.010)	(0.011)
L. mode =DCX	0.256***	0.221***	0.255***	0.220***
	(0.009)	(0.008)	(0.008)	(0.008)
Firm controls		Y		Y
Year FE	Y	Y	Y	Y
Industry-City FE	Y	Y	Y	Y
Observations	101,479	93,071	101,479	93,071
R-squared	0.250	0.266	0.252	0.267

Note: (1) Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1; (2) η =0.10 in the baseline regression.

As expected, the estimation results in Table 7 show that the IFTZP policy has a significantly negative impact on the probability of exporting via DCX for the above 7 industries and private firms, which are more sensitive to capacity constraints.

4. A Simple Theoretical Model

Based on the previous facts and empirical results, here we attempt to build a simple model of how ECCs impact firms' export mode, and derive predictions that match the empirical regularities established so far. We use the model to conduct counterfactual analysis, and show that removing the constraints and bottlenecks can increase firm productivity, export volume and social welfare, essentially by reallocating resources from less efficient firms to more productive ones.

4.1 Preference

Consumers maximize a CES utility, $U = [\int_{\omega\in\Omega} q(\omega)^{\frac{\sigma-1}{\sigma}} d\omega]^{\frac{\sigma}{\sigma-1}}$, where $q(\omega)$ denotes the consumption of variety ω, and $\sigma = 1/(1-\rho) > 1$ is the elasticity of substitution between any two varieties. The set Ω measures the mass of available varieties. Utility maximization yields the demand function:

$$q(\omega) = Bp(\omega)^{-\sigma}, B = EP^{\sigma-1} \tag{3}$$

where $P = [\int_{\omega\in\Omega} p(\omega)^{1-\sigma} d\omega]^{\frac{1}{1-\sigma}}$ is the price index, E is total expenditure on all varieties and B measures the real market size. The associated revenue from variety ω is

$$R(\omega) = q(\omega)^{1-1/\sigma} B^{1/\sigma} = Bp(\omega)^{1-\sigma} \tag{4}$$

4.2 Production

The timing is as follows. In stage 1, a mass of firms M_e enter, 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: $G(\varphi) = 1 - (\varphi / b)^{-k}$ where b>0 is the location parameter and $k > \sigma - 1$ is shape parameter.

In stage 2, given its type, each firm decides whether or not to produce and sell domestically by paying the fixed production cost wf_d. Then, if the firm decides to export, it must choose the mode of export: either to export directly by paying the fixed cost wf_D, or indirectly by paying the fixed cost wf_I where $f_I < f_D$, 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 via intermediaries, where w is the wage and $\gamma > 1$. Here as in Ahn et al. (2011), exporting via 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. Alternatively, γ can also be interpreted as the loss in productivity due to not being able to learn directly from the foreign market.

However, in the presence of ECC, a firm may be forced to use intermediaries even when it is capable of overcoming the fixed cost associated with direct exporting. This is more so for developing countries whose export 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 ECC that limits a country's export quantity and leads to a convex trade cost. In this sense, infrastructure bottlenecks play a similar role as export quotas.

The situation could get worse in the presence of poor *soft infrastructure* when export opportunity is not based on efficiency but other considerations. First, as is reported in Khandelwal et al. (2013), export quotas in China are managed by inefficient institutions, e.g., the export license allocation is not based on productivity. Second, the allocation of transport opportunities is also managed inefficiently in China.[19] As mentioned earlier, because transportation 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 $\bar{q}$ such that if it exports $q > \bar{q}$, and the above-capacity quantity ($q_x - \bar{q}$) must be exported via intermediaries. Hence, $\bar{q}$ can also be interpreted as the inverse of the infrastructure bottleneck: less bottleneck, a higher $\bar{q}$. Then the variable cost and trade costs of exporting associated with each mode are given in Eq. (5) and Table 8, respectively:

[19] 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.

$$VC_x(\varphi, q_x) = \begin{cases} \dfrac{w}{\varphi}\gamma\tau q_x & \text{Indirect exporters} \\ \dfrac{w}{\varphi}\tau q_x & \text{Direct exporters} \\ \dfrac{w}{\varphi}\tau\overline{q} + \dfrac{w}{\varphi}\gamma\tau\left(q_x - \overline{q}\right) & \text{DCX} \end{cases} \tag{5}$$

where q_x is the quantity of exports that reach foreign consumers, $\tau\omega$ is the iceberg trade cost of direct export and $\tau > 1$ such that for each unit arriving at the foreign country $\tau\omega$ units must be shipped, and $\gamma\tau\omega$ is the iceberg trade cost of indirect export. Observe that in the existing literature, infrastructure bottlenecks are modelled as either a higher cost or higher uncertainty in delivery time. In our setup, the bottlenecks will force above-capacity firms to export via intermediaries, thus increasing their costs.

Table 8. Export mode and trade costs

Export mode	Variable cost	Fixed cost
Indirect	$w\gamma\tau$	wf_I
Direct	$w\tau$	wf_D
DCX	$w\tau$ *for* $q \le \overline{q}$; $w\gamma\tau$ *for* $q > \overline{q}$	wf_D

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.

4.3 Profits

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

$\pi_H(\varphi) = \max\limits_q B^{\frac{1}{\sigma}} q^{1-\frac{1}{\sigma}} - \frac{w}{\varphi}q - wf_d$. Maximization enables us to rewrite:

$$\pi_H(\varphi) = \frac{1}{\sigma}B\left(\frac{w}{\rho\varphi}\right)^{1-\sigma} - wf_d \tag{6a}$$

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

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

$$\pi_I(\varphi) = \max_q B^{\frac{1}{\sigma}} q^{1-\frac{1}{\sigma}} - \frac{\gamma w \tau}{\varphi} q - wf_I = \frac{1}{\sigma} B\left(\frac{\gamma w \tau}{\rho\varphi}\right)^{1-\sigma} - wf_I \tag{6b}$$

Finally, for a direct exporter, the profit is

$$\pi_D(\varphi) = \max_q B^{\frac{1}{\sigma}} q^{1-\frac{1}{\sigma}} - \frac{w}{\varphi}\tau q - wf_D = \frac{1}{\sigma} B\left(\frac{w\tau}{\rho\varphi}\right)^{1-\sigma} - wf_D \tag{6c}$$

4.4 Sorting of firms

4.4.1 Benchmark: no ECC

We start our analysis from the benchmark of zero 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

$$\begin{aligned} &\frac{1}{\sigma} B\left(\frac{\gamma}{\rho\varphi_I^*} w\tau\right)^{1-\sigma} = wf_I, \\ &\frac{1}{\sigma} B\left(\frac{w\tau}{\rho\varphi_D^*}\right)^{1-\sigma} \left(1 - \gamma^{1-\sigma}\right) = w(f_D - f_I), \end{aligned} \tag{7}$$

Combing Eqs. (6a)-(6c) and (7) to give

$$\left(\frac{\varphi_I^*}{\varphi_H^*}\right)^{\sigma-1} = \left(\gamma\tau\right)^{\sigma-1} \frac{f_I}{f_d},\ \left(\frac{\varphi_D^*}{\varphi_I^*}\right)^{\sigma-1} = \frac{\frac{f_D}{f_I} - 1}{\gamma^{\sigma-1} - 1} \tag{8}$$

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.

4.4.2 Export capacity constraints

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

The profit function of a typical DCX firm is given by

$$\pi_{DCX} = \max_{q_2} B^{\frac{1}{\sigma}} \left(\bar{q} + q_2\right)^{\frac{\sigma-1}{\sigma}} - \frac{w\gamma\tau}{\varphi} q_2 - \frac{w\tau}{\varphi}\bar{q} - wf_D, \;\; s.t. \; q_2 \geq 0 \tag{9}$$

Maximization yields:

$$\pi_{DCX} = \frac{1}{\sigma} B \left(\frac{w\gamma\tau}{\rho\varphi}\right)^{1-\sigma} + \frac{\left(\gamma - 1\right) w\tau}{\varphi}\bar{q} - wf_D \tag{9'}$$

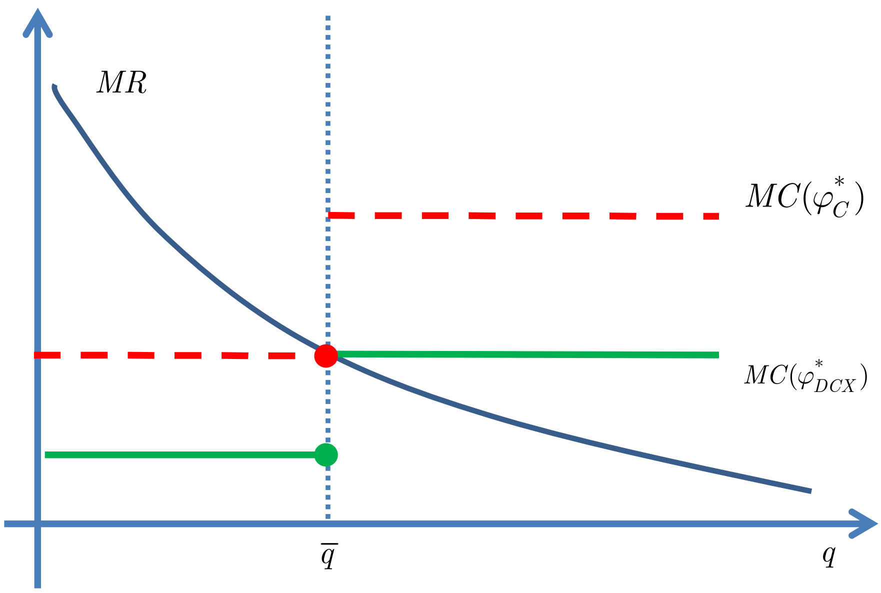
The ECC leads to a "jump" in the firm's marginal cost curve which occurs at the constrained output $\bar{q}$. Specifically, for a firm with productivity φ the marginal cost equals $\frac{w\tau}{\varphi}$ if $q \leq \bar{q}$, and equals $\frac{\gamma w\tau}{\varphi}$ if otherwise. Figure 4 illustrates how a firm decides its optimal export quantity in the presence of the capacity constraint, in which the horizontal axis represents the firm's export quantity and the vertical axis represents the marginal revenue and marginal cost. There exist two cutoffs φ_C^* and φ_{DCX}^*, with

$\varphi_C^* < \varphi_{DCX}^*$, such that the optimal export quantity for both the firm with $\varphi = \varphi_C^*$ and $MC(\varphi) = \frac{w\tau}{\varphi}$ and the firm with $\varphi = \varphi_{DCX}^*$ and $MC(\varphi) = \frac{\gamma w\tau}{\varphi}$ are just equal to $\bar{q}$, where

$$B\left(\frac{\rho\varphi_{DCX}^*}{w\gamma\tau}\right)^{\sigma} = \bar{q} \text{ and } \varphi_{DCX}^* = \gamma\varphi_C^* \tag{10}$$

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

Figure 4. Output choice of DCX firms



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

$$\left(\frac{\varphi_{DCX}^*}{\varphi_D^*}\right)^{\sigma} = \frac{\bar{q}^*}{\varphi_D^*}, \quad \bar{q}^* \equiv \frac{\tau\left(1-\gamma^{1-\sigma}\right)\gamma^{\sigma}}{(\sigma-1)\left(f_D - f_I\right)}\bar{q} \tag{11}$$

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* $\varphi \in (\varphi_{DCX}^*, \infty)$ *are the dual-channel exporters, those with* $\varphi \in (\varphi_D^*, \varphi_{DCX}^*)$ *export directly, the ones with*

$\varphi \in (\varphi_I^*, \varphi_D^*)$ *export via intermediaries, and the least productive firms with productivity* $\varphi < \varphi_H^*$ *exit the export market.*

Proposition 1 shows that under ECC, the most productive firms become the so-called "dual channel exporters". This proposition is consistent with our Facts #1 and #3 established earlier.

We next derive the productivity premium of the DCXs, over the direct exporters. Define $\bar{\varphi}_m = \int_{\varphi \in \Omega_m} \varphi dG_m(\varphi)$, $m = D, DCX$ as the average productivity for firms of exporting mode m, with $G_m(\varphi)$ representing the corresponding probability distribution function. Calculations give:

Proposition 2 (Productivity premium of DCX): $\bar{\varphi}_{DCX} > \bar{\varphi}_D$, *and* $\frac{\bar{\varphi}_{DCX}}{\bar{\varphi}_D}$ *is increasing in the export capacity* ($\bar{q}$).

Proposition 2 states that the average productivity is higher for the DCXs than for the direct exporters. Further, as $\bar{q}$ approaches infinity, so does $\frac{\bar{\varphi}_{DCX}}{\bar{\varphi}_D}$. It follows that the productivity premium of the DCXs increases with the relaxation of the export capacity ($\bar{q}$ going up), which justifies Facts #4 and #6; that is, the productivity advantage of DCXs is larger for firms that have a higher export capacity.

