Bilateral Economies of Scope*

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Abstract

International transactions are costly because they require investments in logistics, contracts, and the acquisition of local institutional knowledge. We posit that a portion of the fixed costs of entering a specific export market can be used toward costs of acquiring imports from that same market, and vice versa. Using dis-aggregated transactions data for Chinese firms from 2000 to 2015, we document firm-level trading patterns that suggest such market-specific bilateral economies of scope. Using a structural model, we estimate that the simultaneous export and import in a given country reduces export and import fixed costs by over 41 and 37 percent, respectively.

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1 Introduction

International transactions are costly, requiring participating firms to make large investments in logistics, contracting, and foreign institutional knowledge. Since the publication of the seminal paper by Melitz (2003), the literature has developed an appreciation of the size and nature of these costs. The fact that only the most productive firms export and import suggests substantial fixed costs to both activities. The size and nature of these fixed costs have implications for almost every dimension of international economics including the welfare effects of trade policy (e.g. Costinot, Rodríguez-Clare, and Werning, 2020), the effect of trade liberalization on aggregate productivity (e.g. Pavcnik, 2002), and exchange rate pass-through (e.g. Amiti, Itskhoki, and Konings, 2014).

The goal of this paper is to present stylized facts on and to estimate the size of *h9}c0§] q0H_»H @_e9§0}9e 0Hnjnh_0 nT Hnq0* in international trade, which arises when resources used to pay the fixed cost of entering a specific export (import) market can be simultaneously used toward paying the fixed cost of establishing an import (export) relationship in the same market. For example, firms may use the same translation service for both export and import purpose, or hire lawyers to meet the market-specific regulations on both sides.

We provide three sets of facts that corroborate the above narrative based on the universe of Chinese firm-country-level transaction data from 2000 to 2015. Our first observation is that, given a specific foreign market, the share of exporters conditional on being importers from that market is around an order of magnitude larger than that for the non-importers. Symmetric patterns are observed if we look at the conditional share of importers. To substantiate the relationships between firm's export and import within the same country, we conduct firm-country-level regression analysis following Chaney (2014) and Morales, Sheu, and Zahler (2019), and show firm's import (export) experience in a given country significantly increases the likelihood of exporting to (importing from) that market. Several additional robustness tests further confirm this finding, where we use Arellano-Bond dynamic panel regressions, isolate (non)foreign-related firms and perform sub-sample analysis across different periods. At the aggregate level, such market-specific export-import interdependence manifests itself as a pronounced positive correlation between the rankings of the destinations in number of Chinese exporters and the rankings of the origins in number of Chinese importers. Despite the fact that competing drivers (such as the correlations of country-level characteristics) might account for the documented findings in isolation, these facts as a whole suggest the presence of the market-specific bilateral economies of scope.

To estimate the size of our mechanism when various competing forces are present, we extend the quantitative framework of Antràs, Fort, and Tintelnot (2017) (AFT) to an environment where firms simultaneously source inputs from a set of origins and sell differentiated final products to these markets. Firms that engage in only export face a distribution of export fixed costs by market while firms that engage in only import face a different distribution of fixed costs by market. To incorporate economies of scope in bilateral trading relations, we

allow these distributions to shift downward when exports and imports are simultaneously arranged for a given market. We show that the model inherits the tractability of AFT in that it allows for separate identification of the parameters associated to country-level characteristics (e.g., sourcing and sales potential) and the parameters governing firm pricing and trade profile (e.g., the elasticity of substitution across exported goods and across imported goods).

The separation of identification allows us to estimate the model in a less numerically cumbersome way, where we extend the algorithm of Jia (2008) and Arkolakis, Eckert, and Shi (2022) to a setting when firm's export and import choices across countries are jointly determined. Disciplined by the aforementioned stylized facts and estimated via the simulated method of moments routine, the model identifies large market-specific bilateral economies of scope: simultaneous export and import in a given market reduces, on average, export fixed cost by 41 percent and import fixed cost by 37 percent.

We show the estimated model aligns with the empirical regularities regarding the trade decisions of exporter and importer, their relative size to domestic firms, and the correlations between firm's export and import profiles. Based on the model, we assess its ability in replicating the documented correlations between the ranking of sourcing and exporting destinations by confronting the performance of the baseline against that of a series of restricted models, where we selectively mute the bilateral economies of scope mechanisms. The exercise separates our mechanism with the competing ones and thus enables transparent comparison on the quantitative performance of different channels. We show that roughly all of the rank-rank correlations are explained by the baseline model, 61% are explained when there is unilateral cost reduction and 38% when there is no fixed cost reduction at all. The practice underscores the role of two-sided cost reduction in understanding the Chinese firms' bilateral partnerships.

The estimated model provides a flexible quantitative device to study the aggregate impact as well as firm's response to various types of trade shocks. We are interested in how our mechanism adds to the understanding on the impact of trade liberalization on Chinese firms' global market participation. An important feature of China's accession to the WTO is that there are two-sided trade cost reductions. While canonical trade models study the impact of export and import liberalization in isolation, our model allows for simultaneous trade cost reductions from both sides and allows for the dissection of Chinese firm's global market accession into the contributions from different sides of trade liberalization. By sequentially feeding the models with the estimated trade shocks, we find that the aggregate impact of import (export) liberalization on export (import) entry are three times larger for the baseline specification compared to the restricted one. Such difference at the aggregate level originates from firm-level amplification where the import (export) liberalization induces much larger response to firm's export (import) participation when the bilateral cost reduction mechanisms are present.

We contribute to several strands of literature. First, our paper is related to the recent

study of complementarity between firm's export and import activity. Exporters and importers are more productive, with the most productive ones being both and accounting for substantial share of international trade flow (Bernard et al., 2009; Muûls and Pisu, 2009). The relationships between firm's export and import activities play an important role in shaping several margins of international trade (Bernard et al., 2018) and firm's strategic behavior in trade, such as exchange rate pass-through (Amiti, Itskhoki, and Konings, 2014). Empirical works also document causal linkage through which firm's importing activity promotes export performance (Feng, Li, and Swenson, 2016; Pierola, Fernandes, and Farole, 2018). Our paper provides a unified account on the relationships between firm's export and import decisions across countries, by documenting new stylized facts and gauging the quantitative magnitude through the lens of an estimated structural model.

We also add to the theoretical and quantitative work on firm's optimal trade decisions. While the existing papers examine the determinants of firm's export decisions (e.g. Chaney, 2008; Eaton, Kortum, and Kramarz, 2011; Tintelnot, 2017) or import decisions (e.g. Antràs, Fort, and Tintelnot, 2017) in isolation, our model allows for a more flexible and potentially inter-dependent bilateral trade linkages. Our study is similar to Antràs et al. (2022) in studying the joint production and sourcing decisions for firms. We differ from their work in two critical aspects. First, Antràs et al. (2022) emphasize the bilateral economies of scope induced by FDI. In contrast, we focus on a bilateral cost reduction mechanism leading to within-firm export-import complementarity, which applies to a wider scope of firms. Second, we highlight the market-specific nature of the bilateral economies of scope. This has important policy implications because it suggests that a change in trade policies, e.g., regional trade agreement (RTA) and preferential trade agreement (PTA), affects bilateral trade relationships with targeted countries disproportionately more than the others.

