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International trade and firm innovation: patterns and evidence from the Chinese Employer-Employee Survey data

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ABSTRACT

How international trade fosters firm innovation is crucial in understanding how economic integration boosts productivity growth. This study uses the Chinese Employer-Employee Survey data set, which contains detailed, firm-level information on exports, imports, and innovation. The study documents several stylized facts characterizing the interaction between international trade and innovation among Chinese firms. The main findings are that exporters and importers are exceptional in production and innovation; exporters are more inclined to import material and machinery inputs; domestic and private firms do not seem to be more innovative than their counterparts.

Abbreviations: CEES: Chinese Employer-Employee Survey; FIE: Foreign investment enterprise; NBS: National Bureau of Statistics of China; SOE: State-owned enterprise

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1. Motivation

Productivity is a catalyst for economic growth. Understanding the driving force of productivity growth becomes a crucial issue not only for academia, but also for policy makers. On the one hand, firms' innovation is regarded as one of the most important internal sources of productivity growth. On the other hand, as global markets integrate, changing external circumstances incurred by trade liberalization are also key in triggering firms' productivity evolution. Therefore, the interaction between international trade and firm-level innovation behavior deserves further exploration.

How does international trade boost firms' innovation? Previous studies suggest various mechanisms through which international trade can foster innovation. Among these mechanisms, three are of particular interest for economists. The first is the competition effect. When a country opens up to trade, domestic producers are faced with more foreign competitors, forcing the domestic producers to upgrade their product quality and technologies to retain their market shares and profits for survival. Less capable firms may exit. The competition effect is discussed extensively, theoretically and empirically, by Pavcnik (2002), Melitz (2003), Melitz and Ottaviano (2008), and Bloom, Draca, and Van Reenen (2016).

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The second mechanism is the market size effect. Upon trade liberalization, domestic firms encounter a positive shock in the potential market size they are facing. As innovation behavior typically features economies of scale, increased market size can substantially reduce the average cost of innovation and hence stimulate firms' innovation motives. Lileeva and Trefler (2010) use the launch of North American Free Trade Agreement as a natural experiment, and find that increased market access does induce new exporters to improve their productivity by conducting more research and development (R&D) and adopting more advanced technologies. Verhoogen (2008) uses the peso crisis as a natural experiment, and finds that sharp depreciation of the home currency catalyzes the quality upgrading behavior of more productive exporters.

The third mechanism is the input variety effect. As import tariffs fall, domestic firms can obtain imported inputs more easily, on the extensive margin (more varieties) and the intensive margin (lower price with higher quality). Feenstra (1994) and Broda and Weinstein (2006) demonstrate that this effect is welfare enhancing. Empirical evidence provided by Amiti and Konings (2007), Goldberg et al. (2010), Topalova and Khandelwal (2011), and Yu (2015) documents that input tariff reductions lead to firm productivity growth through the input variety effect, using micro-level data from Indonesia, India, and China, respectively. Yu (2015) finds that in China, the productivity-enhancing effect of input tariff reductions is increasing as a firm's processing export share falls.

Although ample theoretical and empirical work has been devoted to understanding the interplay between international trade and firm innovation, various fields are still calling for clearer answers, particularly for China. As the largest country in international trade, and the largest developing country as well, how China benefits from trade liberalization in terms of productivity improvement is worth exploring. One of biggest obstacles hampering researchers in pursuing these answers lies in data limitations.

Researchers use several existing data sets to study the interaction between international trade and firm innovation. Three of the most widely used data sets are the Annual Survey of Industrial Firms from the National Bureau of Statistics of China (NBS data set henceforth), the Customs data set from the General Administration of Customs (Customs data set henceforth), and the Patent data set from the National Bureau of Statistics of China (Patent data set henceforth). The NBS data set is a firm-year panel data set maintained by NBS every year. It covers all state-owned enterprise (SOE) manufacturers and all non-SOE manufacturers with annual sales exceeding 5 million yuan. In the NBS data set, comprehensive production and financial information is recorded. However, although the NBS data set contains the value of export shipments, further information, such as export destinations or product categories, is absent. Moreover, the NBS data set does not contain any import information, and the R&D variable is subject to severe measurement error, with most firms reporting missing data for R&D expenses.