From Eq. (11), one sees that φ_{DCX}^* is increasing in $\bar{q}$, giving:

Proposition 3 (Share of DCX): *The share of the dual-channel exporters decreases in the ECC.*

A corollary of Proposition 3 is that with the loosening of the ECC, the share of DCX declines. This predication is validated in Fact #5, which shows that the share of DCXs is lower in regions with better port infrastructure.

4.5 General equilibrium

Free entry requires the fixed entry cost equal the expected value of entry. We classify the market into r regions and assume that the fixed entry cost is common to all regions. Then we obtain three separate cases as shown in Appendix E1.

5. Quantitative Analysis

In the previous section, our model shows that ECC is able to qualitatively explain a number of patterns regarding the DCXs in China. It is then natural to ask, does the presence of such constraint matter for the gains from trade? Here we proceed to estimate the quantitative effects of ECCs on welfare, aggregate productivity and export volume. The results suggest that removing these constraints brings 0.37% welfare gains, 2.27% aggregate productivity growth and 4.97% export growth under plausible parameters.

5.1 Theoretical framework

We first extend the model laid out in Section 4 to two countries, the home country 1 with eight different regions[20] and foreign country 2, which can be thought of as China and the rest of the world (ROW) respectively. In each country, there are L_i units of

[20] We classify the Chinese provinces into 8 large regions following Tombe and Zhu (2019): Northeast (Heilongjiang, Jilin, Liaoning), North Municipalities (Beijing, Tianjin), North Coast (Hebei, Shandong), Central Coast (Jiangsu, Shanghai, Zhejiang), South Coast (Fujian, Guangdong, Hainan), Central (Shanxi, Henan, Anhui, Hubei, Hunan, Jiangxi), Northwest (Inner Mongolia, Shaanxi, Ningxia, Gansu, Qinghai, Xinjiang), and Southwest (Sichuan, Chongqing, Yunnan, Guizhou, Guanxi, Tibet).

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 ECC nor trade intermediaries as in Melitz (2003) (see Table 9 for details).

Table 9. Export mode and trade costs

Export mode	Variable cost	Fixed cost
Country 1		
Indirect	$w_1\gamma\tau$	$w_1 f_{12I}$
Direct	$w_1\tau$	$w_1 f_{12D}$
DCX	$w_1\tau$ *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 $\dfrac{f_{12D}}{f_{12I}} > \gamma^{\sigma-1}$.

Then the productivity cutoffs can be written as

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

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 $\varphi \in [\varphi_{12C}^*, \varphi_{12DCX}^*]$ export at the constrained output $\overline{q}$, and those with $\varphi \in [\varphi_{12DCX}^*, \infty)$ become DCX. Evidently, the share of firms exporting at the constrained quantity is increasing in the relative variable cost of indirect exporting, γ. From Eq. (12), we further obtain

$$
\begin{aligned}
\varphi_{21}^* &= \varphi_{11}^* \tau \left(\frac{f_{21}}{f_{11}} \right)^{\frac{1}{\sigma-1}} \left(\frac{w_2}{w_1} \right)^{\frac{\sigma}{\sigma-1}} \\
\varphi_{12I}^* &= \varphi_{22}^* \gamma \tau \left(\frac{f_{12I}}{f_{22}} \right)^{\frac{1}{\sigma-1}} \left(\frac{w_1}{w_2} \right)^{\frac{\sigma}{\sigma-1}} \\
\varphi_{12D}^* &= \varphi_{22}^* \tau \left[\frac{f_{12D} - f_{12I}}{\left(1 - \gamma^{1-\sigma}\right) f_{22}} \right]^{\frac{1}{\sigma-1}} \left(\frac{w_1}{w_2} \right)^{\frac{\sigma}{\sigma-1}} \\
\varphi_{12C}^* &= \varphi_{22}^{*\frac{\sigma-1}{\sigma}} \left[\frac{\overline{q}}{\left(\sigma - 1\right) f_{22}} \right]^{\frac{1}{\sigma}} \left(\frac{w_1 \tau}{w_2} \right) \\
\varphi_{12DCX}^* &= \varphi_{22}^{*\frac{\sigma-1}{\sigma}} \left[\frac{\overline{q}}{\left(\sigma - 1\right) f_{22}} \right]^{\frac{1}{\sigma}} \left(\frac{w_1 \gamma \tau}{w_2} \right)
\end{aligned}
\tag{13}
$$

Overall, we have seven productivity cutoffs to solve: $\{\varphi_{22}^*, \varphi_{21}^*, \varphi_{11}^*, \varphi_{12I}^*, \varphi_{12D}^*, \varphi_{12C}^*, \varphi_{12DCX}^*\}$. By Eq. (13), we can express φ_{21}^* as a function of φ_{11}^* and w_2, and φ_{12I}^*, φ_{12D}^*, φ_{12C}^* and φ_{12DCX}^* as functions of φ_{22}^* and w_2. Consequently, we obtain φ_{11}^* and φ_{22}^* by solving the free entry conditions (see Appendix E2 for detailed expressions) for the two countries given w_2. And φ_{21}^*, φ_{12I}^*, φ_{12D}^*, φ_{12C}^* and φ_{12DCX}^* can be derived subsequently.

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

$$M_i^e = \frac{\sigma - 1}{k\sigma}\frac{L_i}{F_i} \tag{14}$$

By normalizing country 1's wage to one, we can further solve country 2's wage via the trade balance condition (see Appendix E3 for detailed expression):

$$w_2 L_2 = L_1 \frac{M_2^e \phi_{21}}{M_2^e \phi_{21} + M_1^e} + w_2 L_2 \frac{M_2^e}{M_2^e + M_1^e \phi_{12}} \quad \text{or} \quad w_2 = \frac{L_1 \phi_{21}}{L_2 \phi_{21} + L_1} + w_2 \frac{L_2}{L_2 + L_1 \phi_{12}} \tag{15}$$

where $\phi_{ij} = \dfrac{X_{ij} / M_i^e}{X_{jj} / M_j^e}$ with X_{ij} being the total export from country i to country j. Clearly, ϕ_{12} and ϕ_{21} are only functions of $\{\varphi_{22}^*, \varphi_{21}^*, \varphi_{11}^*, \varphi_{12I}^*, \varphi_{12D}^*, \varphi_{12C}^*, \varphi_{12DCX}^*\}$ and w_2.

Then the social welfare can be expressed as,

$$W_i = \frac{w_i}{P_i} \tag{16}$$

The weighted productivity is given by,

$$\tilde{\varphi} = \frac{1}{1 - G(\varphi_{11}^*)} \sum_{r=1...8} \frac{A}{R} \tag{17}$$

where R is the total sales of all firms in country 1,

$$\begin{aligned} A \equiv & \int_{\varphi_{11}^{r*}}^{\varphi_{12I}^{r*}} r_{11}(\varphi) dG_1(\varphi) + \int_{\varphi_{12I}^{r*}}^{\varphi_{12D}^{r*}} r_{12I}(\varphi) dG_1(\varphi) + \int_{\varphi_{12D}^{r*}}^{\varphi_{12C}^{r*}} r_{12D}(\varphi) dG_1(\varphi) \\ & + \int_{\varphi_{12C}^{r*}}^{\varphi_{12DCX}^{r*}} r_{12D}(\varphi_{12C}^{r*}) dG_1(\varphi) + \int_{\varphi_{12DCX}^{r*}}^{\infty} r_{12DCX}(\varphi) dG_1(\varphi) \end{aligned}$$

and $\{\varphi_{12I}^{r*}, \varphi_{12D}^{r*}, \varphi_{12C}^{r*}, \varphi_{12DCX}^{r*}\}$ is the vector of productivity cutoffs for a typical region.

Finally, the export volume can be denoted as,

$$X_1 = \sum_{r=1,2,\ldots 8} M_1^{er}\left(A - \int_{\varphi_{11}^{r*}}^{\varphi_{12I}^{r*}} r_{11}(\varphi)dG_1(\varphi)\right) \tag{18}$$

where $M_1^{er} = \frac{\sigma - 1}{k\sigma}\frac{L^r}{F_1}$. Compared with the case where $\overline{q} = \left\{\infty, \max_{r=1\ldots 8}\left(\overline{q}^r\right), \min_{r=1\ldots 8}\left(\overline{q}^r\right)\right\}$, it is clear that the welfare, aggregate productivity and export volume are all different, due to the existence of ECCs.

5.2 Quantification

In this subsection we first quantify the impacts of ECCs on welfare, aggregate productivity and export volume, and then compare them to the effects under potential trade liberalization.

5.2.1 Parameters

To solve for the counterfactual outcome, we need values for the parameters, namely, $L_i, \sigma, F_{ii}, f_{ii}, f_{12I}, f_{12D}, \gamma, k$ and b in our theoretical framework. We normalize the labor force of country one to 1, and foreign labor to 4 to match the labor size of China and ROW. We set the elasticity of substitution between varieties to $\sigma = 3$, consistent with Bernard et al. (2013).

Given that ROW affects China only through the aggregate variables, we assume entry cost F_i and fixed cost f_{ii} to be identical across countries. F_i is identified by using the free entry condition: $F_i = \frac{1}{\sigma - 1}[1 - G(\varphi_{ii}^*)]\{\mathrm{E}[l(\varphi)] - l_{\min}\}$. We use the one period survival rate[21] to measure $[1 - G(\varphi_{ii}^*)]$, and the difference between the mean and

[21] We follow Brandt et al. (2012) and use unique numerical IDs to link firms over time. We also have aimed to track firms as their boundaries or ownership structure changes, using information on the firm's name, industry,

lowest 5% labor to measure $\mathrm{E}[l(\varphi)] - l_{\min}$ in the data. Following Bai et al. (2018), we identify f by using the fact that the smallest firms have their profit just cover fixed cost: $\pi = R - wl = \frac{1}{\sigma - 1} wl = wf$, hence the fixed cost of domestic production can be expressed as $f_{ii} = \frac{1}{\sigma - 1} l_{\min}$, where we use the 5% lowest firm labor to proxy $l_{\min}$. Given the estimates of f_{11}, the fixed cost of indirect exporting f_{12I} 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 $\frac{B_2}{B_1}(\gamma\tau)^{1-\sigma}$. Finally, we can compute the fixed cost of direct exporting f_{12D} from the share of indirect exporters which equals $1 - \left(\gamma^{\sigma-1} - 1\right)^{\frac{k}{\sigma-1}} \left(\frac{f_{12D}}{f_{12I}} - 1\right)^{\frac{k}{1-\sigma}}$.

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),[22] and the other is the "implicit" cost associated with bribery and kickbacks. The latter one seems to be more important in practice, because the strict control of railway and ocean shipping has made transportation into a state of chronic shortage, creating 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 out of 25.5 billion yuan as bribes

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address, etc. According to the adjusted and unique firm ID code, we classify each firm in year *t* as belonging to one of three statuses: new entrants, exit and incumbent firms to calculate the survive rate.

[22] https://zhidao.baidu.com/question/309184569441265564.html

to get "guanxi" (see footnote 19). In another bribery case of Shanghai Wansheng International Freight Agency co., LTD, the total kickbacks amounted to 0.4242 million yuan associated with sales of 4.1081 million yuan (including taxes).[23] In the former case, the firm spends more than 78% of its gross profits to book 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 set $\gamma = 1.10$.

Table 10. Model parameters

Parameter	Definition	Value	Identification
L_1	Home labor force	1	Normalization
L_2	ROW Labor force	4	Relative labor size of ROW to China
σ	Elasticity of substitution	3	
f_{11}, f_{22}	Fixed cost of production	1.498	Lowest 5% of Labor
f_{12I}	Fixed cost of indirect exporting	1.551	Fraction of exporters
f_{12D}, f_{21}	Fixed cost of direct exporting	2.083	Fraction of indirect exporters
F_1, F_2	Entry cost	0.516	Fraction of firm producing
$\gamma - 1$	Commission rate of the intermediary	0.10	
b_1, b_2	Lower bound of the productivity draw	0.007	Lower bound of TFP
k	Pareto shape parameter	4.123	Properties of the Pareto distribution

For the productivity distribution, we back out the shape parameter k from the productivity data using the equation: $\frac{tfp_{median}}{tfp_{mean}} = \frac{k-1}{k} 2^{\frac{1}{k}}$. The location parameters b_1, b_2 are estimated using the lower bound of the productivity distribution and assumed to be common to all countries (e.g., Hsieh and Ossa, 2016). Table 11 reports the parameters calibrated based on standard moments.

[23] http://www.cicn.com.cn/zggsb/2015-06/10/cms72533article.shtml.