Finally, this paper is complementary to a large strand of literature on trade policy and firm performance, particularly to those studying the relationship between trade liberalization and global market participation (Amiti and Konings, 2007; Kasahara and Rodrigue, 2008; Brandt et al., 2017). Our estimated model provides a quantitative device to analyze and decompose the impact of trade cost reductions, especially when both export and import liberalization are present. In addition, the findings that the effect of export (import) liberalization gets amplified through import (export) entry suggest potential under-estimation on the impact of trade policy shock when the bilateral economies of scope is neglected.

The remainder of this paper is structured as follows. Section 2 provides conceptual and empirical motivations for our study. Section 3 presents a quantitative trade model that reconciles the empirical regularities. Section 4 provides several remarks regarding the quantitative model and discuss how to connect the model to data. Section 5 presents the estimation results and Section 6 shows counter-factual experiments. Finally, Section 7 concludes.

2 Motivations

In this section, we first illustrate the idea of market-specific bilateral economies of scope with a fixed costs structure. Then, we present several stylized facts suggesting the existence of such bilateral economies of scope using dis-aggregated transaction level data for Chinese firms. Finally, we provide further robustness checks.

2.1 Conceptual Motivation

In this paper, we explore the market-specific bilateral economies of scope as one key determinant of firm's export and import decisions across countries. It is based on the idea that to some extent, fixed investments of exporting to one country can be simultaneously used to covering the fixed investments of importing from the same country, and vice versa. As a result, when firm trades with a country in both directions, it saves part of export fixed cost and also part of import fixed cost.[o]

Table 1 enumerates firm's market-specific fixed cost bundles conditional on different export and import decisions. If a firm only exports to or only imports from the foreign country, its fixed costs payment is given by f^X and f^M, respectively. The bilateral economies of scope arises when firm engages in both export and import activities within the foreign country. In this case, firm's export fixed cost is reduced by $_0$ fraction while its import fixed cost is reduced by $_1$ fraction. Therefore, it is cost-effective to export to and import from a foreign country simultaneously. The total cost saving is given by the sum of $_0 f^X$ and $_1 f^M$. Moreover, we assume that firm's trade decisions in a country do not affect fixed costs in trading with other countries due to the legal, cultural and geographic gap across borders. In other words, such bilateral economies of scope is market-specific.

Table 1: Market-Specific Economies of Scope and Fixed Investments in Exporting and Importing

Export Dummy \ Import Dummy	0	1
0	$[0; 0]$	$[0; f^M]$
1	$[f^X; 0]$	$(1 \quad _0) f^X; (1 \quad _1) f^M$

i n§0I This table shows the different bundles of fixed investments firm needs to pay when deciding whether to export to and/or import from a foreign country. Export/Import dummy takes value one if firm exports to/imports from foreign.

In reality, the cost saving from concurrent export and import in a foreign country can

[1]This echos the finding of Grieco, Li, and Zhang (2022) that importing (exporting) experience significantly reduces export (import) fixed cost for Chinese firms, though they do not consider this mechanism as market-specific.

emerge from a business travel that helps firm to get familiar with not only local customers but also suppliers, or from hiring a lawyer or translator facilitating trade in both directions—both coming along with potentially asymmetric benefits on export and import fixed costs. Another example is that firm contracting with transportation company for both selling to and sourcing from a foreign country saves on receiving favorable contractual terms simply due to larger scope in two-way transactions compared to the case with only export or only import. Then the saved costs could be in terms of fixed investment in trade.

An immediate implication from the fixed costs structure is, exporters in a foreign country are more likely to import from the same country compared to non-exporters because of lower import fixed costs they need to pay. Symmetrically, importers in a foreign country are more likely to export to the same country compared to non-importers. Therefore, the fixed costs structure generates firm's export-import complementarity in the same foreign country.

2.2 Empirical Motivations

In this section, we describe the data and present empirical evidence consistent with the conceptual discussion above.

Data Description Our main data source, Chinese Customs Trade Statistics (henceforth CCTS) maintained by General Administration of Customs of China (2000-2015), covers the universe of Chinese export and import transactions. We restrict attention to ordinary trade records only and exclude processing trade records from our sample.[©] This is to focus on firm's trade decisions that reflect their active and strategic investment in finding foreign costumers and suppliers.[¨] Furthermore, we keep only manufacturing firms and drop trade intermediaries from our sample (Ahn, Khandelwal, and Wei, 2011). The basic units of our analysis are firm-country-year triplets indicating firm's trade decisions across foreign countries in each year from 2000 to 2015. In the baseline sample, we limit our attention to firm's import of intermediate goods and export of final goods identified by Broad Economic

[2]In the customs sample, firms may engage in both ordinary trade and processing trade. We only drop their trade records classified as processing trade. As a result, there are two types of firms in our sample: firms who only do ordinary trade and hybrid firms who do both. The empirical results are robust to taking into account the second type of firms. See Appendix A.2 for more details. Furthermore, in Section 2.3.1, the presence of hybrid firms allow us to use firm's processing trade experience as an instrument in system GMM estimation following Feng, Li, and Swenson (2016)'s estimation strategy.

[3]Under processing trade, it is mandatory for Chinese firms to export assembled goods back to foreign supplier (pure assembly, PA) or to any foreign country (import and assembly, IA). This generates a mechanical correlation between firm's export and import decisions which reflects only supply contract firm signed with foreign company but not firm's own trade strategy. For this reason, we drop processing trade records from the sample. However, the issue still remains if firms have under-reported processing trade in customs. Nevertheless, given that tariff duty can be exempted if transaction is reported as processing trade, one should anticipate firms in general would over-report their processing trade status. See Chen et al. (2021) for details on the R&D expenditure over-reporting induced by R&D subsidy in China. Hence, dropping the observed processing trade records is sufficient to remove most supply chain or offshoring relationship of Chinese firms. In Appendix A.2, we conduct several additional tests suggesting that the unobserved processing trade is not a major driver for our empirical findings.

Categories Revision 4 (BEC4). This is to bring our empirical analysis closer to quantitative framework where firms are assumed to import intermediate inputs and export final products. Our empirical results remain stable to including all types of goods in the sample. Finally, we focus only on the top 30 export destinations and top 30 import sourcing origins for China in terms of trade value that account for, on average, over 93% of China's annual export value and 96% of annual import value.[V] As our study focuses on firm's trade decisions at the extensive margin, this restriction helps to eliminate firm's ad-hoc trading activity in small countries and also makes both empirical and quantitative analysis computationally feasible. Appendix A.1 lists detailed data cleaning process for CCTS. Finally, in 2007, the customs sample contains over 68,000 unique Chinese exporters and the mean and median number of export destination per exporter is 5.77 and 2, respectively. On the import side, there are about 82,000 unique importers in 2007. The mean and median number of import sourcing origins per importer is 3.01 and 2, respectively.

In addition, we obtain firm's accounting information, such as total sales revenue and total input purchase from the Annual Survey of Industrial Enterprise (henceforth ASIE) from National Bureau of Statistics of China (1998-2009). We follow the standard approach in cleaning ASIE, e.g. dropping observations with missing or wrong sales revenue, output, establishment date, and employment.[U] Merging ASIE and CCTS gives us a full picture of Chinese firms' sales and sourcing activity in both domestic and foreign countries. In the merged sample, there are around 300,000 firms in 2007, and the share of exporters and importers is 8.73% and 10.78%, respectively. Lastly, the gravity variables including population weighted geographic distances, indicator for common language are from the CEPII.