The lack of export and import information in the NBS data set can be partly resolved by merging the NBS data set with the Customs data set. The Customs data set contains detailed information on each export/import transaction, including firm name, firm ownership, transaction value, volume and unit, source/destination country, trade mode, and so on. Yu (2015) develops a procedure to match the two data sets by using firms' Chinese name, phone number, and zip code. Nevertheless, the Customs

data set does not distinguish whether a firm's imports are used for material inputs, machinery, or resale. Therefore, although analysis on this matched data set has already delivered insightful conclusions on how China's trade liberalization boosts firm productivity, one still cannot examine the input variety effect directly and precisely.

Similarly, merging the NBS data set with the Patent data set provides additional information for analysis of innovation. The Patent data set provides the date of application, date of publication, applicant, inventor, and International Patent Category of each patent registered with the State Intellectual Property Office of China. However, the matching is much more difficult, since, as noted by Xie and Zhang (2015), patent inventors must be individuals, while patent applicants can be firms, institutions, or individuals. Therefore, a large proportion of registered patents cannot be matched to any particular firm in the NBS data set using the name of the applicant or inventor. Loss of patent information thus undermines the validity of the NBS-Patent merged data in analyzing firms' innovation behavior.

Different from the currently widely used micro-level data sets, the Chinese Employer-Employee Survey (CEES) provides information on Chinese firms' production, exports/imports, and innovation behavior in a single data set for the first time. The novel and unique feature of the CEES data set comes from its detailed and comprehensive coverage of each firm. For example, various innovation indexes are surveyed, including the number of R&D workers, number of trademarks and brands, patents/inventions granted by China or other countries/regions or international organizations, and even usage of computer numerical control (CNC) devices. The CEES data set also documents detailed import information, including the extent of import material inputs and machinery.

The rich and detailed information in the CEES data set allows us to analyze directly the interplay between firms' involvement in international trade and their innovation behavior. In this paper, we explore patterns linking trade and innovation, using this novel data set. Rather than seeking to identify a causal relationship, our goal is first to use the CEES data set to confirm previous findings in the literature. For example, we aim to confirm whether exporters are exceptional in production and innovation, to validate the quality of the data. Further, we explore other aspects of the links between trade status and innovation, which have not been studied extensively, by documenting correlations between these variables. Our main findings are that importers are exceptional in production and innovation; exporters are more inclined to import material and machinery inputs; and domestic firms and private firms do not seem to be more innovative than their counterparts.

We first introduce the CEES data set in Section 2, and present some basic descriptive statistics. In Section 3, we document the correlation between export/import status and various production and innovation variables in the data set. We also explore correlations between export and import decisions, and between different ownership types and innovation behaviors. Section 4 draws conclusions from our findings, and motivates further research using this novel data set.

2. Description of the CEES data set

The CEES covers 570 randomly sampled manufacturing enterprises in Guangdong Province in 2014. Currently, one wave of the data is available; therefore, only cross-

sectional variations can be explored. However, lack of time-dimension variation is irrelevant for this paper, since our aim is to explore the cross-sectional variations in the new data set. The CEES data set covers a wide range of information, including firms' ownership structure, production and sales, innovation and quality upgrading, human resources, and so on. We mainly focus on the interaction between firms' export/import decision and innovation behavior.

Previous literature has typically used the NBS data set, which is an annual survey conducted by NBS every year. The NBS data set covers all SOE manufacturers and all non-SOE manufacturers with annual sales exceeding 5 million yuan. In contrast, the CEES data set is sampled from only one province, Guangdong Province, with a small sample size, leading to some potential concerns about the representativeness of the data set.

We argue that the sampling design does not cause any severe selection bias, since Guangdong is the largest province in China in gross domestic product; the size of the province's economy is comparable to that of Russia or Indonesia. In addition, many manufacturing clusters are located in Guangdong Province, making it an ideal resource for understanding China's role as the world's factory.

Moreover, compared with the NBS data set, the CEES data set is skewed toward large firms, although the NBS data set already consists of large manufacturers in the economy. Table 1, panel I, shows that the number of firms in the CEES data set accounts for 1.39% of the number of firms in Guangdong Province in the NBS data set. In addition, the totals of the value added, sales, and number of employees in the CEES data set account for 2.21, 4.70, and 4.24% of those in the NBS data set, respectively.

Table 1, panel II, shows comparisons of the means of the key variables in the two data sets. On average, firms in the CEES data set are larger than their counterparts in the NBS data set in value added, sales, and number of employees. Therefore, conclusions drawn from the CEES data set are more applicable to large manufacturers.