Table 11. Data and model moments

Region	τ^r	$\overline{q}^r$	Export intensity of indirect exporters		Share of DCXs	
			Data	Model	Data	Model
South Coast	1.043	0.130	0.983	0.983	0.121	0.121
Central	2.770	0.116	0.139	0.139	0.140	0.140
North Municipalities	2.163	0.109	0.229	0.229	0.153	0.153
Northwest	2.519	0.089	0.169	0.169	0.204	0.204
Northeast	2.905	0.089	0.127	0.127	0.204	0.204
Central Coast	1.573	0.085	0.433	0.433	0.216	0.216
Southwest	2.948	0.083	0.123	0.123	0.224	0.224
North Coast	2.027	0.078	0.260	0.260	0.242	0.242

We calibrate τ and $\overline{q}$ to match the export intensity of the indirect exporters and the share of DCXs in eight regions. The resulted parameters are reported in Table 11: trade cost is generally lower for coastal regions (1.043 for South Coast, 1.573 for Central Coast, 2.027 for North Coast and 2.163 for North Municipalities) and larger for inland regions (2.519 for Northwest, 2.770 for Central, 2.905 for Northeast, 2.948 for Southwest). As for the value of $\overline{q}$, South Coast shows the lowest ECC (0.130), followed by the Central (0.116), North Municipalities (0.109), Northwest (0.089), Northeast (0.089), Central Coast (0.085) and Southwest (0.083), while firms in the North Coast are constrained by the severest bottlenecks (0.078). The last two columns in Table 11 show the discrepancy between the model and data, which is reasonably small, indicating our model can achieve preferably fitting effects.

5.2.2 Counterfactuals

We now quantify the welfare, aggregate productivity and export effects of ECCs. Welfare effects are calculated using Eq. (16), and changes in productivity and exports using Eqs. (17)-(18), respectively. As shown in Table 12, when $\gamma = 1.10$, removal of the

ECC leads to gains of 2.27% in aggregate productivity, 4.97% in total exports and 0.37% in welfare, respectively. We also calculate the potential gains when the value of $\overline{q}$ is raised to the maximum, i.e., $\overline{q}^r = 0.130 \quad (r = 1, 2, \ldots 8)$. Still, we find that higher export capacity leads to welfare, productivity and export gains of 0.04%, 0.12% and 0.99%, respectively. Finally, by lowering $\overline{q}$ to the minimum, we find that it causes loss of 0.11%, 0.24% and 0.78% in welfare, productivity and trade volume, respectively.

Table 12. Potential gains of counterfactual analysis

	welfare	*tfp*	*export*
Eliminating ECC			
$\overline{q} = \infty$	0.37%	2.27%	4.97%
$\overline{q} = \max\limits_{r=1\ldots8}\left(\overline{q}^r\right)$	0.04%	0.12%	0.99%
$\overline{q} = \min\limits_{r=1\ldots8}\left(\overline{q}^r\right)$	-0.11%	-0.24%	-0.78%
Trade liberalization			
$\tau' = \tau(1 - 8\%)$	1.89%	8.88%	14.25%

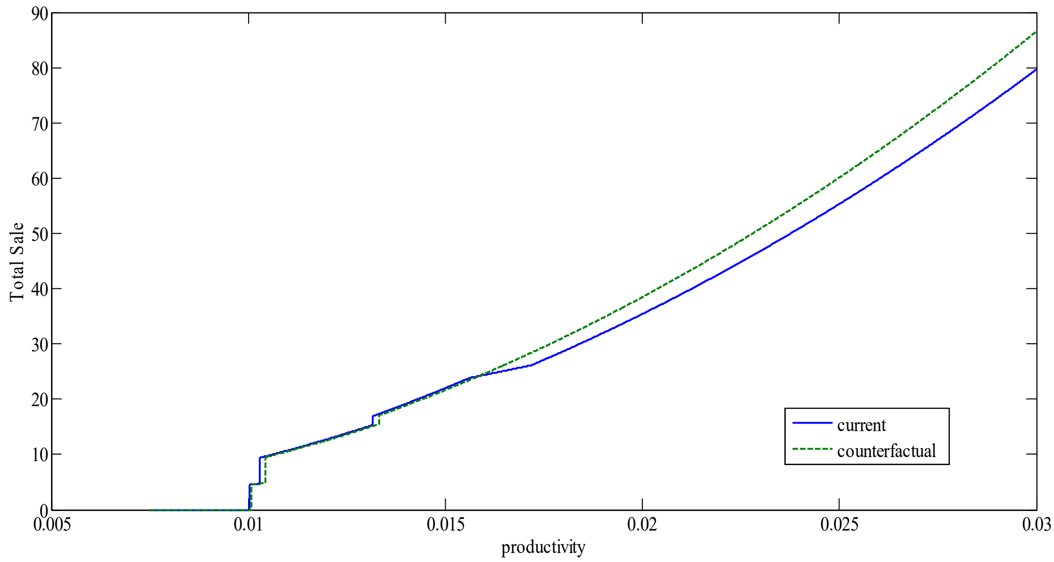
Note: $\Delta\%$ represents percentage change of the variable in interest under ECCs.

Next, to gauge the importance of capacity constraints, we compare the effects considered so far to that of trade liberalization. Following Tombe and Zhu (2019), we let China's trade costs fall by 8% in non-agriculture sectors during our sample period, i.e., $\tau' = \tau(1 - 8\%)$. Then given $\overline{q}$, we calculate the quantitative impacts of trade liberalization on welfare, productivity and export volume. The last column of Table 12 shows that the reduction in trade cost has led the welfare, productivity and total exports to increase by 1.89%, 8.88% and 14.25%, respectively. Taken together, the magnitude of welfare loss from ECCs is about 20% of the potential gains from trade liberalization. Still, the long run impacts can be much larger as exporting via intermediaries restrict a firm's ability of learning and customer accumulation.

Finally, we discuss the mechanisms through which ECCs affect the aggregate TFP. In our model the aggregate productivity is defined as the weighted average of firm productivity, the latter of which is assumed exogenous. However, aggregate productivity can still increase by eliminating the capacity constraint, since the DCXs (more productive than other firms) can now export more directly, leading to more efficient resource reallocation. The specifics are as follows.

First, as in Hsieh and Klenow (2009), the loss in aggregate productivity is proportional to the variances of the firm-specific distortions. Here exporting costs are firm-specific distortions. In the presence of export constraints, the exporting firms face higher exporting costs, and as a result, removal of the capacity constraint reduces the variances of the firm-specific distortions.

Figure 5. Firm productivity and total sale



Second, we show graphically in Figure 5 that the removal of the export constraint increases the size of the most efficient firms and simultaneously raises the productivity cutoff, causing a reallocation of resources from the least productive firms to the more productive ones, increasing aggregate productivity.

Table 13. Decomposition of aggregate productivity growth

Group	Current	Counterfactual	Δ%tfp
Aggregate productivity	0.736	0.753	2.27%
$\left(\varphi_{11}^{*i},\varphi_{12I}^{*i}\right)$	0.255	0.257	0.40%
$\left(\varphi_{12I}^{*i},\varphi_{12D}^{*i}\right)$	0.120	0.119	-0.24%
$\left(\varphi_{12D}^{*i},\infty\right)$	0.361	0.376	2.11%
including: $\left(\varphi_{12D}^{*1},\varphi_{12C}^{*1}\right)$	0.034		
$\left(\varphi_{12C}^{*1},\varphi_{12DCX}^{*1}\right)$	0.016	/	/
$\left(\varphi_{12DCX}^{*1},\infty\right)$	0.311		

Note: i=0,1. i=1 denotes the productivity cutoff under the current case while i=0 denotes the cutoff under the counterfactual case.

Third, as shown in Table 13, eliminating the ECC raises the productivity threshold φ_{11}^{*}, and the weighted productivity of the domestic firms increases by 0.40%, while the share of indirect exporters declines from 13.48% to 13.03%, and the weighted productivity drops by 0.24%. Most importantly, 4.78% of firms (or 22.59% of exporters) are no longer constrained by export capacity and become direct exporters, leading to a productivity increases of 2.11%.

6. Concluding Remarks

In this paper we have examined how ECCs affect resource misallocation and aggregate productivity by distorting firms' export mode. Specifically, (i) with linked annual survey of industrial production and transaction level customs datasets in China, we uncover a new export mode, the "dual-channel exporters", which export some products directly and others via intermediaries. From the data, we have documented seven stylized facts, based on which we develop a model of heterogeneous firms whose export capacities are constrained. (ii) We provide direct evidence for the existence of ECCs by presenting several stylized examples and testing the causal link between the capacity constraints and DCX status of a firm with the DDD method. (iii) Based on the above facts and evidence, we build a simple model to show that exporters can be categorized into three types according to productivity: the least productive ones become indirect exporters, the most productive ones export a fraction of their products by themselves and the rest through intermediaries, thus becoming DCXs, and those with intermediate productivity are direct exporters. (iv) Finally, the counterfactual analysis shows that the ECCs can substantially reduce total exports and the aggregate productivity by shifting resources from the DCXs to exporters with lower productivity.

Although our analysis is based on China, the present paper has important implications for all countries aiming to promote economic growth via international trade, as ECCs widely exist. Even in highly developed countries like the U.S, container terminals are struggling with unprecedented congestion. Nevertheless, the impact of ECCs may be more severe in developing countries—according to "Doing business 2020" by the World Bank, China's ease of trade is ranked 85th among the 190 countries. Therefore, while China faces severe export constraints, the situation in the remaining 105 developing countries might be worse, as scare ports, ships and distribution channels are usually controlled by either government-owned businesses with low productivity or people with connections.

Consequently, domestic infrastructure construction, deregulation or anticorruption campaigns and international cooperation aimed at improving regional infrastructure can significantly improve the gains from trade, especially for countries whose export capacity is constrained by hard or soft infrastructure and for firms that are sensitive to export capacity.

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Appendix

A. Matching methods of ASIF and CGAC

We match the above two datasets following the approach in Yu (2015). First, we identify each firm's Chinese name and year. 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 technique to serve as a supplement; namely, we rely on two other common variables to identify the firm: postal code and the last seven digits of the firm's phone number.

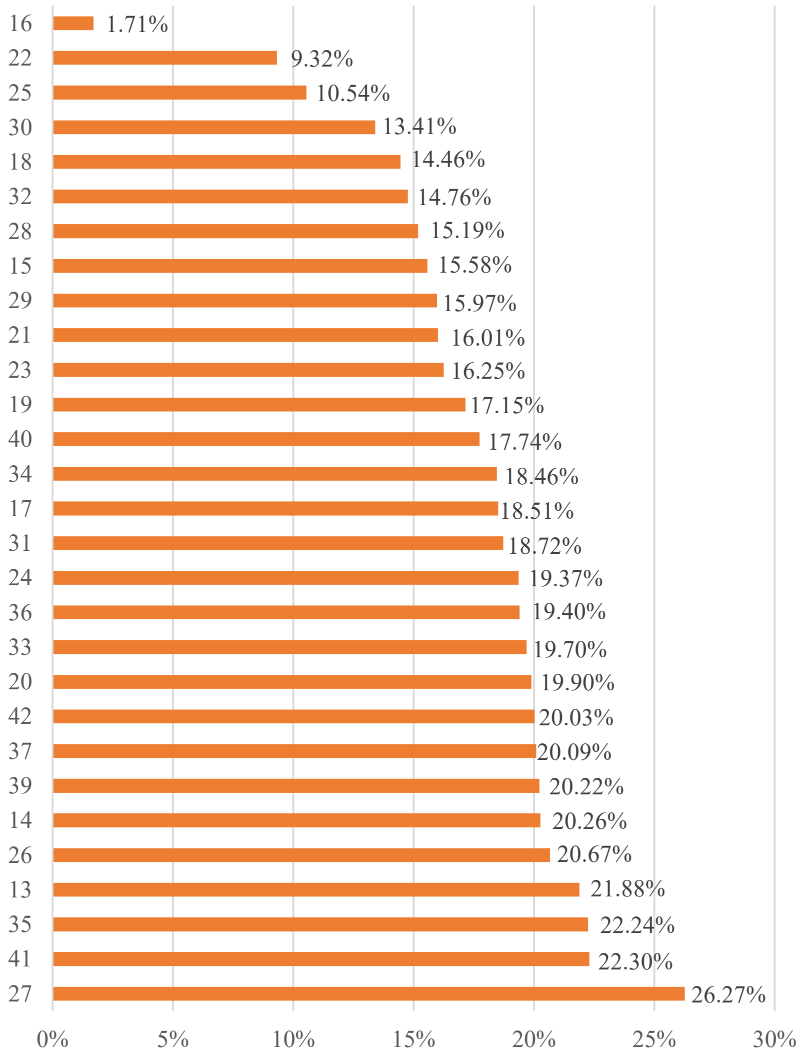
B. Summary statistics

Table B1. Summary statistics.