With the above data, we test the presence of market-specific bilateral economies of scope. Fact 1 shows our first piece of evidence from testing the key implication of the fixed costs structure in Table 1.

Fact 1. *Sn} 9 qOH_»H Tn}0_Xj Hn«j§}´J§\0 \9}0 nT G_j0 0 0²qn}§0} r_hqn}§0} s HnjL_§_nj9e nj @0_jX _hqn}§0} r0²qn}§0} s _ _Xj_»H9j§e´ _X\0} §\9j §\9§ HnjL_§_nj9e nj @0_jX jnj] _hqn}§0} rjnj]0²qn}§0} su*

Table 2 shows the conditional shares of exporters (column (1)-(2)) and the conditional shares of importers (column (4)-(5)) for different groups of firms in China. Column (1) presents the share of exporters in a foreign country among firms who also import from the same country and column (2) calculates the share of exporters among those who do not import from that country. Then in column (3), we present the ratio between these two conditional shares, indicating importers' advantage in export participation relative to non-importers. Symmetrically, we calculate the share of importers in a foreign country

[4]In 2007, the top 30 export destinations and top 30 import sourcing origins include 36 unique foreign countries.

[5]See, for example, Brandt, Van Biesebroeck, and Zhang (2012).

for exporters in the same country (column (4)) and for non-exporters (column (5)). The ratio in column (6) stands for exporters' advantage in import participation relative to non-exporters. In the first two rows, we define exporter and importer for each foreign country separately[£], calculate the conditional shares, and then take the mean level (the first row) and the median level (the second row) across countries. Hence, the results represent an average foreign country. According to the first row, on the export side, the probability of an importer in a foreign country becoming an exporter in the same country is 9.33 times that of a non-importer. Similarly, on the import side, firm exporting to one country is 9.05 times more likely to import from the same country relative to a non-exporter. The above findings echo our conceptual discussion in the previous section, suggesting the presence of market-specific bilateral economies of scope.

We also conduct the same calculation for the global market as a whole (the last row) and show that the ratios in this case are significantly lower than that for the average foreign country.[¢] Specifically, the importers' (exporters') advantage in export (import) participation is, on average, 46.47% (59.33%) higher for average country (the mean level in the first row) than for global market.[P] It suggests that a large fraction of the ratios in the first two rows should be attributed to market-specific factors.

We further validate the idea of market-specific bilateral economies of scope with an empirical model. The aim is to show whether firm's import (export) decision in a country plays a significant role in its export (import) decision for the same country, after taking into account several well-documented determinants of firm's trade decisions. Throughout the reduced-form exercises, we use the customs sample from 2000 to 2015 to fully utilize the data. We keep only firms who at least export to a foreign market and import from a foreign origin in each year, i.e. two-way traders. This is to ensure all firms in our sample are able to export and import at the same time.[k] The finding is summarized in Fact 2.

Fact 2. *S_}hl q9 § _hqn}§_jX r0²qn}§_jXs 0²q0}_0jH0 _j nj0 Hn«j§}´ _Xj_»H9j§e´ _jH}09 0 §\0 e_c0e_\nnL nT @0_jX 9j 0²qn}§0} r_hqn}§0}s _j §\0 9h0 Hn«j§}´ _j §\0 H«}}0j§ ´09}u*

Following Chaney (2014) and Morales, Sheu, and Zahler (2019), we specify the following

[6]For instance, if a firm only exports to US, then it is considered as exporter only when we do the calculation for US. When we calculate conditional shares for the other countries like Japan, the firms is considered as a non-exporter.

[7]In the case of the global market, exporters are defined as firms that export to any foreign country and importers are defined as those who import from any foreign country in the sample.

[8]The pattern remains stable to alternative calculation methods and to different years. For instance, we may first calculate ratios for each foreign country and then take mean level of ratios across countries. In this case, the mean ratio across countries is 10.19 and 9.10 on export and import side, respectively. A simple t-test rejects the null hypothesis that the mean ratio across countries is lower than or equal to that for global market with p-value 0.00 on both export and import side.

[9]Including one-way traders generates downward bias in our estimates as they only trade with foreign countries in one direction. The empirical results are robust to including all firms, to using merged sample as in Fact 1, and to restricting the number of foreign countries.

Table 2: Conditional Share of Exporters and Importers

	Share of Exporters			Share of Importers		
	Importers	Non-Importers	Ratio	Exporters	Non-Exporters	Ratio
	(1)	(2)	(3)	(4)	(5)	(6)
Avg. Cty. (Mean)	9.68%	1.04%	9.33	7.34%	0.81%	9.05
Avg. Cty. (Median)	7.43%	0.73%	10.18	4.72%	0.52%	9.08
Global Market	35.23%	5.53%	6.37	43.47%	7.65%	5.68

i n§0I This table shows the conditional share of exporters (column (1)-(2)) and importers (column (4)-(5)). Column (1) presents the share of exporters in a foreign country among importers in the same country and column (2) presents the share of exporters in a foreign country among those who do not import from that country. Column (3) calculates the ratio between figures shown in column (1) and (3). Symmetrically, column (4)-(6) show the share of importers in a foreign country among exporters in the same country, the share of importers among non-exporters, and the ratio between these two conditional shares. This exercise uses the merged sample of ASIE and CCTS which includes top 30 export destinations and top 30 sourcing origins for China in year 2007, amounting to 36 foreign countries. The patterns are robust if we look across different years.

regression equations:[10]

$$\begin{aligned}\Pr(\text{Trade}_{fct} > 0 | \text{Observables}) = {} & {}_1\mathrm{I}\left[\text{Imp.}_{fct\ 1} > 0\right] + {}_2\mathrm{I}\left[\text{Exp.}_{fct\ 1} > 0\right] \\ & + \text{Standard Gravity}_{G[i;ct} \\ & + {}_1\text{Extended Gravity: Distance}_{fct\ 1} + {}_2\text{Remoteness}_{ct\ 1} \\ & + {}_3\text{Other Extended Gravity}_{fct\ 1} \\ & + !\,\text{Controls}_{ft\ 1}); \end{aligned} \tag{1}$$

where Trade_{fct} 2 $\text{Exp.}_{fct}; \text{Imp.}_{fct}$ denotes firm f's export or import value in country c in year t. The corresponding dummy for trade decision is denoted by $\mathrm{I}\{\text{Trade}_{fct} > 0\}$ which takes the value one if firm f exports to or imports from country c in year t. We control for firm-level and country-level factors such firm size, productivity and country size using firm-year fixed effect and country-year fixed effects whenever possible. These forces might affect firm's trade decisions and work independently from our mechanism. As a result, the identification of market-specific bilateral economies of scope comes from variation of firm's trade decisions across countries that are not driven by firm-level and country-level characteristics. ( ) is the cumulative density function of the standard normal distribution, leading to a Probit model of firm's trade probability as in Chaney (2014). Compared to the previous reduced-form exercise which studies either firm's export decisions or import decisions separately, the new feature of our empirical model is to include firm's past import decision, $\mathrm{I}\left[\text{Imp.}_{fct\ 1} > 0\right]$ as a key explanatory variable when estimating its export prob-

[10]The reason why we estimate the lagged effect here is to be consistent with previous studies of firm trade decisions. Our results are robust to including firm's current trade decision or focusing on the contemporaneous effect only.

ability, and to include its past export decision, $\mathbf{I}\ \ \text{Exp.}_{fct\ \ 1} > 0$ when estimating import probability. Note that we also incorporate the standard gravity variables and the extended gravity variables following the practice of Chaney (2014); Morales, Sheu, and Zahler (2019). Appendix A.4 presents detailed construction of extended gravity variables. This is to capture the fact that firm is more likely to trade with countries that are geographically close to its established export and import network or share other characteristics with the countries that it exported to and imported from, such as language and income level.