Since we mainly focus on the interaction between firms' export/import decision and firms' innovation, we provide descriptive statistics in Tables 2–4 to illustrate some features of this new data set.

For export information (Table 2, panel I), in addition to the value of total exports, the CEES data set provides firms' processing export value, export value through trade intermediation, and number of destinations. CEES also surveys firms' export share to the largest export destination country, and the share of the largest export product. In the sample, 65.8% of the firms export, and 27.5% of the firms conduct processing exports. Among exporters, 23.9% of their exports are processing exports on average. Of

Table 1. Comparison of key variables in the CEES and NBS data sets

	I. Sum comparison (in RMB1 millions)			
Total	Number of firms	Value added	Sales	Number of employees
CEES data	570	62,192	547,297	616,741
NBS data	41,154	2,818,869	11,633,646	14,557,800
Percentage (%)	1.39	2.21	4.70	4.24
	II. Mean comparison (in RMB10 thousands)			
Mean	Number of firms	Value added	Sales	Number of employees
CEES data	570	109,880	96,017	1092
NBS data	41,154	68,496	28,269	354

Table 2. Summary statistics: export and import variables

Variable	Obs.	Mean	Std. Dev.	Min	Max
I. Exports					
Export indicator	570	0.658	0.47	0	1
Exports (RMB1000)	567	210,939	3,278,427	0	7.48E+07
Processing indicator	570	0.28	0.45	0	1
Extent of processing exports (%)	567	23.93	38.51	1	100
Number of export countries	570	8.33	15.00	1	130
Trade intermediate indicator	570	0.58	0.49	0	1
High direct export indicator	570	0.44	0.50	0	1
Export share to the largest export country (%)	344	58.31	26.48	0.1	100
Export share of the largest export product (%)	351	74.89	27.47	0	100
II. Imports					
Extent of imported machinery (%)	570	22.13	40.75	0	100
Extent of imported inputs (%)	570	11.21	23.76	0	100
Imported machinery indicator	570	0.289	0.45	0	1
Imported inputs indicator	570	0.353	0.48	0	1

the firms in the sample, 58.1% export their products through trade intermediaries, and 43.9% export more than half of their products through direct export. Regarding diversification of destinations and products, the number of destinations ranges from one to 130, with an average of 8.33 destinations. On average, firms export 58.3% of their export value to the largest export destination country, and the share export value of their largest export product is 74.9%. Therefore, firms typically export multiple products to multiple destinations.

The CEES data set also provides firms' import information. In particular, the CEES data set focuses on imported inputs (Table 2, panel II), which are regarded as an important source through which firms can improve their productivity. Machinery inputs and material inputs are recorded separately. In the data set, 28.9% (35.3%) of firms report imports of machinery (materials), and, on average, firms source 22.1% (11.2%) of their machinery (materials) outside mainland China. Therefore, in the CEES data set, use of imported inputs is quite prevalent.

One of the salient features in the CEES data set is that it includes ample information on firms' innovation behavior. In addition to regular innovation measures, such as R&D and patents, the CEES data set provides information on trademark, product brand, and use of CNCs. To some extent, the use of CNCs directly measures firms' process innovation rather than product innovation. Table 3 shows that 46% of firms report that they use CNCs, and 26.8% of firms are classified as operating in a high-tech industry.

For the R&D dimension, on average, firms employ 57.7 workers for R&D, accounting for 7.2% of total employment. R&D expenses exhibit substantial growth compared with the previous year. The average expenditure on R&D was 12.2 million yuan in 2013 and 23.1 million yuan in 2014. Turning to patent data, 39.5% of firms reported patent applications in 2014. For the average firm, 21.7 patents were granted by China, and 5.3 patents were granted by other countries or regions, or international organizations during 2012–2014. Among the granted patents, 6.8 were inventions granted by China, and 2.6 were inventions granted by other countries or regions, or international organizations. The average firm also reports 5.2 trademarks and 1.2 product brands.