Variable	Obs	Mean	Std. Dev.	Min	Max
Indirect	280842	0.636	0.481	0	1
Direct	280842	0.177	0.382	0	1
DCX	280842	0.187	0.390	0	1
tfp_acfl	258157	0.686	0.223	0.009	1.724
lnl	280842	5.111	1.134	2.079	11.993
lnage	280584	2.000	0.843	0	5.380
soe	280842	0.133	0.340	0	1
private	280842	0.419	0.493	0	1
foreign	280842	0.302	0.459	0	1
custom	280842	0.357	0.479	0	1
custom_clearance	232461	4.532	2.245	1.137	14.857

C. Share of DCXs for two-digit CIC manufacturing industries

Figure C1. Share of DCXs for 2-digit CIC manufacturing industries (η=0.10)



D. Robustness checks: firm productivity across export modes

Table D1. Share of firms switching export mode

2000	2001			2002			2003		
	Indirect	*Direct*	*DCX*	*Indirect*	*Direct*	*DCX*	*Indirect*	*Direct*	*DCX*
Indirect	88.42%	1.38%	10.20%	82.11%	2.53%	15.36%	77.31%	3.51%	19.18%
Direct	5.70%	71.02%	23.28%	4.99%	67.70%	27.32%	8.55%	66.27%	25.18%
DCX	9.32%	16.95%	73.74%	14.37%	21.03%	64.60%	16.59%	19.88%	63.53%
2000	2004			2005			2006		
	Indirect	*Direct*	*DCX*	*Indirect*	*Direct*	*DCX*	*Indirect*	*Direct*	*DCX*
Indirect	71.54%	7.46%	21.00%	68.23%	7.97%	23.80%	68.60%	9.35%	22.05%
Direct	8.79%	71.26%	19.95%	9.74%	66.03%	24.23%	10.69%	64.61%	24.70%
DCX	16.68%	27.95%	55.37%	18.54%	25.55%	55.90%	23.69%	24.93%	51.38%

Table D2. Robustness check I: redefining DCX

Dependent variable: tfp	(1)	(2)	(4)	(5)	(7)	(8)	(10)	(11)
	η=-0.0184		η=0		η=0.25		η=0.40	
Direct	0.004***	0.000	0.004***	0.000	0.006***	0.002**	0.006***	0.003**
	(0.001)	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
DCX	0.013***	0.008***	0.014***	0.009***	0.016***	0.013***	0.016***	0.013***
	(0.001)	(0.001)	(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	Y	Y
Industry FE× Province FE	Y	Y	Y	Y	Y	Y	Y	Y
N	257,218	257,090	257,218	257,090	248,715	248,560	242,707	242,554
R-squared	0.487	0.487	0.487	0.487	0.486	0.487	0.485	0.486

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

Table D3. Robustness check II: alternative measures of TFP

Dependent variable: tfp	(1)	(2)	(3)	(4)	(5)	(6)
	tfp_acf2		*tfp_op*		*tfp_lp*	
Direct	0.006***	0.002**	0.003**	0.000	0.007***	0.004***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
DCX	0.016***	0.013***	0.011***	0.014***	0.018***	0.014***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Firm controls		Y		Y		Y
Year FE	Y	Y	Y	Y	Y	Y
Industry FE× Province FE	Y	Y	Y	Y	Y	Y
N	257,216	257,059	257,477	257,320	257,642	257,483

R-squared	0.487	0.488	0.601	0.604	0.465	0.466

Note:(1) Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1; (2) η=0.10 in the regression.

Table D4. Robustness check III: controlling for markups

Dependent variable: tfp_acf	(1)	(2)	(3)	(4)
Direct	0.007***	0.005***	0.005**	0.002**
	(0.001)	(0.001)	(0.002)	(0.001)
DCX	0.019***	0.017***	0.010***	0.009***
	(0.001)	(0.001)	(0.002)	(0.002)
Markup	0.174***	0.173***	0.230***	0.230***
	(0.005)	(0.005)	(0.010)	(0.010)
Firm controls		Y		Y
Year FE	Y	Y	Y	Y
Industry FE×Province FE	Y	Y	Y	Y
Observations	257,203	257,046	58,629	58,591
R-squared	0.509	0.510	0.530	0.532

Note: (1) Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1; (2) η=0.1 in the baseline regression. (3) We estimate markup μ_{it} using the ACF approach, following Brandt et al. (2017): $\mu_{it} = \theta_{it}^{m} / \alpha_{it}^{m}$, where θ_{it}^{m} is the output elasticity of intermediate inputs and α_{it}^{m} is the share of expenditure on intermediates over revenue. (4) Columns (3)-(4) keep only single-product firms.

Table D5. Robustness check IV: adding processing-trade firms

Dependent variable: tfp_acf	(1)	(2)	(4)	(5)
	ordinary trade+ processing trade ($\alpha \leq 25\%$)		ordinary trade+ processing trade ($\alpha \leq 50\%$)	
Direct	0.019***	0.009***	0.020***	0.010***
	(0.002)	(0.002)	(0.002)	(0.003)
DCX	0.024***	0.014***	0.023***	0.014***
	(0.002)	(0.003)	(0.003)	(0.003)
Firm controls		Y		Y
Year FE	Y	Y	Y	Y
Industry FE×Province FE	Y	Y	Y	Y
Observations	264,667	264,544	252,953	252,835
R-squared	0.231	0.231	0.230	0.230

Note: (1) Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1; (2) η=0.1 in the baseline regression. (3) α denotes the share of processing trade in exports.

Table D6. Robustness check V: isolating the impacts of trade restrictions

Dependent variable: tfp_acf	(1)	(2)	(3)	(4)
	Indirect+Direct+DCX		Direct+DCX	
Direct	0.005***	0.002		

	(0.001)	(0.001)		
DCX	0.014***	0.011***	0.011***	0.012***
	(0.001)	(0.001)	(0.001)	(0.002)
lngdp				0.003*
				(0.001)
lndistance				0.000
				(0.004)
Firm controls		Y	Y	Y
Year FE	Y	Y	Y	Y
Industry FE×Province FE	Y	Y	Y	Y
Observations	214,740	214,614	75,395	61,647
R-squared	0.484	0.485	0.541	0.743

Note: (1) Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1; (2) η =0.10 in the baseline regression.

E. Theoretical and quantitative analysis

E1. Free entry condition in theoretical model

Free entry requires the fixed entry cost equal the expected value of entry. We classify the market into *r* regions and assume that the fixed entry cost is common to all regions. Then we obtain three separate cases:

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

$$F = \sum_{r=1,2\ldots r} \alpha^r \left[\begin{array}{l} \int_{\varphi_H^{r*}}^{\infty} \pi_H(\varphi) dG(\varphi) + \int_{\varphi_I^{r*}}^{\varphi_D^{r*}} \pi_I(\varphi) dG(\varphi) + \int_{\varphi_D^{r*}}^{\varphi_C^{r*}} \pi_D(\varphi) dG(\varphi) \\ + \int_{\varphi_C^{r*}}^{\varphi_{DCX}^{r*}} \pi_D(\overline{q},\varphi) dG(\varphi) + \int_{\varphi_{DCX}^{r*}}^{\infty} \pi_{DCX}(\varphi) dG(\varphi) \end{array} \right]; \quad \text{(E1.a)}$$

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

$$F = \sum_{r=1,2\ldots r} \alpha^r \left[\begin{array}{l} \int_{\varphi_H^{*}}^{\infty} \pi_H(\varphi) dG(\varphi) + \int_{\varphi_I^{r*}}^{\varphi_D^{r*}} \pi_I(\varphi) dG(\varphi) \\ + \int_{\varphi_D^{r*}}^{\varphi_{DCX}^{r*}} \pi_D(\overline{q},\varphi) dG(\varphi) + \int_{\varphi_{DCX}^{r*}}^{\infty} \pi_{DCX}(\varphi) dG(\varphi) \end{array} \right]; \quad \text{(E1.b)}$$

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

$$F = \sum_{r=1,2\ldots r} \alpha^r \left[\int_{\varphi_H^*}^{\infty} \pi_H(\varphi) dG(\varphi) + \int_{\varphi_I^{r*}}^{\varphi_D^{r*}} \pi_I(\varphi) dG(\varphi) + \int_{\varphi_D^{r*}}^{\infty} \pi_{DCX}(\varphi) dG(\varphi) \right], \tag{E1.c}$$

where α^r is the firm share of region r and the profit functions are specified in Eqs. (6a)-(6c) and (9'), respectively, and $\pi_D(\overline{q},\varphi) = B^{\frac{1}{\sigma}} \overline{q}^{\frac{\sigma-1}{\sigma}} - \frac{w\tau}{\varphi}\overline{q} - wf_D$.

E2. Free entry condition in quantitative analysis

The free entry condition for country 2 is standard, given by

$$w_2 F_2 = \int_{\varphi_{22}^*}^{\infty} \pi_{22}(\varphi) dG_2(\varphi) + \int_{\varphi_{21}^*}^{\infty} \pi_{21}(\varphi) dG_2(\varphi) . \tag{E2.a}$$

For country 1,

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

$$w_1 F_1 = \sum_{r=1\ldots8} \alpha^r \left[\begin{array}{l} \int_{\varphi_{11}^*}^{\infty} \pi_{11}(\varphi) dG_1(\varphi) + \int_{\varphi_{12I}^{r*}}^{\varphi_{12D}^{r*}} \pi_{12I}(\varphi) dG_1(\varphi) + \int_{\varphi_{12D}^{r*}}^{\varphi_{12C}^{r*}} \pi_{12D}(\varphi) dG_1(\varphi) \\ + \int_{\varphi_{12C}^{r*}}^{\varphi_{12DCX}^{r*}} \pi_{12D}(\overline{q}^r, \varphi) dG_1(\varphi) + \int_{\varphi_{12DCX}^{r*}}^{\infty} \pi_{12DCX}(\varphi) dG_1(\varphi) \end{array} \right]; \tag{E2.b}$$

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

$$w_1 F_1 = \sum_{r=1\ldots8} \alpha^r \left[\begin{array}{l} \int_{\varphi_{11}^*}^{\infty} \pi_{11}(\varphi) dG_1(\varphi) + \int_{\varphi_{12I}^{r*}}^{\varphi_{12D}^{r*}} \pi_{12I}(\varphi) dG_1(\varphi) \\ + \int_{\varphi_{12D}^{r*}}^{\varphi_{12DCX}^{r*}} \pi_{12D}(\overline{q}^r, \varphi) dG_1(\varphi) + \int_{\varphi_{12DCX}^{r*}}^{\infty} \pi_{12DCX}(\varphi) dG_1(\varphi) \end{array} \right]; \tag{E2.c}$$

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

$$w_1 F_1 = \sum_{r=1\ldots8} \alpha^r \left[\int_{\varphi_{11}^*}^{\infty} \pi_{11}(\varphi) dG_1(\varphi) + \int_{\varphi_{12I}^{r*}}^{\varphi_{12D}^{r*}} \pi_{12I}(\varphi) dG_1(\varphi) + \int_{\varphi_{12D}^{r*}}^{\infty} \pi_{12DCX}(\varphi) dG_1(\varphi) \right]. \quad \text{(E2.d)}$$

E3. Trade balance condition in quantitative analysis

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

$$w_2 L_2 = L_1 \frac{M_2^e \phi_{21}}{M_2^e \phi_{21} + M_1^e} + w_2 L_2 \frac{M_2^e}{M_2^e + M_1^e \phi_{12}}, \quad \text{(E3.a)}$$

$$\phi_{21} = \frac{\int_{\varphi_{21}^*}^{\infty} r_{21}(\varphi) dG_2(\varphi)}{\int_{\varphi_{11}^*}^{\infty} r_{11}(\varphi) dG_1(\varphi)}. \quad \text{(E3.b)}$$

For ϕ_{12},

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

$$\phi_{12} = \frac{\sum_{r=1\ldots8} \beta^r \left[\begin{array}{l} \int_{\varphi_{12I}^{r*}}^{\varphi_{12D}^{r*}} r_{12I}(\varphi) dG_1(\varphi) + \int_{\varphi_{12D}^{r*}}^{\varphi_{12C}^{r*}} r_{12D}(\varphi) dG_1(\varphi) \\ + \int_{\varphi_{12C}^{r*}}^{\varphi_{12DCX}^{r*}} r_{12D}(\varphi_{12C}^{r*}) dG_1(\varphi) + \int_{\varphi_{12DCX}^{r*}}^{\infty} r_{12DCX}(\varphi) dG_1(\varphi) \end{array} \right]}{\int_{\varphi_{22}^*}^{\infty} r_{22}(\varphi) dG_2(\varphi)} \quad \text{(E3.c)}$$

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

$$\phi_{12} = \frac{\sum_{r=1\ldots8} \beta^r \left[\int_{\varphi_{12I}^{r*}}^{\varphi_{12D}^{r*}} r_{12I}(\varphi) dG_1(\varphi) + \int_{\varphi_{12D}^{r*}}^{\varphi_{12DCX}^{r*}} r_{12D}(\varphi_{12C}^{r*}) dG_1(\varphi) + \int_{\varphi_{12DCX}^{r*}}^{\infty} r_{12DCX}(\varphi) dG_1(\varphi) \right]}{\int_{\varphi_{22}^*}^{\infty} r_{22}(\varphi) dG_2(\varphi)} \quad \text{(E3.d)}$$

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

$$\phi_{12} = \frac{\sum_{r=1\ldots8} \beta^r \left[\int_{\varphi_{12I}^{r*}}^{\varphi_{12D}^{r*}} r_{12I}(\varphi) dG_1(\varphi) + \int_{\varphi_{12D}^{r*}}^{\infty} r_{12DCX}(\varphi) dG_1(\varphi) \right]}{\int_{\varphi_{22}^{*}}^{\infty} r_{22}(\varphi) dG_2(\varphi)} \tag{E3.e}$$

where β^r is the export share of region *r* and $r_{22}(\varphi) = B_2 \left(\frac{w_2}{\rho\varphi} \right)^{1-\sigma}$, $r_{21}(\varphi) = B_1 \left(\frac{w_2 \tau}{\rho\varphi} \right)^{1-\sigma}$, $r_{11}(\varphi) = B_1 \left(\frac{w_1}{\rho\varphi} \right)^{1-\sigma}$, $r_{12I}^r(\varphi) = B_2 \left(\frac{w_1 \gamma \tau^r}{\rho\varphi} \right)^{1-\sigma}$, $r_{12D}^r(\varphi) = B_2 \left(\frac{w_1 \tau^r}{\rho\varphi} \right)^{1-\sigma}$ and $r_{12DCX}^r(\varphi) = B_2 \left(\frac{w_1 \gamma \tau^r}{\rho\varphi} \right)^{1-\sigma}$.