Table 3 shows the regression result, where the dependent variable is an indicator for firm's current export decision in a foreign country. Column (1) reports the two coefficients of our interest, one showing the effect of firm's past import experience from a foreign country on its current export decision to the same country and the other measuring country-specific export persistence; column (2) adds the firm-level controls including the number of export destinations, the number of import sourcing origins, and firm ' s export and import values; column (3) incorporates the country fixed effects, and column (4) instead uses the country-year fixed effects. The results from column (1) to (4) show that firm 's past import experience in a foreign country has a significant and positive effect in facilitating export decision to the same country. In addition, there is strong persistence in firm's export presence, which is a standard result in the exporter dynamics literature (e.g. Albornoz et al. (2012); Chaney (2014); Morales, Sheu, and Zahler (2019)). Columns (5) to (7) include the extended gravity variables, and the results remains stable.[oo] Taking column (7) as the baseline result, the coefficient on the past import decision is 0.287 and the corresponding marginal effect is 0.028, suggesting that importing from a country increases the probability of firm exporting to the same country by 2.8%. The coefficient measuring export persistence is 1.277 and its marginal effect is 0.126 which indicates that past export experience increases the probability of firm continuing to export by 12.6%. Overall, the results suggest, at firm level, market-specific import experience is an important determinant of current export decision. In Table 4, we show firm's past export decision affects its current import decision in a symmetric way. In column (7), the estimated coefficient on past export decision is 0.286 and the marginal effect is 0.017, while the estimated coefficient measuring firm's import persistence is 1.474 and its marginal effect is 0.088. In a nutshell, these results suggest that firm's bilateral trade decisions in a foreign country are inter-dependent.

[11] We cannot control for all firm-level characteristics using fixed effects due to large number of firms in our sample. In a robustness check, we pick a single industry with limited number of firms in which we are able to add firm fixed effects in Probit model, and our qualitative results remain stable. In Appendix A.3, we instead use a linear probability model. This allows us to control for firm-level time-varying factors that may affect our results with firm-year and firm-country fixed effects. We obtain qualitative results similar to the Probit model.

Table 3: The Effect of Import Choice on Export Decision: Probit

	Dependent Var.: I Exp.$_{fct}$ > 0						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
I Imp.$_{fct\ 1}$ > 0	0.483***	0.590***	0.327***	0.328***	0.487***	0.286***	0.287***
	(0.00356)	(0.00309)	(0.00335)	(0.00337)	(0.00282)	(0.00307)	(0.00309)
I Exp.$_{fct\ 1}$ > 0	2.087***	1.792***	1.555***	1.551***	1.488***	1.281***	1.277***
	(0.00410)	(0.00343)	(0.00381)	(0.00383)	(0.00324)	(0.00351)	(0.00352)
Exp. Ext. Distance$_{fct\ 1}$					-0.176***	-0.220***	-0.220***
					(0.00201)	(0.00220)	(0.00221)
Exp. Ext. Contiguity$_{fct\ 1}$					0.217***	0.206***	0.205***
					(0.00207)	(0.00270)	(0.00271)
Exp. Ext. Continent$_{fct\ 1}$					0.195***	0.208***	0.209***
					(0.00326)	(0.00371)	(0.00371)
Exp. Ext. Com. Lang.$_{fct\ 1}$					0.191***	0.268***	0.268***
					(0.00195)	(0.00280)	(0.00282)
Exp. Ext. Income Group$_{fct\ 1}$					0.403***	0.309***	0.311***
					(0.00324)	(0.00387)	(0.00399)
Constant	-0.652***	-0.788***	-2.337***	-2.529***	-5.775***	-9.662***	-11.69***
	(0.0203)	(0.0233)	(0.0155)	(0.0361)	(0.0322)	(0.176)	(0.608)
Gravity Variables	YES	YES	YES	YES	YES	YES	YES
Firm-level Controls	NO	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES	YES
Country FE			YES			YES	
Country-Year FE				YES			YES
Observations	13,026,937	13,026,937	13,026,937	13,244,910	12,840,780	12,840,780	13,020,420
Pseudo R^2	0.384	0.412	0.447	0.449	0.438	0.466	0.468

i n§0I This table presents the estimation results from specification (1) using Probit model. The dependent variable is firm f's export decision in country c in year t. Firm-level controls include the number of export destinations, the number of import sourcing origins, and firm ' s export and import values. Extended gravity for distance$_{fct\ 1}$ is constructed following Chaney (2014) while the other extended gravity variables are constructed after Morales, Sheu, and Zahler (2019). Standard gravity variables include distance, indicator for contiguity, common continent, common language, common income group and RTA between China and foreign country, and foreign GDP per capita. Standard errors are in the parentheses and clustered at firm and country level. The number of asterisk indicates significance at 1%(***), 5%(**) and 10%(*) level.

Table 4: The Effect of Export Choice on Import Decision: Probit

	Dependent Var.: I Imp.$_{fct}$ > 0						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
I Exp.$_{fct\ 1}$ > 0	0.433***	0.563***	0.318***	0.320***	0.489***	0.285***	0.286***
	(0.00381)	(0.00301)	(0.00323)	(0.00323)	(0.00291)	(0.00309)	(0.00310)
I Imp.$_{fct\ 1}$ > 0	2.282***	2.032***	1.702***	1.696***	1.812***	1.478***	1.474***
	(0.00439)	(0.00349)	(0.00383)	(0.00384)	(0.00369)	(0.00391)	(0.00392)
Imp. Ext. Distance$_{fct\ 1}$					-0.0971***	-0.186***	-0.186***
					(0.00196)	(0.00219)	(0.00221)
Imp. Ext. Contiguity$_{fct\ 1}$					0.279***	0.195***	0.194***
					(0.00284)	(0.00355)	(0.00355)
Imp. Ext. Continent$_{fct\ 1}$					0.128***	0.0601***	0.0600***
					(0.00348)	(0.00424)	(0.00426)
Imp. Ext. Com. Lang.$_{fct\ 1}$					0.120***	0.176***	0.175***
					(0.00251)	(0.00355)	(0.00356)
Imp. Ext. Income Group$_{fct\ 1}$					0.253***	0.147***	0.141***
					(0.00335)	(0.00425)	(0.00445)
Constant	2.301***	2.632***	-2.254***	-2.353***	-1.469***	-0.759***	-0.877***
	(0.0234)	(0.0257)	(0.0140)	(0.0353)	(0.0406)	(0.0243)	(0.0404)
Gravity Variables	YES	YES	YES	YES	YES	YES	YES
Firm-level Controls	NO	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES	YES
Country FE			YES			YES	
Country-Year FE				YES			YES
Obs.	11,712,877	11,712,820	11,712,820	11,764,732	11,543,307	11,712,820	11,764,732
Pseudo R^2	0.468	0.492	0.536	0.537	0.504	0.544	0.546

i n§0I This table presents the estimation results from specification (1) using Probit model. The dependent variable is firm f's import decision in country c in year t. Firm-level controls include the number of export destinations, the number of import sourcing origins, and firm ' s export and import values. Extended gravity for distance$_{fct\ 1}$ is constructed following Chaney (2014) while the other extended gravity variables are constructed after Morales, Sheu, and Zahler (2019). Standard gravity variables include distance, indicator for contiguity, common continent, common language, common income group and RTA between China and foreign country, and foreign GDP per capita. Standard errors are in the parentheses and clustered at firm and country level. The number of asterisk indicates significance at 1%(***), 5%(**) and 10%(*) level.