Table 3. Summary statistics: innovation variables

Variable	Obs.	Mean	Std. Dev.	Min	Max
Computer numerical control (CNC) indicator	568	0.460	0.499	0	1
High-tech indicator	570	0.268	0.444	0	1
Number of workers in R&D	570	57.67	263.6	0	5000
Ratio of number of workers in R&D	560	0.072	0.148	0	1
R&D expenses (RMB 10,000)	567	2310	24,613	0	550,000
R&D expenses in previous year (RMB 10,000)	566	1217	7355	0	132,000
Patent indicator	570	0.395	0.489	0	1
Number of patents granted by China	568	21.68	167.6	0	3500
Number of patents granted by foreign countries	568	5.336	38.1	0	800
Number of inventions granted by China	568	6.782	105.3	0	2500
Number of inventions granted by foreign countries	568	2.614	30.1	0	650
Number of trademarks	569	5.176	36.1	0	781
Number of product brands	569	1.204	2.712	0	50

Table 4. Summary statistics: ownership and production variables

Variable	Obs.	Mean	Std. Dev.	Min	Max
I. Type of Ownership					
Foreign indicator (HK/TW/MC included)	570	0.437	0.496	0	1
Foreign indicator (HK/TW/MC excluded)	570	0.139	0.346	0	1
State-owned enterprises indicator	570	0.016	0.125	0	1
II. Production					
Sales in previous year (RMB 10,000)	570	96,017	736,334	10	1.27E+07
Sales (RMB 10,000)	569	101,203	732,884	12	1.35E+07
Material expenses (RMB 10,000)	568	89,814	964,887	0	2.10E+07
Material expenses in previous year (RMB 10,000)	568	115,863	1,219,892	0	2.28E+07
Number of employees	561	1092	3,268	0	50,000
Number of employees in previous year	551	1152	3,473	0	48,000
Capital (net) (RMB 10,000)	570	120,936	2,527,418	0	6.03E+07
Capital (net) in previous year (RMB 10,000)	570	118,187	2,526,907	0	6.03E+07
Value added (RMB 10,000)	566	109,880	2,134,744	0	5.07E+07
Value added in previous year (RMB 10,000)	566	71,226	1,306,124	0	3.09E+07

Apart from information on exports, imports, and innovation, the CEES data set also records regular ownership and production information (Table 4, panels I and II). In the data set, 43.7% (13.9%) of firms report foreign ownership, including (excluding) Hong Kong/Macau/Taiwan ownership. Only 1.6% of firms report themselves as SOEs. CEES also reports the values of sales, material expenses, number of employees, net capital, and value added, in the current and previous years.

3. Export/import decision and innovation

The novel features of the CEES data set allow for direct exploration of the relationship between firms' export/import decision and firms' innovation. We first characterize several stylized facts that are widely documented in the previous literature; namely, exporters are exceptional in production and innovation, as revealed by Bernard and Jensen (1999), Eaton, Kortum, and Kramarz (2011), Melitz (2003), and others. In Section 3.1, we conduct an analysis to confirm previously documented findings that exporters are exceptional in production and innovation, therefore ensuring the validity of the CEES data set. We then proceed to explore the relationship between import status, ownership, and performance on production and innovation in Sections 3.2 and 3.3. In Section 3.4, we use regression analysis to wrap up all the findings.

Table 5. Are exporters exceptional in production?

	I. Non-exporters versus exporters		
Variable	Non-exporters	Exporters	Difference
Sales (RMB 10,000)	29,545	78,285	−48,740***
Sales in previous year (RMB 10,000)	20,092	70,988	−50,897***
Labor	297	1516	−1219***
Capital (10,000 yuan)	4231	15,205	−10,974***
Capital in previous year (RMB 10,000)	3718	14,208	−10,490***
Value added (RMB 10,000)	6472	13,571	−7098**
Value added in previous year (RMB 10,000)	5263	12,156	−6892***
Labor productivity (RMB 10 per worker)	12.6	11.26	1.339
	II. Non-exporters versus non-processing exporters		
Variable	Non-exporters	Exporters	Difference
Sales (RMB 10,000)	29,505	67,852	−38,347**
Sales in previous year (RMB 10,000)	20,014	62,550	−42,536***
Labor	281	1266	−984**
Capital (10,000 yuan)	4201	13,732	−9530***
Capital in previous year (RMB 10,000)	3686	12,393	−8707***
Value added (RMB 10,000)	6362	10,536	−4174***
Value added in previous year (RMB 10,000)	5150	9631	−4481***
Labor productivity (RMB 10 per worker)	12.62	11.41	1.218

All variables are winsorized at 1%. ** and *** denote significance at 5% and 1%, respectively.