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

E4. Estimation

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

$$M^r = \left(m_1^r\right)^2 + \left(m_2^r\right)^2, \quad m_1^r = \hat{\iota}_I^r - \iota_I^r, m_2^r = \hat{s}_{DCX}^r - s_{DCX}^r,$$

where $\iota_I^r = \frac{B_2}{B_1}\left(\gamma\tau^r\right)^{1-\sigma}$ and $\hat{\iota}_I^r$ are export-domestic sales ratio of the indirect exporters in region *r*, $s_{DCX}^r = \left(\frac{\varphi_{12DCX}^{r*}}{\varphi_{12I}^{r*}} \right)^{-k} = \left(\frac{(\sigma - 1) f_{12I} \varphi_{12I}^{r*}}{\gamma \tau^r \bar{q}^r} \right)^{\frac{k}{\sigma}}$, and $\hat{s}_{DCX}^r$ are the shares of DCXs computed from the model and data in region *r*, respectively.

Inner loop: Given τ^r and $\bar{q}^r$, we first get $\{\varphi_{11}^{*}, \varphi_{22}^{*}, w_2\}$ by solving the free entry and labor market clearing conditions, then we compute $B_i = w_i L_i P_i^{\sigma-1}, i = 1,2$, the price index, social welfare, aggregate productivity and the export volume.

F. Robustness check VI: η=-0.0184, 0, 0.25 and 0.40.

F.1. Facts

Figure F1. Share of firms across export modes (η=-0.0184)

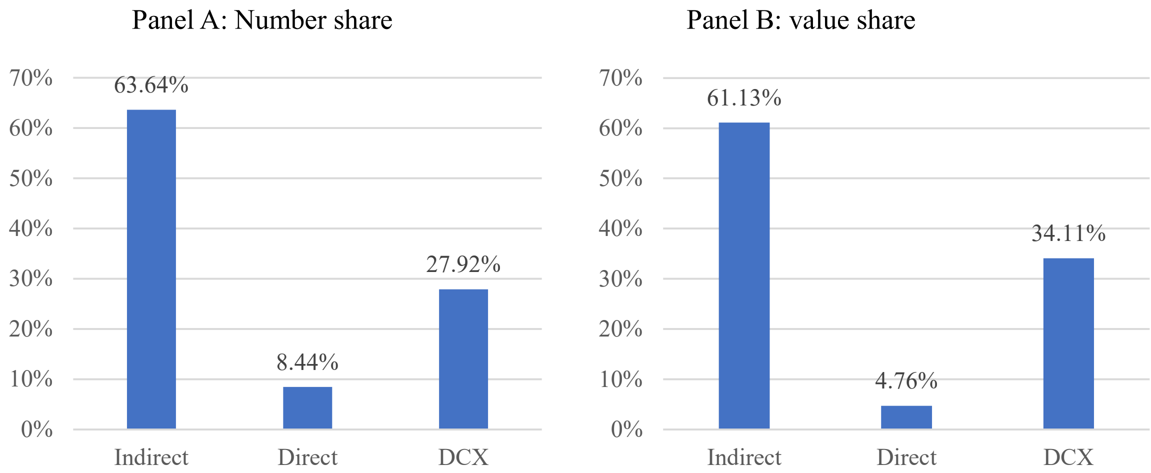


Figure F2. Share of firms across export modes (η=0)

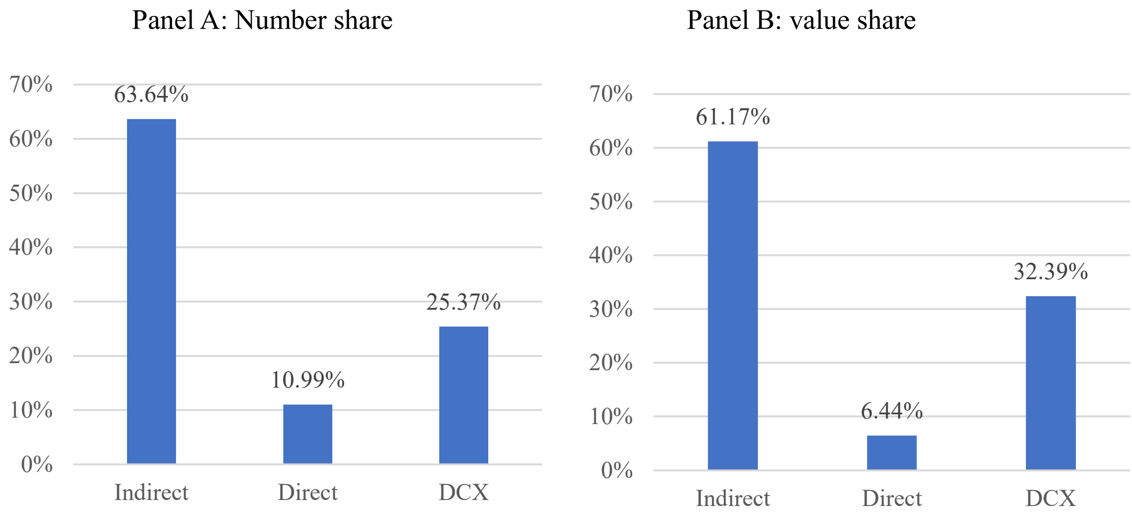


Figure F3. Share of firms across export modes (η=0.25)

Panel A: Number share

Panel B: value share

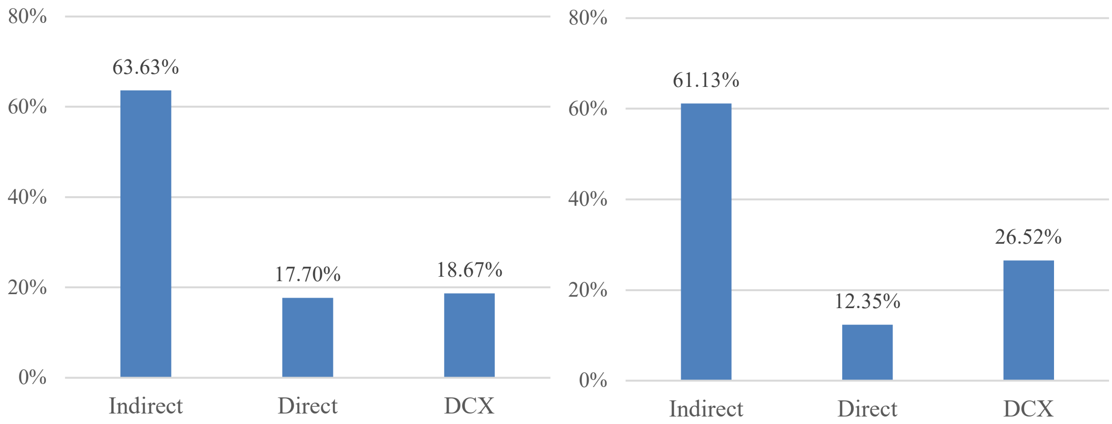


Figure F4. Share of firms across export modes (η=0.40)

Panel A: Number share

Panel B: value share

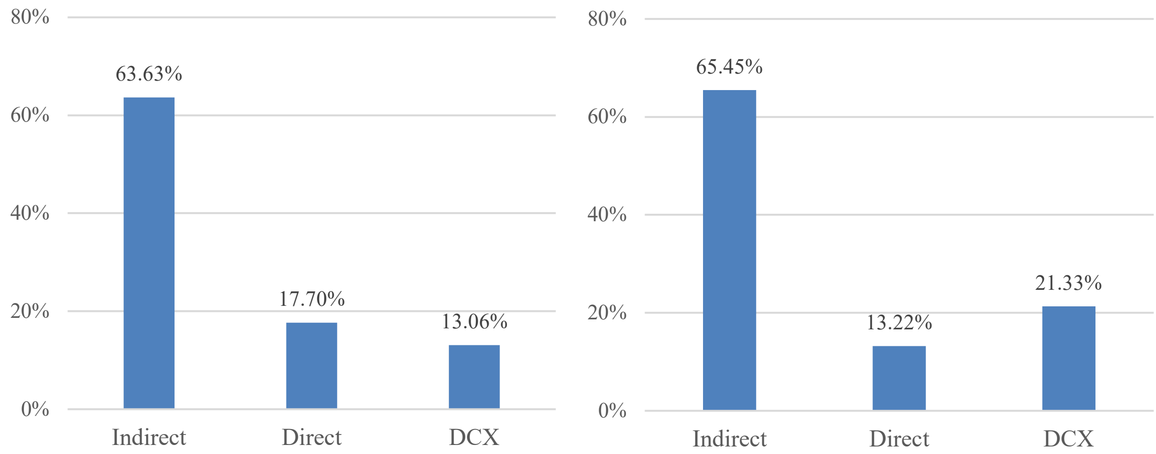


Figure F5. Average export volume of DCXs/Direct for CIC2 industries

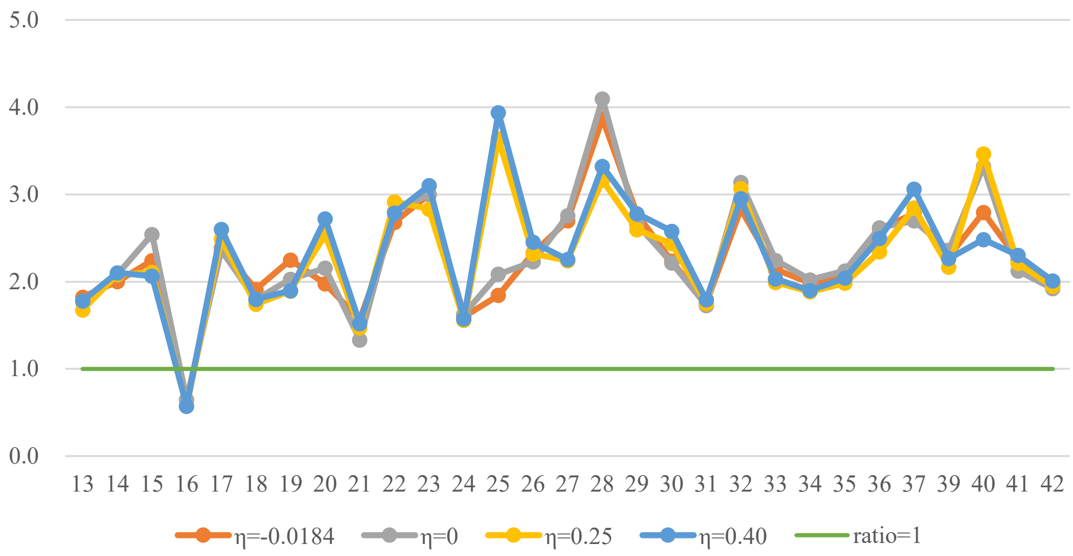


Table F1. Firm productivity across export modes: baseline regression (η=-0.0184)

Dependent variable: tfp	(1)	(2)	(3)	(4)	(5)	(6)
	Indirect+Direct+DCX		*Direct+DCX*			
Direct	0.004***	0.000				
	(0.001)	(0.002)				
DCX	0.013***	0.008***	0.011***	0.010***	0.008***	0.008***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)
lngdp						0.001
						(0.001)
lndistance						0.001
						(0.002)
Firm controls		Y		Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y
Industry FE× Province FE	Y	Y	Y	Y		
Firm FE					Y	Y
Observations	257,218	257,090	92,851	92,824	76,659	76,570
R-squared	0.487	0.487	0.537	0.538	0.738	0.738

Note: (1) Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1; (2) η =-0.0184 in the baseline regression.

Table F2. Firm productivity across export modes: baseline regression (η=0)

Dependent variable: tfp	(1)	(2)	(3)	(4)	(5)	(6)
	Indirect+Direct+DCX		*Direct+DCX*			
Direct	0.004***	0.000				
	(0.001)	(0.001)				
DCX	0.014***	0.009***	0.011***	0.011***	0.008***	0.008***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)
lngdp						0.001
						(0.001)
lndistance						0.000
						(0.002)
Firm controls		Y		Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y
Industry FE× Province FE	Y	Y	Y	Y		
Firm FE					Y	Y
Observations	257,218	257,090	92,851	92,824	76,659	76,570
R-squared	0.487	0.487	0.537	0.538	0.738	0.738

Note: (1) Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1; (2) η =0 in the baseline regression.