Finally, at the aggregate level, a natural prediction based on previous findings is: country with more Chinese exporters should have more Chinese importers as well. To show whether this is the case, we rank foreign countries by the number of Chinese exporters and importers separately. Figure 1 scatters country's export rank and its import rank from China's perspective. The correlation between two ranks is positive and large (0.75), suggesting that country with a larger number of exporters from China also has a larger number of Chinese importers. Fact 3 summarises the finding.

Fact 3. *Gn«j§}´ °_§\ hn}0 G_j0 0 0²qn}§0} 9℮ n \9 hn}0 G_j0 0 _hqn}§0}* ш

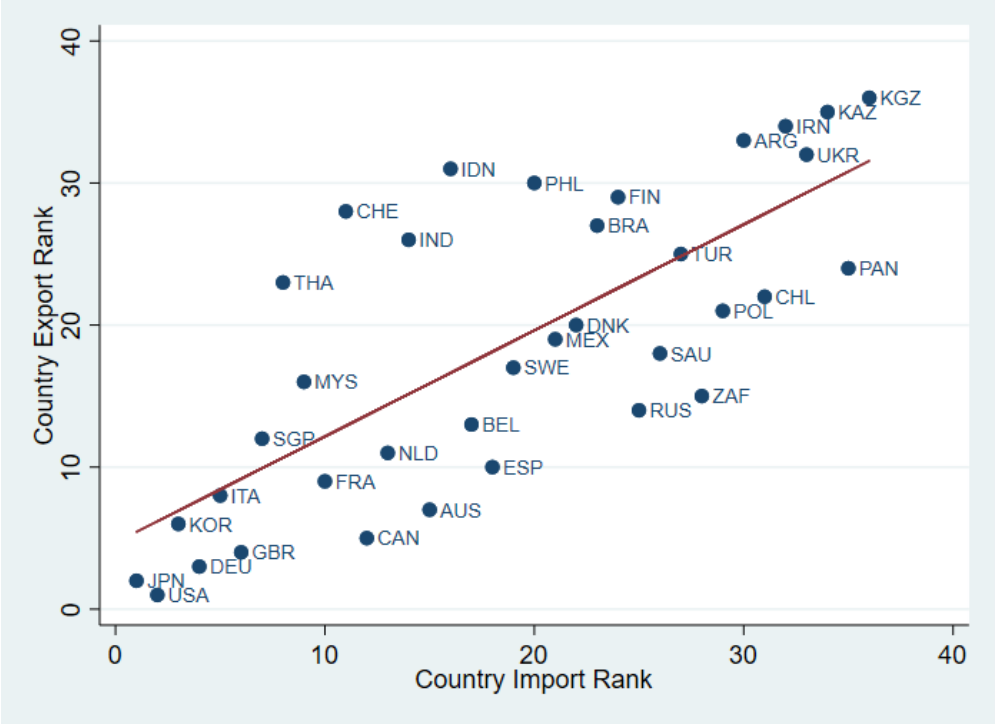

Figure 1: Country Rank Correlation by Number of Firms

i n§0I The export and import ranking across countries are based on number of Chinese exporters and importers, respectively. The rank-rank correlation in the figure is 0.75 with p-value 0.00. This exercise uses the customs sample only which includes top 30 export destinations and top 30 sourcing origins for China in year 2007, amounting to 36 foreign countries.

Admittedly, the above rank-rank correlation could be explained by multiple competing mechanisms that work independently from our market-specific bilateral economies of scope. For example, markets attracting more Chinese firms to export could be larger in scale or have lower trade costs which, in turn, induces more Chinese firms to import from. Dissecting the effect of our channel and the alternative ones is itself an interesting question, which we intend to answer in our quantitative exercise.

2.3 Further Discussions

We conclude the motivation section by presenting further tests addressing the issues related to dynamic panel specification and showing that our results are robust to taking into account

foreign-related firms, additional extended gravity variables and different sample periods.

2.3.1 Dynamic Panel Regressions

To address the endogeneity issue from the dynamic panel regression, we follow the solution suggested by Wooldridge (1997, 2010) and employ dynamic Probit model with random effects.[12] The results are shown in column (1) and (2) of Table 5 where the dependent variable is firm's export dummy and of Table 6 where the dependent variable is firm's import dummy. Since it is computationally demanding to estimate dynamic Probit model, we restrict sample size in two different ways and cross-check the results. In column (1) of Table 5 and 6, we estimate the model with sample from 2008 to 2015 which constitutes around 75% observations of the full sample while in column (2) of Table 5 and 6, we randomly select half of firms and estimate the model with this random sample. Our parameters of interest (the first row of column (1) and (2)) remain significant and positive, suggesting that our finding of market-specific bilateral economies of scope is robust to accounting for unobserved heterogeneity and serial correlation. Besides, the estimated coefficients in column (1) and (2) are quite close to each other.

In addition, we employ the standard system GMM model with instrument variables (IVs). Following Feng, Li, and Swenson (2016), we use two IVs. The first one is firm-country-specific exposure to import (export) tariff, and the second one is an indicator for firm as processing importer (exporter) in a foreign country. Appendix A.5 presents how to construct the IVs and details about system GMM. The result is given in column (3) of Table 5 and 6.[13] Our qualitative result is robust to using system GMM with these two instrument variables.

2.3.2 Foreign-Related Firms

Several recent papers, notably Antràs et al. (2022), show that ownership linkage across countries (mostly through FDI) is one key determinant for bilateral trade relationships. Firms that are owned by foreign entities tend to trade more with their headquarters. To show the robustness of our channel to this potential force, we repeat the reduced-form exercises by adding an interaction term between our variable of interest and dummy for foreign-related firm. Here we identify foreign-related firms as those marked as "Owned by foreign entity"(**外商独资企业**), "Jointly owned by domestic and foreign entity"(**中外合资企业**), and "Jointly maintained by domestic and foreign entity"(**中外合作企业**) in CCTS. Column (4) and (7) of Table 5 and 6 show the results. After controlling foreign ownership, there is a significant and positive correlation between firm's current export (import) decision

[12] Morales, Sheu, and Zahler (2019) use a mixed Logit model with random effects which is computationally infeasible in our case due to a much larger sample size in our study.

[13] Here we use sample from 2001 to 2007 since after 2007 variation in export and import tariffs is quite limited. The sample size shrinks a lot as we focus on a balanced panel when constructing the firm-country-specific tariffs.

and its past import (export) decision in the same country. The magnitude of estimated coefficient barely changes. Furthermore, the estimated coefficient of the interaction term is also significant and positive, confirming the findings of Antràs et al. (2022) that foreign-related firms do have additional incentive to export to and import from the same market compared to the others.