3.1 *Are exporters exceptional?*

Table 5, panel I, shows that on average, exporters are exceptional in production: exporters are larger than non-exporters in sales, labor, capital, and value added, and the differences are all at least significant at the 5% level. These patterns are highly consistent with the findings of previous researchers. Yu (2015) and Dai, Maitra, and Yu (2016) document that Chinese processing exporters are less productive than ordinary exporters. Therefore, we exclude processing exporters and replicate the comparison in Table 6, panel II. The same patterns of production are observed for exporters when we exclude processing exporters.

In Table 6, we explore whether exporters are exceptional in innovation. Previous research has shown that exporters are on average more productive and more innovative. A simple comparison shows that exporters are more likely to use CNCs, more

Table 6. Are exporters exceptional in innovation?

Variable	Non-exporters	Exporters	Difference
Computer numerical control (CNC) indicator	0.35	0.52	−0.16***
High-tech indicator	0.19	0.31	−0.13***
Number of workers in R&D	15.31	79.70	−64.39***
R&D expenses (RMB 10,000)	3076	1915	1161
R&D expenses in previous year (RMB 10,000)	229	1724	−1495**
Number of trademarks	3.18	6.22	−3.04
Number of product brands	1.24	1.18	0.057
Patent indicator	0.29	0.45	−0.156
Number of total patents	6.81	37.69	−30.88*
Number of patents granted by China	4.39	30.73	−26.34*
Number of patents granted by foreign countries	2.42	6.86	−4.44
Number of total inventions	1.79	13.37	−11.58
Number of inventions granted by China	1.09	9.73	−8.64
Number of inventions granted by foreign countries	0.70	3.62	−2.92

*, **, and *** denote significance at 10%, 5%, and 1%, respectively.

likely to be in high-tech industries, and have more R&D workers and more R&D expenses in the previous year. Exporters also report more patents granted in total and more patents granted by China. All these differences are at least significant at the 10% level. Comparisons of other variables, although not significant, are mostly consistent with the claim that exporters are more innovative than non-exporters.

3.2 *Are importers exceptional?*

Since the CEES data set also documents firms' import information, we explore whether importers are exceptional compared with non-importers in production and innovation. Table 7, panel I, presents simple comparisons and t-tests for the production variables. On average, importers are larger in sales, labor, capital, and value added, and more productive as measured by labor productivity. All these differences are at least significant at the 5% level.

Turning to innovation, importers are more likely to use CNCs, more likely to be in high-tech industries, and have more trademarks and patent applications (Table 7, panel II). These differences are at least significant at the 10% level. Our preliminary findings also suggest that importers are exceptional in production and innovation, compared with non-importers.

We complement the analysis by looking into the relationship between exporting and importing. In particular, we are interested in whether exporters are more inclined to import. Table 8, panel I, presents the simple correlation between the export indicator and various import indicators. In the extensive margin, exporters are more inclined to import inputs and machinery; in the intensive margin, exporters import more inputs

Table 7. Are importers exceptional?

Variable	Non-importers	Importers	Difference
I. Production			
Sales (RMB 10,000)	32,192	96,757	−645,565***
Sales in previous year (RMB 10,000)	29,020	82,855	−53,836***
Labor	595	1693	−1098***
Capital (10,000 yuan)	5712	18,293	−12,581***
Capital in previous year (RMB 10,000)	5234	17,040	−11,806***
Value added (RMB 10,000)	5595	17,755	−12,160***
Value added in previous year (RMB 10,000)	5036	15,473	−10,437***
Labor productivity (RMB 10 per worker)	9.49	14.42	−4.93**
II. Innovation			
Computer numerical control indicator	0.29	0.66	−0.37***
High-tech indicator	0.18	0.38	−0.20***
Number of workers in R&D	43.93	74.07	−30.14
R&D expenses (RMB 10,000)	2734	1807	927
R&D expenses in previous year (RMB 10,000)	825	1682	−857
Number of trademarks	2.65	8.17	−5.52*
Number of product brands	1.24	1.16	0.078
Patent indicator	0.30	0.50	−0.201***
Number of total patents	21.70	33.50	−11.80
Number of patents granted by China	15.35	29.24	−13.90
Number of patents granted by foreign countries	6.33	4.15	2.18
Number of total inventions	12.29	5.93	6.36
Number of inventions granted by China	9.24	3.83	5.40
Number of inventions granted by foreign countries	3.06	2.08	0.98

*, **, and *** denote significance at 10%, 5%, and 1%, respectively.