Table F3. Firm productivity across export modes: baseline regression (η=0.25)

Dependent variable: tfp	(1)	(2)	(3)	(4)	(5)	(6)
	Indirect+Direct+DCX		*Direct+DCX*			
Direct	0.006***	0.002**				
	(0.001)	(0.001)				
DCX	0.016***	0.013***	0.012***	0.013***	0.012***	0.012***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)
lngdp						0.000
						(0.001)
lndistance						0.001
						(0.002)
Firm controls		Y		Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y
Industry FE× Province FE	Y	Y	Y	Y		
Firm FE					Y	Y
Observations	248,715	248,560	84,316	84,283	67,932	67,847
R-squared	0.486	0.487	0.538	0.539	0.742	0.742

Note: (1) Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1; (2) η =0.25 in the baseline regression.

Table F4. Firm productivity across export modes: baseline regression (η=0.40)

Dependent variable: tfp	(1)	(2)	(3)	(4)	(5)	(6)
	Indirect+Direct+DCX		*Direct+DCX*			
Direct	0.006***	0.003**				
	(0.001)	(0.001)				
DCX	0.016***	0.013***	0.012***	0.012***	0.009***	0.009***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.003)	(0.003)
lngdp						0.000
						(0.001)
lndistance						0.002
						(0.003)
Firm controls		Y		Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y
Industry FE× Province FE	Y	Y	Y	Y		
Firm FE					Y	Y
Observations	242,707	242,554	78,291	78,260	61,698	61,616
R-squared	0.485	0.486	0.538	0.540	0.745	0.745

Note: (1) Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1; (2) η =0.40 in the baseline regression.

F.2. Quantitative analysis

Table F5. Potential Gains of counterfactual analysis (η=-0.0184)

	welfare	*tfp*	*export*
Eliminating export capacity constraint			
$\overline{q}=\infty$	0.48%	2.51%	6.17%
$\overline{q}=\max\limits_{r=1...8}\left(\overline{q}^r\right)$	0.03%	0.07%	0.63%
$\overline{q}=\min\limits_{r=1...8}\left(\overline{q}^r\right)$	-0.07%	-0.14%	-0.64%
Trade liberalization			
$\tau'=\tau(1-8\%)$	1.78%	8.48%	13.87%

Table F6. Potential gains of counterfactual analysis (η=0)

	welfare	*tfp*	*export*
Eliminating export capacity constraint			
$\overline{q}=\infty$	0.45%	2.46%	5.84%
$\overline{q}=\max\limits_{r=1...8}\left(\overline{q}^r\right)$	0.03%	0.08%	0.71%

$\overline{q} = \min_{r=1...8}\left(\overline{q}^r\right)$	-0.08%	-0.16%	-0.67%
Trade liberalization			
$\tau' = \tau(1-8\%)$	1.84%	8.67%	14.31%

Table F7. Potential gains of counterfactual analysis (η=0.25)

	welfare	*tfp*	*export*
Eliminating export capacity constraint			
$\overline{q} = \infty$	0.40%	2.35%	4.76%
$\overline{q} = \max_{r=1...8}\left(\overline{q}^r\right)$	0.01%	0.03%	0.01%
$\overline{q} = \min_{r=1...8}\left(\overline{q}^r\right)$	-0.05%	-0.10%	-0.65%
Trade liberalization			
$\tau' = \tau(1-8\%)$	1.87%	8.79%	14.28%

Table F8. Potential gains of counterfactual analysis (η=0.40)

	welfare	*tfp*	*export*
Eliminating export capacity constraint			
$\overline{q} = \infty$	0.38%	2.28%	4.41%
$\overline{q} = \max_{r=1...8}\left(\overline{q}^r\right)$	0.01%	0.03%	0.04%
$\overline{q} = \min_{r=1...8}\left(\overline{q}^r\right)$	-0.05%	-0.12%	-0.66%
Trade liberalization			
$\tau' = \tau(1-8\%)$	1.89%	8.86%	14.25%

G. Robustness check VII: Industries where firms export mainly to East/Southeast Asia

One might argue that DCXs could arise when firms directly export to relatively easy-to-enter markets, and simultaneously, indirectly export to more remote markets which require higher entry costs. To rule out this possibility, we further restrict our sample to the industries where the exporters' main destinations are East/Southeast Asian countries (share of exports in industry level > 50%), since they are relatively close to China and the role of specialized or experienced intermediaries is less important.

Figure G1. Share of firms across export modes (η=0.10)

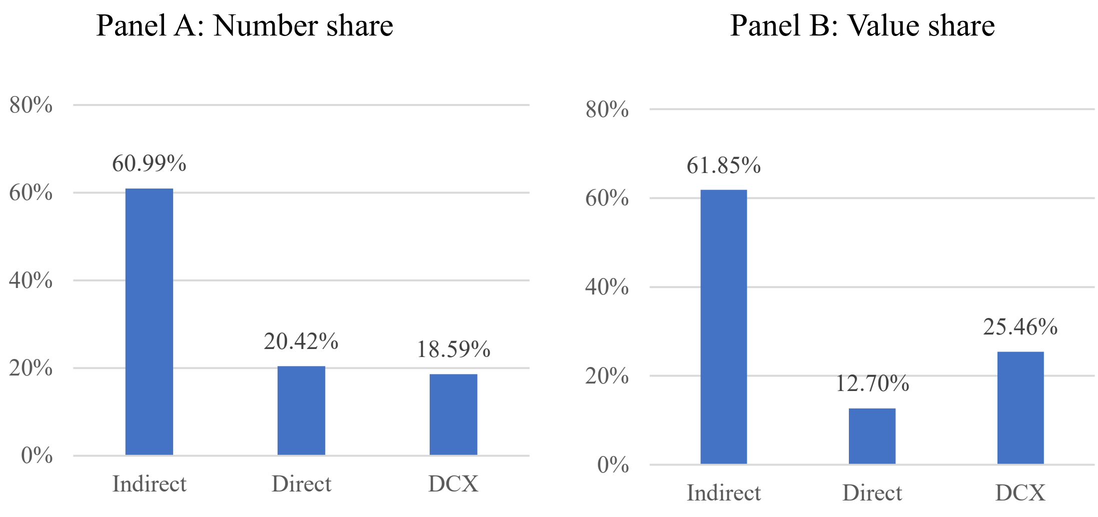


Figure G2. Average export volume of DCXs/Direct for two-digit CIC industries (η=0.10)

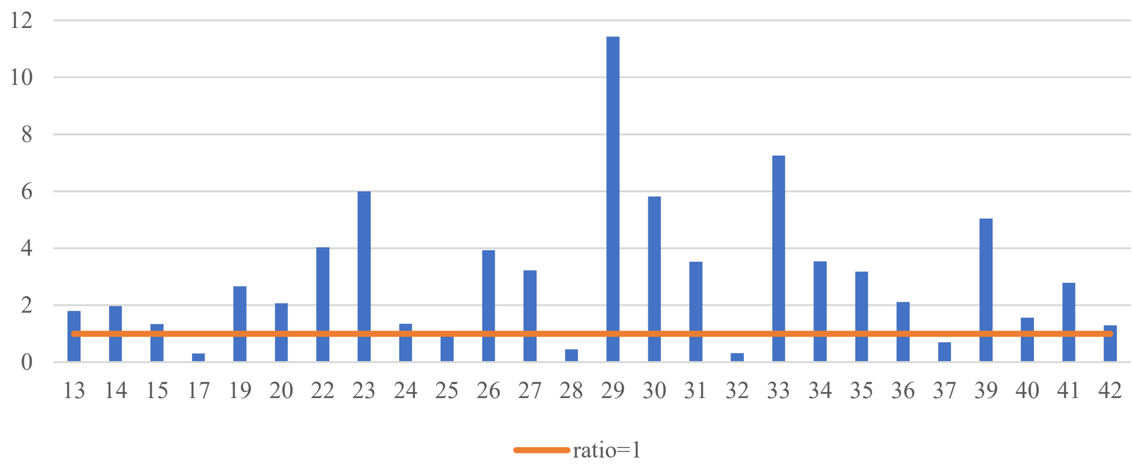


Table G1. Firm productivity across export modes: baseline regression

Dependent variable: tfp	(1)	(2)	(3)	(4)	(5)	(6)
	Indirect+Direct+DCX		*Direct+DCX*			
Direct	0.005**	0.002				
	(0.002)	(0.002)				
DCX	0.019***	0.015***	0.014***	0.013***	0.011***	0.011***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)	(0.003)
lngdp						0.000
						(0.002)
lndistance						0.002
						(0.005)
Firm controls		Y		Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y

Industry FE× Province FE	Y	Y	Y	Y		
Firm FE					Y	Y
Observations	72,923	72,875	28,386	28,376	22,656	22,614
R-squared	0.539	0.541	0.578	0.580	0.778	0.778

Note: (1) Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1; (2) η =0.10 in the baseline regression.

Table G2. Productivity premium of private and non-private firms

Dependent variable: tfp	(1)	(2)	(3)	(4)
	Z= CIC 25/32/33/35/36/37/39		*Z=private firm*	
*DCX*Z*	-0.016***	-0.016***	-0.009**	-0.010***
	(0.005)	(0.005)	(0.004)	(0.004)
Direct	0.011***	0.008***	0.007**	0.006**
	(0.002)	(0.002)	(0.003)	(0.003)
DCX	0.023***	0.019***	0.021***	0.019***
	(0.002)	(0.002)	(0.003)	(0.003)
Firm controls		Y		Y
Year FE	Y	Y	Y	Y
Industry FE×Province FE	Y	Y	Y	Y
Observations	72,923	72,875	72,923	72,875
R-squared	0.540	0.541	0.540	0.541

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

Figure G3. The share of DCXs and (inverse of) infrastructure quality

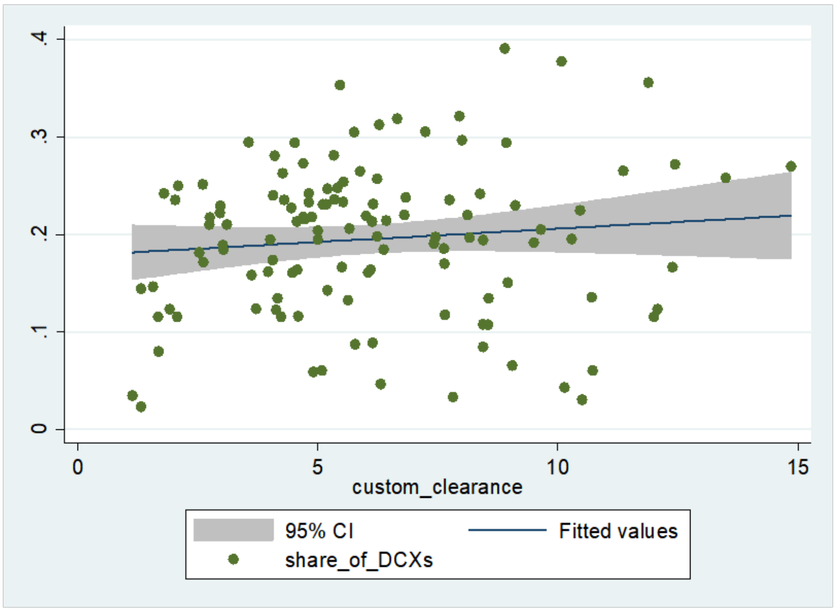


Table G3. Infrastructure quality and productivity premium of DCXs

Dependent variable: tfp	(1)	(2)	(3)	(4)
	Z= custom_clearance		*Z*=custom	
Direct×Z	-0.002**	-0.003**	0.023***	0.023***
	(0.001)	(0.001)	(0.004)	(0.004)
DCX×Z	-0.003***	-0.004***	0.011**	0.011**
	(0.001)	(0.001)	(0.004)	(0.004)
Z	-0.000	0.000	-0.014***	-0.013***
	(0.001)	(0.001)	(0.002)	(0.002)
Direct	0.016***	0.015***	-0.004	-0.007***
	(0.005)	(0.005)	(0.002)	(0.002)
DCX	0.034***	0.031***	0.016***	0.012***
	(0.005)	(0.005)	(0.002)	(0.002)
Firm controls		Y		Y
Year FE	Y	Y	Y	Y
Industry FE×Province FE	Y	Y	Y	Y
Observations	60,319	60,293	72,923	72,875
R-squared	0.542	0.544	0.540	0.541

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

Table G4. Share of direct exports among DCXs

Dependent variable: direct_share	(1)	(2)
lnexport	-0.045***	-0.047***
	(0.002)	(0.002)
Firm controls		Y
Year FE	Y	Y
Industry FE×Province FE	Y	Y
Observations	16,723	16,706
R-squared	0.232	0.233