2.3.3 Cross-Market Bilateral Economies of Scope

In reality, it is possible that exporting to one country encourages firm to import from the country that shares similar geographic or economic characteristics with its export destination. In this subsection, we check if such cross-market bilateral economies of scope exists and whether it affects our baseline result or not. For this purpose, we do the regressions including both export-side and import-side extended gravity variables.[oV] Column (5) and (8) of Table 5 and 6 show the results. Several takeaways are worth mentioning. First, incorporating extended gravity variables on the other side does not alter the sign or change the significance of our key coefficients. Second, there seems to be no cross-market bilateral economies of scope, as the estimated coefficients on the additional variables (import-side extended gravity variable in Table 5 and export-side extended gravity variable in Table 6) are in general not significant.

2.3.4 Different Sample Period

Our baseline empirical exercise covers the period from 2000 to 2015. A potential concern here is that the post-WTO period (i.e., 2000-2007) are special as it is characterized by large declines in trade costs, fast growth in the export and the productivity of Chinese firms. Thus, firms trade strategy might be different in this episode compared to normal times. To address this concern, we repeat the same regression in column (6) and (9) of Table 5 and 6 by using data from 2008 to 2015. The results remain stable.

[14] See Appendix A.4 for detailed construction of the extended gravity variables.

Table 5: The Effect of Import Choice on Export Decision: Robustness

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Table 6: The Effect of Export Choice on Import Decision: Robustness

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LQi2¦,_ §9@e0 q}0 0j§ 9LL_§_nj9e }0 «e§ 9H}n L_¸0}0j§ hnL0e u Gne«hj ros 9jL r©s q}0 0j§ §\0 }0 «e§ T}nh L´j9h_H p}n@_§ hnL0e °_§\ }9jLnh 0¸0H§ u ^j Hne«hj rosJ °0 « 0 §\0 H« §nh 9hqe0 T}nh ©··P §n ©·oU °_e0 _j Hne«hj r©sJ °0 }9jLnhe´ 0e0H§ \9eT nT »}h T}nh §\0 T«ee 9hqe0u Gne«hj r¨s \n° §\0 }0 «e§ T}nh ´ §0h Wg g °_§\ _j §}«h0j§ ®9}_9@e0 « _jX §\0 H« §nh 9hqe0 T}nh ©··o §n ©··¢u ³09} L«hh_0 9}0 _jHe«L0L _j ´ §0h Wg g u Gne«hj rVs §n r£s q}0 0j§ }0 «e§ T}nh p}n@_§ hnL0eJ 9jL Hne«hj r¢s §n rks e_ § }0 «e§ T}nh e_j09} q}n@9@_e_§´ hnL0e rdpg su ^j Hne«hj rVs 9jL r¢sJ °0 §9c0 _j§n 9HHn«j§ Tn}0_Xj]}0e9§0L »}h u ^j Hne«hj rUs 9jL rPsJ °0 9LL hn}0 0²§0jL0L X}9®_§´ ®9}_9@e0 u ^j Hne«hj r£s 9jL rksJ °0 « 0 nje´ §\0 L9§9 T}nh ©··P §n ©·oU §n h_§_X9§0 ¯ ¦m 0j§}´ 0¸0H§u ¦\0 0²§0jL0L X}9®_§´ ®9}_9@e0 °_§\ q}0»² N²qu 9}0 Hnj §}«H§0L « _jX nje´ »}h˛ q9 § 0²qn}§ L0H_ _nj °_e0 §\0 n§\0} °_§\ q}0»² ^hqu 9}0 @9 0L nj »}h˛ q9 § _hqn}§ L0H_ _nj u ~§9jL9}L 0}}n} 9}0 _j §\0 q9}0j§\0 0 9jL He« §0}0L 9§ »}h 9jL Hn«j§}´ e0®0eu ¦\0 j«h@0} nT 9 §0}_ c _jL_H9§0 _Xj_»H9jH0 9§ o t r===sJ U t r==s 9jL o· t r=s e0®0eu

j h?2Q`v

JQiBp i2/ #v i?2 #Qp2 2KTB`B+ H `2;mH `BiB2b- r2 T`QpB/2 bi
2`Q;2M2Biv- K `F2i@bT2+B}+ i` /2 /2+BbBQMb M/ K `F2i@bT2+
q2 #mBH/ Qm` KQ/2H QM i?2 i7 `bK- 6Q`iF Q7 hQvMK2H M/ Qi HHQr }`Kb
iQ i` /2 BM #Qi? }M H M/ BMi2`K2/B i2 ;QQ/bX

jXR 1MpB`QMK2Mi

*QMbB/2` rQ`H/ i? i +QKT`Bb2b- r?B+? i`2 BQM/2+Q/#M bQ`v -+@
BM; Q`B;BM- H2/b K `F2iVX h?2 b2i Q7 +QmMi`B2b Bb /2MQi2/ #v
2 +? ?Qbi +QmMi`v ?2`2 2tBbib N 2Q7 /Q2K2biB+ }M H@;QQ/b T`Q/m
}`K Bb +? ` +i2`Bx2/ #v Bib +Q`2 /TT`Q/m+iBpBiv/Bz2`2MiB i2/ }M H
S`Q/m+iBQM Q7 }M H ;QQ/b `2[mB`2b bb2K#HBM; mMBi K2 bm`
BMTmibX 6B`Kö b Q#D2+iBp2 Bb iQ K tBKBx2 Bib iQi H T`Q}ib #v b
iQ bQm`+2 BMi2`K2/B i2 BMTmib 7`QK M/ i?2 QTiBK H b2i Q7 /2b
iQr `/bX AM 2 +? Q`B;BM +Qm2Mi`v Bbib mMBi K2 bm`2 Q7 BMi2`
bmTTHB2`bX 1 +? bmTTHB2` T`Q/m+2b /2bQiB7 Qi }M i2`K2/B i2
T`Q/m+2`b M/ Bb +? ` +i2`Bx2/ #v Bib ;(MXB ihH?BbQ2M?pBm Q`MK2Mi
BMi2`K2/B i2@;QQ/b bmTTHB2`b Bb #v 7Q`+BM; 1 H2Mi Q7 BMTmi bmTTH
2M; ;2 BM T2`72+i +QKT2iBiBQM M/ H #Q` Bb i?2 QMHv BMTmi m
/B i2 BMTmibX 6BM HHv- i?2 `2T`2b2Mi iBp2k-QM2b mK2` BM H2B+?
7`QK +QMbmKTiBQM Q7 }M H ;QQ/b p BH #H2 i?2`2X

jXk S`272`2M+2

h?2 `2T`2b2Mi iBp2 +QMbmK2` Bb K2 i`B+ HHv +QMbmKBM;
;QQ/b M/ +QMiBMmmK Q7 K Mm7 +im`BM; }M H ;QQ/bX h?2 K2
;QQ/b p BH #H2 iQ i?2 +QMbmK2` Bb 2M/Q;2MQmbHv /2i2`KBM2
i` /2X h?2 +QMbmK2`öb miBHBiv 7mM+iBQM Bb r`Bii2M b

$$U_k = U_{Mk} U_{Nk}^{1} ; \qquad \text{UkV}$$

r?2`2

$$U_{Mk} = \int_{! 2 k} q_k(!)^{\frac{1}{}} d! \, ^{\frac{}{1}} ; \qquad \text{UjV}$$

Bb i?2 2H biB+Biv Q7 bm#biBimiBQM KQM; $_k$/Bz2`2Mi BMi2`K2/B i2
Q7 /Bz2`2MiB i2/ }M H ;QQ/b kpXBh?2#H2 B`2 K`F2i Bb +QKKQM rQ`