Table 8. Do exporters import more?

	I. Correlations			
Export indicator	Imported machinery indicator 0.240	Extent of imported machinery 0.199	Imported inputs indicator 0.285	Extent of imported inputs 0.231

	II. Mean comparison and t-test		
Variable	Non-exporters	Exporters	Difference
Imported inputs indicator	0.16	0.45	−0.29***
Imported machinery indicator	0.14	0.37	−0.23***
Extent of imported inputs (%)	3.60	15.17	−11.57***
Imported machinery	5223.28	5286.87	−63.59

*** denotes significance at 1%.

and machinery on average. Table 8, panel II, compares the means of the various import indicators between exporters and non-exporters. The table clearly shows that exporters are 29% (23%) more likely to import inputs (machinery), and source an 11.6% larger proportion of their inputs from abroad than non-importers do. All these differences are significant at the 1% level. Exporters also import more machinery in value terms, but the difference is not significant. Therefore, our preliminary description shows that exporters import more inputs than non-importers do.

3.3 *Does ownership matter for innovation?*

In Table 9, we extend our analysis to ownership structure, by testing whether domestic firms are more innovative compared with their foreign counterparts. The table compares all the innovation variables between domestic and foreign firms. Apart from the fact that domestic firms are more likely than foreign firms to be in high-tech industries, which is significant at the 10% level, domestic firms do not exhibit a systematic premium or discount relative to foreign firms for the other innovation variables. Thus, we do not observe any descriptive evidence suggesting that domestic firms are more or less innovative.

Table 9. Are domestic firms more innovative?

Variable	Domestic	Foreign	Difference
Computer numerical control indicator	0.44	0.48	−0.04
High-tech indicator	0.30	0.23	0.06*
Number of workers in R&D	45.51	73.35	−27.84
R&D expenses (RMB 10,000)	1359	3543	−2,183
R&D expenses in previous year (RMB 10,000)	1213	1222	−9.14
Number of trademarks	3.68	7.12	−3.44
Number of product brands	1.32	1.06	0.26
Patent indicator	0.42	0.37	0.05
Number of total patents	24.57	30.27	−5.70
Number of patents granted by China	19.60	24.35	−4.76
Number of patents granted by foreign countries	4.96	5.82	−0.86
Number of total inventions	12.18	5.84	6.34
Number of inventions granted by China	9.42	3.40	6.02
Number of inventions granted by foreign countries	2.76	2.43	0.33

* denotes significance at 10%.

Table 10. Are private firms more innovative?

Variable	Private firms	SOEs	Difference
Computer numerical control indicator	0.46	0.33	0.13
High-tech indicator	0.26	0.78	−0.52***
Number of workers in R&D	57.48	69.78	−12.30
R&D expenses (RMB 10,000)	2331	1032	1299
R&D expenses in previous year (RMB 10,000)	1220	1042	178
Number of trademarks	5.05	12.78	−7.72
Number of product brands	1.19	2.33	−1.15
Patent indicator	0.39	0.89	−0.50***
Number of total patents	27.12	23.67	3.46
Number of patents granted by China	21.69	21.56	0.13
Number of patents granted by foreign countries	5.39	2.11	3.28
Number of total inventions	9.38	11.56	−2.18
Number of inventions granted by China	6.74	9.44	−2.71
Number of inventions granted by foreign countries	2.62	2.11	0.51

*** denotes significance at 1%.

Table 10 presents a similar comparison for private versus SOE ownership. Private firms are more likely to be in high-tech industries, and have more patent applications than SOEs do. These differences are significant at the 1% level. However, the other innovation variables do not suggest that private firms are more or less innovative than SOEs in a statistical sense. Therefore, in general, private firms do not demonstrate systematically exceptional performance in innovation compared with SOEs.