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

Table G5. IFTZP and DCX: main results

Dependent variable: DCX	(1)	(2)	(3)	(4)
	ECSF= CIC 25/32/33/35/36/37/39 industries		*ECSF=private firms*	
IFTZP×post2004×ECSF	-0.048	-0.040	-0.076**	-0.032
	(0.040)	(0.044)	(0.030)	(0.030)
IFTZP×post2004	0.021	0.011	0.011	-0.005
	(0.019)	(0.020)	(0.021)	(0.023)
L. mode =Domestic	-0.039***	-0.036**	-0.042***	-0.036**
	(0.014)	(0.016)	(0.014)	(0.016)
L. mode =Indirect	0.190***	0.181***	0.186***	0.180***
	(0.013)	(0.015)	(0.013)	(0.015)

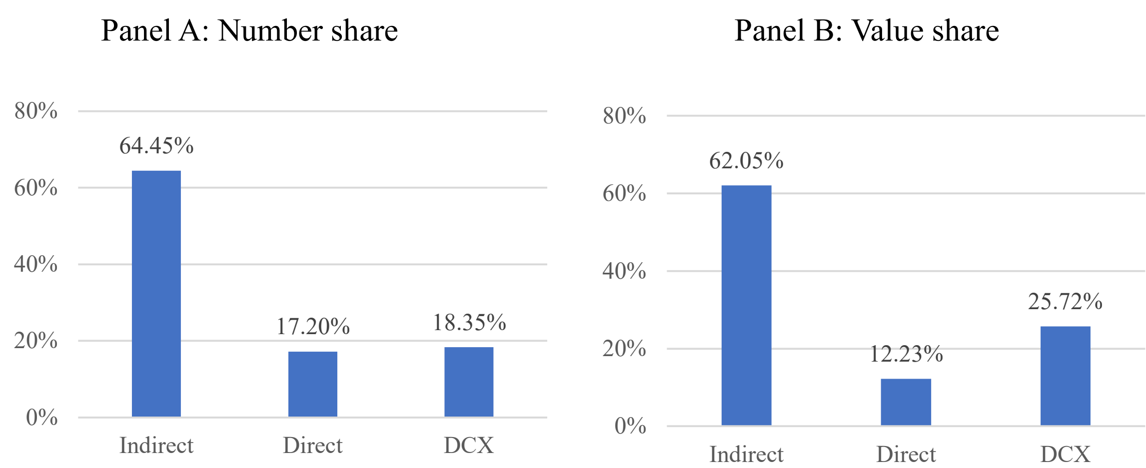
L. mode =Direct	-0.123***	-0.132***	-0.122***	-0.132***
	(0.010)	(0.013)	(0.010)	(0.013)
L. mode =DCX	0.233***	0.205***	0.233***	0.205***
	(0.013)	(0.014)	(0.012)	(0.013)
Firm controls		Y		Y
Year FE	Y	Y	Y	Y
IndustryFE+City FE	Y	Y	Y	Y
Observations	35,749	28,219	35,749	28,219
R-squared	0.255	0.266	0.256	0.266

H. Robustness check VIII: Excluding products subject to export license

During the sample period (2000-2006), China was still subject to different trade restrictions (such as export license and quota), which restricted the extensive and intensive margins of direct export and might lead to the existence of DCX. In light of these concerns, we exclude the products subject to export license in the sample period according to the "2002 Export License Administration Commodity Catalog".[1]

H.1. Facts

Figure H1. Share of firms across export modes (η=0.10)



[1] See http://www.mofcom.gov.cn/aarticle/bi/200402/20040200176990.html.

Figure H2. Average export volume of DCXs/Direct for two-digit CIC industries (η=0.10)

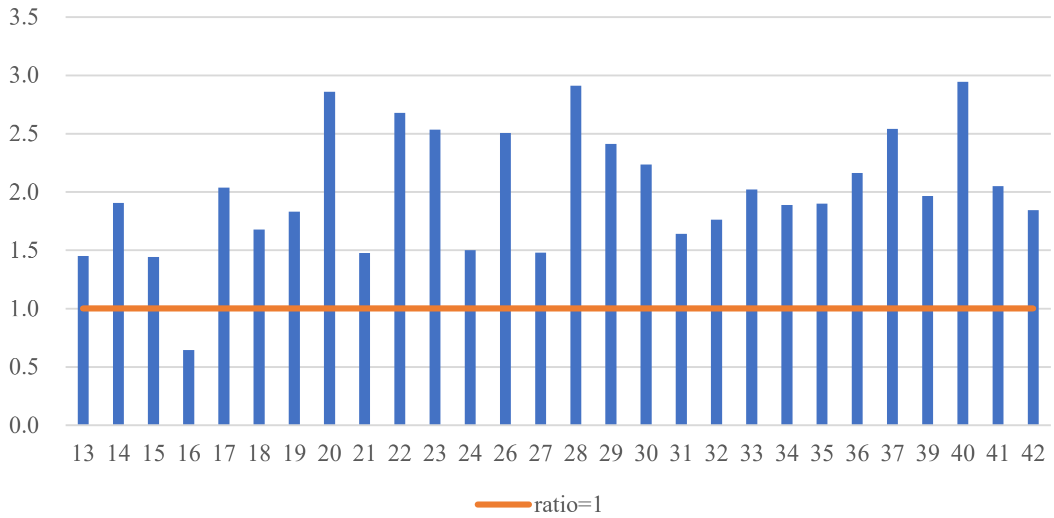


Table H1. Firm productivity across export modes: baseline regression

Dependent variable: tfp	(1)	(2)	(3)	(4)	(5)	(6)
	Indirect+Direct+DCX		*Direct+DCX*			
Direct	0.005***	0.002*				
	(0.001)	(0.001)				
DCX	0.014***	0.011***	0.011***	0.011***	0.012***	0.012***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)
lngdp						0.004*
						(0.002)
lndistance						-0.005
						(0.006)
Firm controls		Y		Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y
Industry FE× Province FE	Y	Y	Y	Y		
Firm FE					Y	Y
Observations	214,740	214,614	75,424	75,395	61,729	61,647
R-squared	0.484	0.485	0.540	0.541	0.743	0.743

Note: (1) Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1; (2) η =0.40 in the baseline regression.

Table H2. The productivity premium of private and non-private firms

Dependent variable: tfp	(1)	(2)	(3)	(4)
	Z= CIC 25/32/33/35/36/37/39		*Z=private*	
*DCX*Z*	-0.009***	-0.009***	-0.004*	-0.004**
	(0.002)	(0.002)	(0.002)	(0.002)
Direct	0.011***	0.008***	0.006***	0.005***

	(0.002)	(0.002)	(0.002)	(0.002)
DCX	0.017***	0.013***	0.014***	0.013***
	(0.001)	(0.001)	(0.002)	(0.002)
Firm controls		Y		Y
Year FE	Y	Y	Y	Y
Industry FE×Province FE	Y	Y	Y	Y
Observations	214,740	214,614	214,740	214,614
R-squared	0.484	0.485	0.484	0.485

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

Figure G3. The share of DCXs and (inverse of) infrastructure quality

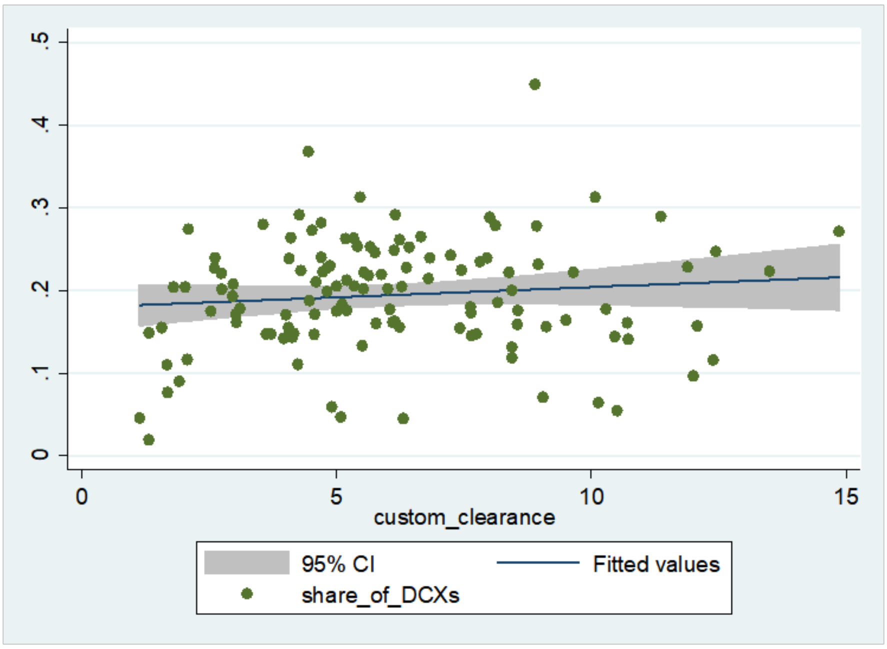


Table H3. Infrastructure quality and productivity premium of DCXs

Dependent variable: tfp	(1)	(2)	(3)	(4)
	Z= custom_clearance		*Z*=custom	
DCX×Z	-0.002***	-0.003***	0.013***	0.013***
	(0.001)	(0.001)	(0.002)	(0.002)
Direct×Z	-0.000	-0.001	0.020***	0.020***
	(0.001)	(0.001)	(0.003)	(0.003)
Z	-0.001**	-0.001*	-0.009***	-0.008***
	(0.000)	(0.000)	(0.001)	(0.001)
Direct	0.026***	0.023***	0.010***	0.006***
	(0.003)	(0.003)	(0.001)	(0.001)
DCX	0.009***	0.007**	-0.002	-0.006***
	(0.003)	(0.003)	(0.002)	(0.002)
Firm controls		Y		Y
Year FE	Y	Y	Y	Y

Industry FE×Province FE	Y	Y	Y	Y
Observations	178,943	178,848	214,740	214,614
R-squared	0.485	0.486	0.484	0.485

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

Table H4. Share of direct exports among DCXs

Dependent variable: direct_share	(1)	(2)
lnexport	-0.038***	-0.042***
	(0.001)	(0.002)
Firm controls		Y
Year FE	Y	Y
Industry FE×Province FE	Y	Y
Observations	42,394	42,369
R-squared	0.210	0.212

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

Table H5. IFTZP and DCX: main results

Dependent variable: DCX	(1)	(2)	(3)	(4)
	ECSF= CIC 25/32/33/35/36/37/39 industries		*ECSF=private firms*	
IFTZP×post2004×ECSF	-0.026*	-0.022*	-0.080***	-0.074***
	(0.014)	(0.013)	(0.020)	(0.017)
IFTZP×post2004	-0.012	-0.023	-0.006	-0.017
	(0.027)	(0.028)	(0.021)	(0.021)
L. mode =Domestic	-0.035***	-0.045***	-0.043***	-0.045***
	(0.010)	(0.011)	(0.010)	(0.011)
L. mode =Indirect	0.218***	0.194***	0.209***	0.193***
	(0.009)	(0.008)	(0.008)	(0.008)
L. mode =Direct	-0.151***	-0.167***	-0.149***	-0.167***
	(0.012)	(0.012)	(0.012)	(0.012)
L. mode =DCX	0.253***	0.216***	0.251***	0.216***
	(0.008)	(0.008)	(0.008)	(0.008)
Firm controls		Y		Y
Year FE	Y	Y	Y	Y
IndustryFE+City FE	Y	Y	Y	Y
Observations	83,656	75,588	83,656	75,588
R-squared	0.257	0.273	0.259	0.274

H.2. Quantitative analysis

Table H6. Data and model moments

Region	τ^r	$\overline{q}^r$	Export intensity of indirect exporters		Share of DCXs	
			Data	Model	Data	Model
South Coast	1.000	0.126	1.255	1.255	0.119	0.119
Central	2.924	0.115	0.139	0.139	0.138	0.138
North Municipalities	1.622	0.110	0.419	0.419	0.147	0.147
Northwest	2.412	0.086	0.201	0.201	0.206	0.206
Northeast	2.868	0.086	0.143	0.143	0.206	0.206
Central Coast	1.478	0.083	0.534	0.534	0.215	0.215
Southwest	3.333	0.081	0.106	0.106	0.222	0.222
North Coast	1.941	0.078	0.267	0.267	0.234	0.234

Table H7. Potential gains of counterfactual analysis

	welfare	*tfp*	*export*
Eliminating export capacity constraint			
$\overline{q} = \infty$	0.54%	3.01%	4.74%
$\overline{q} = \max\limits_{r=1...8}\left(\overline{q}^r\right)$	0.06%	0.18%	0.89%
$\overline{q} = \min\limits_{r=1...8}\left(\overline{q}^r\right)$	-0.14%	-0.35%	-0.70%
Trade liberalization			
$\tau' = \tau(1 - 8\%)$	2.62%	12.02%	12.00%

Note: $\Delta\%$ represents percentage change of the variable in interest under export capacity constraints.