;Bp2b `Bb2 iQ i?2 7QHHQrBM; /2K!M/ 7QH #MHv2 }BMKHK;`QFQ2/ib

$$q_k(!) = p_k(!) \quad E_k P_k{}^{1};$$ U9V

r?2`2 $E_k$ Bb +QmMi`v Q7 i H 2tT2M/Bim`2 QM K Mm7 $P_k$ Bb i?2 T`B+2 BM/2t Q7 K Mm7 +im`BM; b2+iQ`X G #Q` Bb i?2 QMHv 7 +iQ` Q7 T r ;2 w_k BM K `F2i h?2 MQM@K Mm7 +im`BM; b2+iQ` + Tim`2b + 2+QMQKvöb bT2M/BM; QM K T2i2b 7Q` H #Q` rBi? K Mm7 +im`BM; b2+iQ #2 H `;2 2MQm;? iQ TBM /QrM r ;2b BM i2`Kb Q7 MQM@K Mm7

jXj h2+?MQHQ;v M/ J `F2i ai`m+im`2

q2 }`bi /2b+`B#2 }`Köb bQm`+BM; /2+BbBQMX 6B`K +?'` +i2`Bx /2+B/2b i?2 b2i Q7 BMTmib J(') Bi bQm`+2 BMi2`K2/B i2 BMTmib 7`QK- M K2/B i2 BMTmi- Bi +?QQb2b i?2 p BH #H2 bmTTHB2` i? iQz2`b Q7 BMTmi bmTTHB2`b +`Qbb +QmMi`B2b Bb +QKKQM J(') FMQrMX i?2 T`B+2 }`Kvb 7Q` BMi2`K2/B i2 BMTmi

$$z_i(;' ; J(')) = \sum_{j \in J(')} KBM^M_{ij} a_j(\,) w_j \;;$$ U8V

r?2`2 bQm`+BM; 7`QK BMTmi bmTTHB2`b Bb +?2 T2bi ;BM; /2 MQi2 $\#^M_{ij}$ i? i+ M #2 BMi2`T`2i2/ b ;2Q;` T?B+ H Ubm+? bi` MbTQ`i iBQM # ``B2`bX "2bB/2b- bQm`+BM; 7`QK Mv Q`B;BM `2[mB`2b }`K iQ #v $f^M_{ij}$ - r?B+? Bb +QmMi`v@bT2+B}+ #mi +QKKQM iQ HH }`Kb 7`QK K `;BM H +Qbi Q7 T`Q/m+iBQM 7Q` }`K

$$c_i(' ; J(')) = \frac{1}{,} \int_0^1 z_i(;' ; J('))^{1} \, d \quad \frac{1}{1} \;;$$ UeV

r?2`2 Bb i?2 2H biB+Biv Q7 bm#biBimiBQM KQM; BMi2`K2/B i2 BMTmib mb2/ BM T`Q/m+iBQM Bb QM2X

hm`MBM; iQ i?2 BMTmi bmTTHB2`bö T`Q/m+iBQM i2+?MQHQ;v- r2 bbmK2 i? i i?2B` T`Q/m+iBQM 2{+B2M+v $\frac{1}{a_j(\,)}$ 6`û+?2i /Bbi`B#miBQM

$$S(a_j(\,) > a) = e^{T_j a};$$

r?2`2 $T_j$ `2T`2b2Mib i?2 K2 M Q7 T`Q/m+iBpBiv Q7 BMTmi bmTTHB2`b /p Mi ;2 Q7 BMTmi T`Q/m+BM; BMi2`K2/B i2 bmTTHB2`b /m+iBpBiv Q7 BMTmi bmTTHB2`b M/ i?mb i?2 +QKT ` iBp2 /p Mi Q`B;BMbX h?2 T ` K2i2` 1 `2T`2b2Mib i?2 H2p2H Q7 T`Q/m+iBpBiv

:Bp2M Mv bQm`+BM; J(') i?2 }`Kö M/ `;mK2Mi Q7 M/ EQ`imK

UkyyVk BM/B+ i2bi?öb }`?K `2 Q7 BMi2`K2/B i2 BMTmib Bb Q#iBM2/ 7`QK

$$ {}_{ij}(' ; J(')) = \frac{{}^{M}_{ij}}{{}^{M}_{i}(')} ; \qquad (UdV) $$

Bj72 J(') M/ x2`Q Qi?2`rBb2- r?2`2

$$ {}^{M}_{ij} \quad T_j \quad {}^{M}_{ij} w_j \qquad (U3V) $$

K2 bm`2bjQöb ;BTM2 H b BMTmib Qm`T+HBM2 `TQ/m+iBQM Q7 bQm`+2 i- Qm`i`v i- M/

$$ {}^{M}_{i}(' ; J(')) \quad \sum_{j 2 C(')} {}^{M}_{ij} \qquad (UNV) $$

`2T`2b2MiQ i?2 BM; +QT` +2bbiM; T QM/BM; iQ i?2 bQ(m)`+ 6 BMT mi bH Hiv2;}v` Köb K `;BM H +Qbi Q7 T`Q/m+iBQM /2T2M/b(') QM /Bb Bb b/2m`B+pBM;bi` i2;

$$ c_i(' ; J(')) = \frac{1}{,} \quad {}^{M}_{i}(' ; J(')) \quad \frac{1}{} ; \qquad (URyV) $$

r?2`2 $\frac{+1}{}$ $\frac{}{1}$ rBi? #2BM; i?2 ; KK 7mM+iBQMX

1[m iBQM U2b2K#H2b #BH i2` H i` /2 b?iQ2Mb TQ`EQ`UHyyV KXM AM Qm` KQ/2H- Bi bm;;2bib i? i }`K bQm`+2b KQ`2 BMTmib 7`QK TQi2MiB H i? M i?2 Qi?2`b +QM/BiBQM H QM T vBM; bQm`+BM; }

URyV Bb BbQKQ`T?B+ iQ B/2 1H iT`BM+B2M/B2 Ei2`UkyyVKX KLQr Bi /2MQi2b }`Kö K `;BM H +Qbi Q7 T`Q/m+iBQM r?B+? Bb /2+`2 bBM; BM(') iX?2 bQm

6B`K r?Q bQm`+2b 7`QK #2ii2` UBM i2`Kb Q7 bQm`+BM; TQi2MiB iQ T`Q/m+2b i HQr2` K `;BM H +Qbi i? M i?2 Qi?2`RyX }`KQ i2 i? i bQm`+BM; /2+BbBQMb +`Qbb /Bz2`2Mi Q`B;BMb `2 BMi2`@+QM z2+i }`K bQm`+BM; /2+BbBQM 7`QK i?2 Qi?2`b /m2 iQ Bib 2z2+i Q M/ i?2 T`2b2M+2 Q7 bQm`+BM; }t2/ +QbiX b r2 b?Qr #2HQr- r?2i +`Qbb Q`B;BMb `2 +QKTH2K2Mib Q` bm#biBimi2b iQ 2 +? Qi?2`