3.4 *Summary of results using the regression technique*

This subsection illustrates all the findings simultaneously, by including the export/import and ownership characteristics in a single regression. The descriptive regression strategy is specified as in Equation (1):

$$y_i = \alpha_1 \cdot FX_i + \alpha_2 \cdot FIE_i + \alpha_3 \cdot SOE_i + \varepsilon_i \tag{1}$$

where y_i is the production/innovation variable of interest, FX_i is the export indicator, FIE_i is the foreign ownership indicator, and SOE_i is the state ownership indicator. ε_i is the random error. We can replace FX_i with the importer indicator FI_i to generate a similar specification, as in Equation (2):

$$y_i = \alpha_1 \cdot FI_i + \alpha_2 \cdot FIE_i + \alpha_3 \cdot SOE_i + \varepsilon_i \tag{2}$$

We use the various production variables y_i in Equations (1) and (2) to investigate jointly whether exporters/importers, FIEs, and SOE are exceptional in production. Table 11 presents the results. Evidently, exporters and importers exhibit strong and robust size premiums in sales, labor, capital, and value added (or their values in the previous year), which are all significant at the 1% level. The estimates of α_1 suggest that exporters are on average 0.9–1.2 times larger than non-exporters, and importers are on average 0.8–1.05 times larger than non-importers. These findings are consistent with previous empirical evidence across different countries and firm-level data sets.

Moreover, FIEs and SOEs are found to be larger than their counterparts in sales, labor, capital, and value added (or their values in the previous year). The estimates of α_2 and α_3 are quite stable across different production variables, and are significant at the

Table 11. Are exporters/importers exceptional in production?

	I. Non-exporters versus exporters						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Variable	s_i	s_lag_i	l_i	k_i	k_lag_i	va_i	va_lag_i
FX_i	1.011***	1.043***	1.052***	1.093***	1.117***	0.896***	1.201***
	(4.08)	(4.16)	(7.77)	(4.11)	(4.30)	(2.72)	(3.54)
FIE_i	0.956***	1.057***	0.764***	0.654**	0.758***	0.847***	0.891***
	(3.98)	(4.39)	(5.60)	(2.51)	(2.95)	(2.62)	(2.69)
SOE_i	2.032***	1.986***	1.008**	2.573***	2.577***	2.820***	2.674***
	(2.59)	(2.59)	(2.56)	(3.54)	(3.47)	(3.15)	(3.06)
Observations	563	564	555	564	564	560	560
R-squared	0.18	0.19	0.32	0.20	0.20	0.15	0.15
	II. Non-importers versus importers						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Variable	s_i	s_lag_i	l_i	k_i	k_lag_i	va_i	va_lag_i
FI_i	0.947***	0.820***	1.042***	1.049***	1.005***	0.795**	0.785**
	(3.90)	(3.29)	(8.23)	(4.14)	(3.98)	(2.49)	(2.42)
FIE_i	1.103***	1.238***	0.908***	0.806***	0.926***	0.985***	1.132***
	(4.50)	(4.99)	(7.19)	(3.18)	(3.69)	(3.09)	(3.50)
SOE_i	2.121***	2.076***	1.103***	2.669***	2.675***	2.900***	2.779***
	(2.68)	(2.71)	(2.64)	(3.27)	(3.24)	(3.32)	(3.27)
Observations	563	564	555	564	564	560	560
R-squared	0.18	0.18	0.33	0.20	0.20	0.15	0.14

Robust t-statistics in parentheses. s_i, l_i, k_i, and va_i denote sales, labor, capital, and value added in logs, and s_lag_i, k_lag_i, and va_lag_i denote sales, capital, and value added in the previous year in logs. ** and *** denote significance at 5% and 1%, respectively.

1% level in most of the specifications. FIEs are 0.7–1.2 times larger than non-FIEs, and SOEs are 1–3 times larger than non-SOEs. These findings are aligned with empirical evidence documented in previous literature (for example, Hsieh and Klenow (2009)).

We now examine whether exporters, FIEs and SOEs are exceptional in innovation. We use various innovation variables as y_i in Equations (1) and (2). Table 12 presents the results. Consistent with the preliminary descriptive evidence, exporters are 16% more likely to use CNCs and to be in high-tech industries. Moreover, on average, exporters employ 70% more R&D workers, and spend 1.2–1.3 times more on R&D compared with non-exporters. These effects are all significant at the 1% level.

Turning to patent information, exporters are 20% more likely to apply for patents, and are granted 23 more patents, among which 20 more patents are granted by China on average. For patents granted by other countries/regions or international organizations, inventions, trademarks, and product brands, exporters also exhibit better performance (although not significant) than non-exporters do. Combining all this information, export status is strongly and positively correlated with innovation.