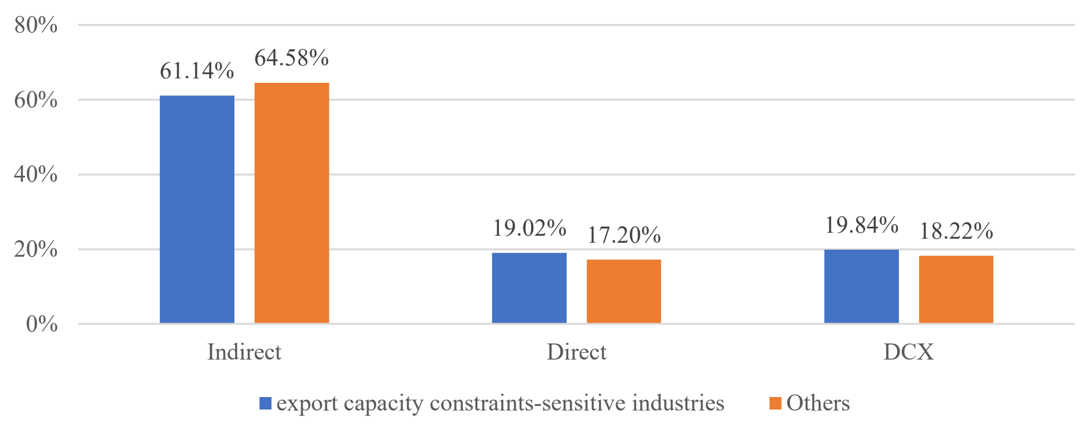
I. Heterogeneity analysis

The severity of export constraints is industry-specific. Here we examine the heterogeneous effects by dividing our sample into two subsamples by industry: export capacity constraints-sensitive industries (CIC 25/32/33/35/36/37/39) and others.

I.1. Facts

Figure I1. Share of firms across export modes

Panel A: Number share



Panel B: Value share

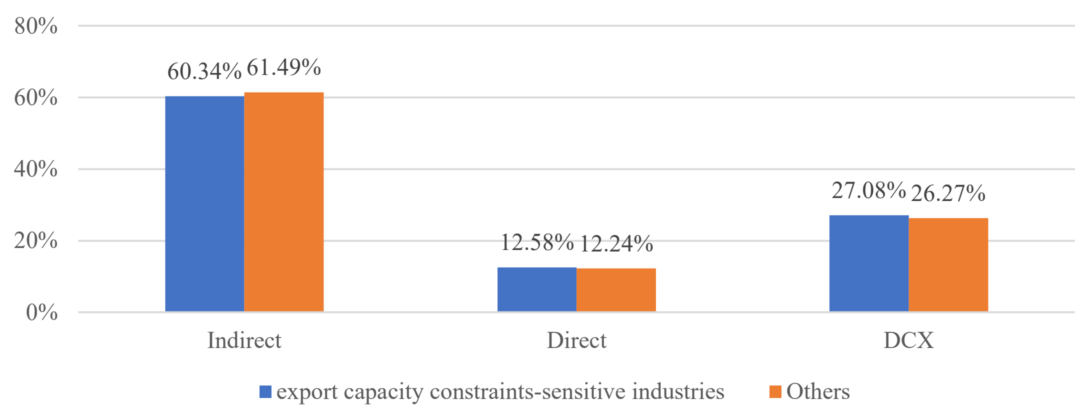


Figure I2. Average export volume of DCXs/Direct for two-digit CIC industries (η=0.10)

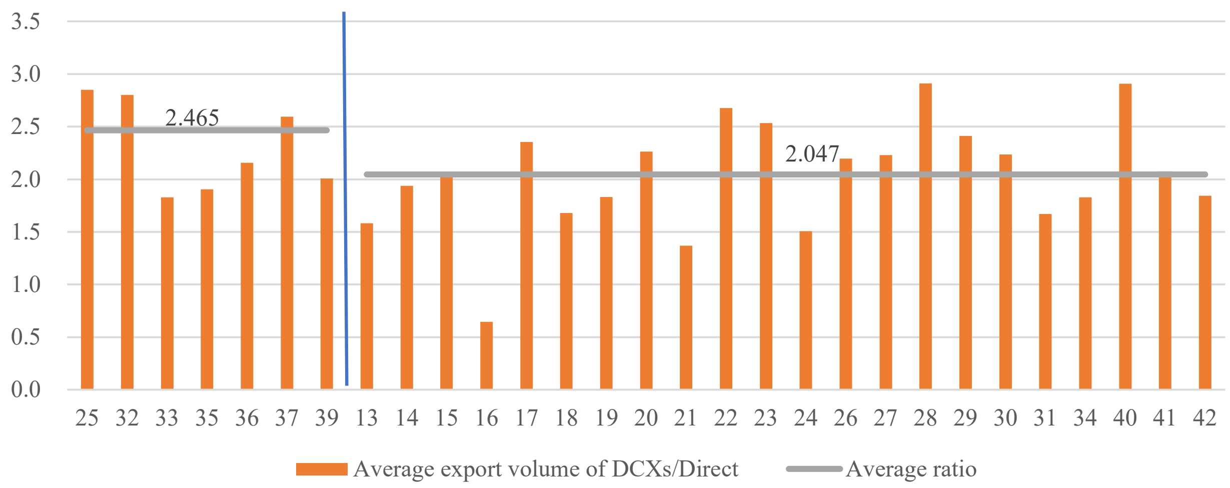


Table I1. Firm productivity across export modes: baseline regression

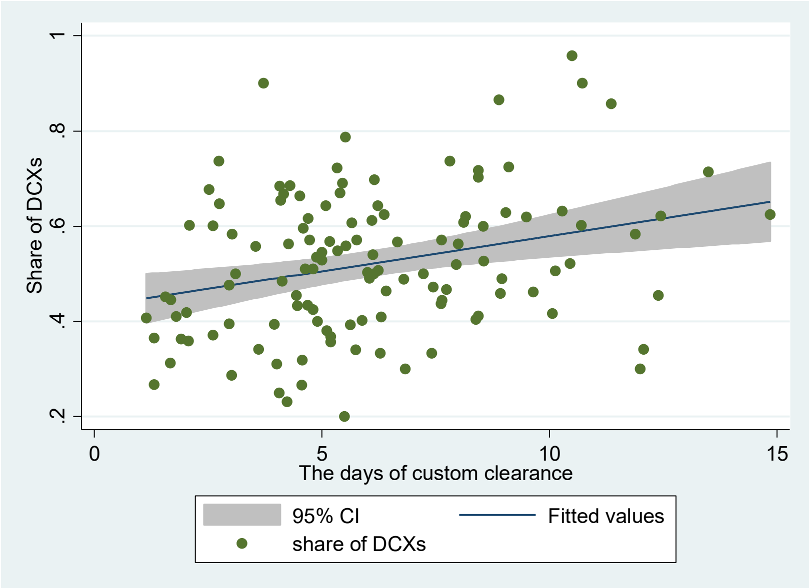
Dependent variable: tfp	(1)	(2)	(3)	(4)
	Indirect+Direct+DCX		*Direct+DCX*	
Panel A: export capacity constraints-sensitive industries				
Direct	0.010***	0.005***		
	(0.017)	(0.009)		
DCX	0.015***	0.010***	0.007***	0.007***
	(0.026)	(0.017)	(0.014)	(0.015)
lngdp				0.004***
				(0.020)
lndistance				-0.013***
				(-0.031)
Panel B: other industries				
Direct	0.005***	0.002*		
	(0.009)	(0.004)		
DCX	0.016***	0.014***	0.014***	0.014***
	(0.030)	(0.026)	(0.032)	(0.032)
lngdp				0.001
				(0.004)
lndistance				0.000
				(0.001)
Firm controls		Y	Y	Y
Year FE	Y	Y	Y	Y
Industry FE×Province FE	Y	Y	Y	Y

Note: (1) Robust normalized beta coefficients in parentheses, *** $p<0.01$, ** $p<0.05$, * $p<0.1$; (2) $\eta=0$ in the baseline regression.

Figure I3. The share of DCXs and (inverse of) infrastructure quality

Panel A: export capacity constraints-sensitive industries

(Correlation coefficient=0.2863)



Panel B: other industries

(Correlation coefficient= 0.1854)

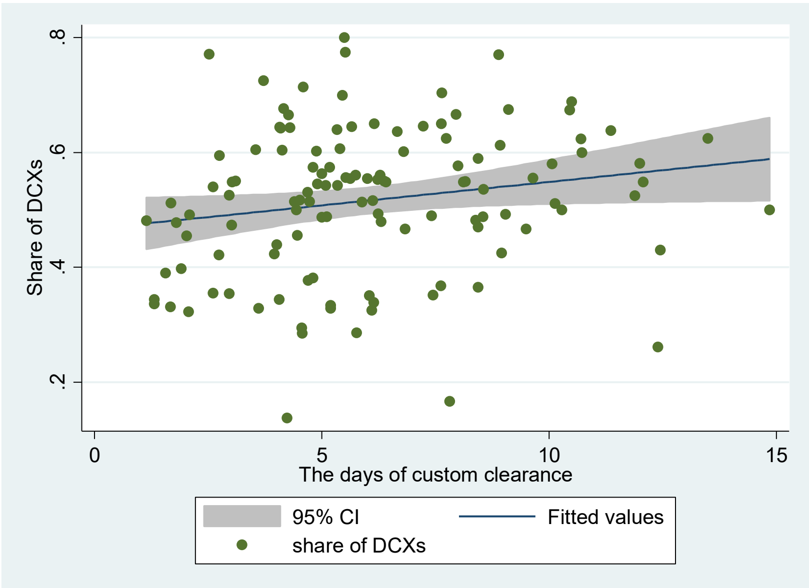


Table I2. Infrastructure quality and productivity premium of DCXs

Dependent variable: tfp	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Export capacity constraints-sensitive industries				Other industries			
	Z= custom_clearance		*Z*=custom		*Z*= custom_clearance		*Z*=custom	
DCX×Z	-0.002***	-0.003***	0.013***	0.013***	-0.001	-0.002	0.012***	0.012***
	(0.001)	(0.001)	(0.004)	(0.004)	(0.001)	(0.001)	(0.003)	(0.003)
Z	-0.003***	-0.003***	-0.006**	-0.005**	-0.000	-0.000	-0.010***	-0.010***
	(0.001)	(0.001)	(0.002)	(0.002)	(0.000)	(0.000)	(0.001)	(0.001)
Direct	0.008	0.005	0.003	-0.002	0.008**	0.006*	-0.003*	-0.006***
	(0.006)	(0.006)	(0.003)	(0.003)	(0.003)	(0.003)	(0.002)	(0.002)
DCX	0.023***	0.018***	0.011***	0.005**	0.028***	0.025***	0.013***	0.011***
	(0.006)	(0.006)	(0.002)	(0.002)	(0.003)	(0.003)	(0.001)	(0.001)
Firm controls		Y		Y		Y		Y
Year FE	Y	Y	Y	Y	Y	Y	Y	Y
Industry FE×Province FE	Y	Y	Y	Y	Y	Y	Y	Y
Observations	60,831	60,795	71,423	71,374	152,695	152,617	185,793	185,685
R-squared	0.554	0.556	0.559	0.561	0.427	0.428	0.425	0.426

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

I.2. Quantitative analysis

We first extend the model laid out in Section 4 to two countries, ***the home country 1 with 2 groups (instead of 8 regions)*** and foreign country 2, which can be thought of as China and the rest of the world (ROW) respectively, then re-calculate the free entry condition and trade balance condition, e.g., when $\varphi_I^{r^*} < \varphi_D^{r^*} < \varphi_C^{r^*} < \varphi_{DCX}^{r^*}$, and the free entry condition is given as:

$$F = \sum_{g=1,2} \alpha^r \begin{bmatrix} \int_{\varphi_H^{g^*}}^{\infty} \pi_H(\varphi)dG(\varphi) + \int_{\varphi_I^{r^*}}^{\varphi_D^{g^*}} \pi_I(\varphi)dG(\varphi) + \int_{\varphi_D^{g^*}}^{\varphi_C^{g^*}} \pi_D(\varphi)dG(\varphi) \\ + \int_{\varphi_C^{g^*}}^{\varphi_{DCX}^{g^*}} \pi_D(\overline{q},\varphi)dG(\varphi) + \int_{\varphi_{DCX}^{g^*}}^{\infty} \pi_{DCX}(\varphi)dG(\varphi) \end{bmatrix}$$

Table I4. Data and model moments

Region	τ^r	$\overline{q}^r$	Export intensity of indirect exporters		Share of DCXs	
			Data	Model	Data	Model
Export capacity constraints-sensitive industries	2.343	0.094	0.176	0.176	0.198	0.198
Other industries	1.372	0.100	0.515	0.515	0.182	0.182

Table I5. Potential gains of counterfactual analysis

	welfare	*tfp*	*export*
Eliminating export capacity constraint			
$\overline{q}=\infty$	0.34%	1.98%	5.08%
$\overline{q} = \max\limits_{r=1...8}\left(\overline{q}^r\right)$	0.002%	0.008%	0.047%
$\overline{q} = \min\limits_{r=1...8}\left(\overline{q}^r\right)$	-0.01%	-0.02%	-0.19%
Trade liberalization			
$\tau' = \tau(1-8\%)$	1.56%	7.09%	15.23%

Note: $\Delta\%$ represents percentage change of the variable in interest under export capacity constraints.