We turn to the ownership perspective. In contrast to the significant innovation differentials between exporters and non-exporters, ownership does not appear to be strongly correlated with innovation. Non-FIEs and SOEs are more likely to be in high-tech industries, and are more likely to apply for patents. However, the other innovation variables do not show any systematic differences between FIEs and non-FIEs, or SOEs and private firms, for example R&D, trademarks, product brands, and patents granted. Therefore, aligned with the descriptive evidence, domestic firms and private firms do not seem to be more innovative than their counterparts.

Table 12. Are exporters exceptional in innovation?

	I. R&D						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Variables	CNC_i	Hi_tech_i	l_rd_i	rd_i	rd_lag_i	tm_i	$brand_i$
FX_i	0.165***	0.163***	0.701***	1.215***	1.276***	1.948	0.272
	(3.43)	(3.90)	(4.37)	(4.35)	(4.91)	(0.99)	(1.06)
FIE_i	−0.032	−0.116***	0.170	−0.099	−0.089	3.544	−0.252
	(−0.71)	(−2.94)	(1.03)	(−0.36)	(−0.33)	(1.17)	(−0.97)
SOE_i	−0.038	0.271**	0.750	0.317	0.398	0.439	0.510
	(−0.24)	(2.38)	(1.47)	(0.31)	(0.38)	(0.05)	(0.58)
Observations	562	564	564	561	560	563	563
R-squared	0.13	0.21	0.17	0.16	0.17	0.05	0.06
	II. Patents						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Variables	pat_ind_i	pat_i	pat_CHN_i	pat_ROW_i	inv_i	inv_CHN_i	inv_ROW_i
FX_i	0.197***	22.817**	20.093**	2.640	9.208	7.454	1.752
	(4.24)	(2.06)	(2.17)	(1.31)	(1.20)	(1.23)	(1.07)
FIE_i	−0.110**	−6.174	−5.867	−0.309	−11.785	−10.253	−1.534
	(−2.50)	(−0.29)	(−0.33)	(−0.07)	(−0.81)	(−0.89)	(−0.47)
SOE_i	0.358***	−36.048	−26.070	−9.956	−29.051	−22.754	−6.297
	(3.06)	(−0.58)	(−0.52)	(−0.85)	(−0.62)	(−0.61)	(−0.65)
Observations	564	561	562	562	561	562	562
R-squared	0.19	0.07	0.07	0.06	0.08	0.08	0.07

Robust t-statistics in parentheses. CNC_i and Hi_tech_i are dummies indicating whether the firm uses computer numerical control devices or is in a high-tech industry, respectively; l_rd_i, rd_i, and rd_lag_i are the number of workers in R&D, R&D expenses in the current year, and R&D expenses in the previous year, respectively, in logs; tm_i and $brand_i$ are the number of trademarks and product brands the firm owns, respectively; pat_ind_i is a dummy indicating whether the firm has patent applications; pat_i, pat_CHN_i, and pat_ROW_i are the number of patents granted in total, granted by China, and granted by other countries/regions or international organizations, respectively; and inv_i, inv_CHN_i, and inv_ROW_i are the number of invention patents granted in total, granted by China, and granted by other countries/regions or international organizations, respectively. ** and *** denote significance at 5% and 1%, respectively.

An important caveat is that our goal in this paper is to explore correlations between firms' export/import decision and firms' innovation behavior, using a newly released and novel data set, rather than to identify any causality links between the variables of interest. Our preliminary descriptions have documented some stylized facts in the CEES data set. First, consistent with previous findings, exporters are on average exceptional in production and innovation, compared with non-exporters. Second, importers are also exceptional in production and innovation, compared with non-importers. Third, exporters are more inclined to import inputs. Fourth, domestic and private firms do not show any advantages in innovation compared with their counterparts.

4. Conclusion

As more and more micro-level data sets have become available to researchers, the interaction between international trade and innovation has been extensively studied. The CEES data set, for the first time, provides unified and detailed information on production, trade, and innovation for Chinese firms. The descriptive analysis in this paper confirms that exporters are exceptional in production and innovation, consistent with existing findings. We proceed to show that importers are also exceptional in

production and innovation; exporters are more likely to import; and firms under different ownership structures do not seem to vary significantly in innovation.

These patterns are all worth further exploration to identify causality between involvement in international trade and innovation. For example, does more imported machinery induce more R&D and patents granted for the importing firm? Or does the outcome of R&D require more usage of high-quality imported inputs? Using this new and novel data set, empirical research can generate new insights for understanding the existing and new channels through which trade and innovation affect firm performance and aggregate outcomes.

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