L2ti- r2 7Q`KmH i2 }`Köb b H2b/2+B/2b BQM2X ?6B`iK b2HH }M H ; 2 +? K `F2iX Aib b H2b bi` i2;v Bb i?2 b2i Q7 bs(')H2+iX /a K H`FBM;/2 iQ K `F2iMi BHb B+2#2`; i` MbX T `Q2iXiQM Q+2Bi;M BKTQ`ii `Bz V- }t2/ +QbiX 6B`K + M b2HH }M H T`QQ/m+ivi Q7 K2 `F2i BM; i?2 b H2b }t h FBM; b ;Bp2M bQm`+BM;(')M/ i?2 }`Köb b H2b `2p2Mm2 7`QK b2`pB Bb

$$ r_{ki}(') = ' \quad {}^{1} \quad {}^{M}_{i}(') \quad \frac{1}{} \quad X_{ki} \; {}^{1} \quad B_k ; \qquad (URRV) $$

r?2`2 $B_k$ $\frac{1}{}$ $\frac{}{1}$ $^{1}$ $P_k$ $^{1}E_k$ /2MQi2b i?2 ;;`2; i2 /2K M/ BM K `F2i F 2 b TQM/(

BM; T`Q}i Bb +QMbi Mi b? `2 Q7 } KXöb 6B`K2 b iQ i2HH `2p2Mm2 Bb bE

bmK Q7 `2p2Mm2 7`QK b2H2+i2/ K `F2ib- K/ BiBb bp2HH2#v b? `2 BM

$$X_{ki}(') = \frac{X_{ki}}{X_i(')};\qquad (URkV)$$

Bk72 s(') M/ x2`Q Qi?2`rBb2- r?2`2

$$X_{ki} \quad X_{ki}^{1} \quad B_k \qquad (URjV)$$

Bb K `F2ib TT2 H b +QMbmK2 `Qi?2` K `F2iQ }`Kb HQ+ i2/ BM ?Q

+QmMi`v M/

$$X_i(') \quad \sum_{k2\,s(')} X_{ki} \qquad (UR9V)$$

/2MQi2b i?2 b + T+Qi2b TQM/BM; iQ i?2 s(') 6Bb K i2; HHb KQ`2

K `F2i rBi? ?B;?2` b H2b TQi2MiB H `2H iBp2 iQ i?2 Qi?2`b 7i2`

hQ bmK mT- iQi H T`Q}i Q7 } K? b H2b bi i2;v M/ bQm`+BM;

bi` i2;v(') J Bb i?2`27Q`2

$$\pi_i(') = ' \quad 1 \quad \underbrace{\quad M_i(') \quad X_i(') \quad}_{\text{LQM@K `F2i@bT2+B}+ \text{ \#BH i2` H 2+QMQKB2b Q7 b+QT2}} \quad w_i \sum_{k2\,s(')} f^{X}_{ki} \quad w_i \sum_{j2\,J(')} f^{M}_{ij}$$

$$+ w_i \underbrace{\sum_{h2\,s(')\setminus J(')} \quad {}_0f^{X}_{hi} + {}_1f^{M}_{ih}}_{\text{J `F2i@bT2+B}+ \text{ \#BH i2` H 2+QMQKB2b Q7 b+QT2}} ; \qquad (UR8V)$$

r?2`2 i?2 }`bi i2`K Bb }`Köb iQi H p `B #H2 T`Q}ib- i?2 b2+QM/ M

iQi H b H2b M/ bQm`+BM; }t2/ +QbibX h?2 H bi i2`K Bb +`m+B H

bT2+B}+ #BH i2` H 2+QMQKB2b Q7 b+QT2- r?2`2 r2 HHQr }`Kb iQ

T `i Q7 bQm`+BM; }t2/ +Qbi 7`QK BM i?2 #B H i2` H +QMmMi`v b H2b

h?Bb Bb #mBHi mTQM }t2/ +Qbib T `2K2i2`b R $_0$ K2M/ $_1$ biQ

/2i2`KBM2 i?2 K ;MBim/2 Q7 K `F2i@bT2+B}+ #BH i2` H 2+QMQ

r? i 2ti2Mi- }`Köb bQm`+BM; /2+BbBQM BM +QmMi`v K v #2M2}i

+QmMi`v i?`Qm;? `2/m+iBQM f $^{X}_{hi}$ M $^{M}_{ih}$ bKHH Kb2HH +QMbi`Q- iQ r? i 2ti2Mi

}`Köb b H2b 2Mi`v K v #2M2}i Bib bQm`+BM; +?QB+2 7`QK i?2 b K

BM bQm`+BM; f $^{M}_{ih}$ X +Qbib-

h?2 T`Q}i 7mM+iBQM U R8V ?b M BHHmbi` iBp2 UrQ ivT2b Q7 #BH i2` H 2+Q

BM+Q`TQ` i2/ BM Qm` KQ/2HX h?2 }`bi QM2 Bb MQM@K `F2i@bT2

Ai bm;;2bib i? i b2HHBM; iQ M //BiBQM H K `F2i BM+`2 b2b i?2

7`QK HQ` H B;BMb /m2 iQ M BM+`2 b2 BM K $X_i$(') B 2- Bb X iQX ?B2;?2`

HBF2HB?QQ/ 7Q` i?2 }`K iQ bQm`+2 7`QK HH Q`B;BMbX AM i?

//BiBQM H Q`B;BM K F2b i?2 }`K iQ #2 KQ`2 HBF2Hv iQ b2HH iQ

K `;BM H +Qbi Q7 T`Q/m+iBQM- BX2X ?B;?2`

AM +QMi` bi- i?2 K `F2i@bT2+B}+ #BH i2` H 2+QMQKB2b Q7

BM/B+ i2 i? i B7 }`K b2HHb iQ M //BiBQM H +QmMi`v- Bi Bb K

b K2 +QmMi`v /m2 iQ b pBM; BM T `i Q7 bQm`+BM; }t2/ +Qbib h

BM+2MiBp2 7Q` }`K iQ i` /2 rBi? i?2 Qi?2` +QmMi`B2b BM 2Bi?2`

bQm`+BM; }t2/ +Qbib BM i?Bb bT2+B}+ +QmMi`v M/ ? b MQ 2z2

+QmMi`B2bX h?2 b K2 HQ;B+ TTHB2b iQ }`Köb bQm`+BM; /2+B

i?2 K `F2i@bT2+B}+ 7Q`+2 2tTHB+BiHv H2 /b iQ i?2 +QKTH2K2M

bQm`+BM; /2+BbBQM rBi?BM bT2+B}+ +QmMi`vX

*QM/BiBQM H QM Bib T`Q/m+iBpBiv H2p2H- }`K Q (φ) KMHHv +?Q

2tTQ`iBM; bi(' )2 iQ K tBKBx2 i?2 T`Q}i 7mM+iBQM π 8X p2Q`K MH2[m

i?2 }`Köb T`Q}i K tBKBx iBQM T`Q#H2K Bb r`Bii2M b 7QHHQrbX

$$K\ t \quad {}_i(\varphi;\ s;\ J) = \varphi^{\ 1} \sum_{j=1}^{J} I^M_{ij} T_j(\ _{ij} w_j)^{\ \frac{1}{}} \sum_{k=1}^{J} I^X_{ki}\ {}^X_{ki}{}^{1}\ B_k$$

$I^M_{ij} \in f0;1g^J_{j=1}$

$I^X_{ki} \in f0;1g^J_{k=1}$

$$w_i \sum_{k=1}^{J} I^J_{ki}\ 1\ \ {}_0 I^M_{ik}\ f^X_{ki} \quad w_i \sum_{j=1}^{J} I^M_{ij}\ 1\ \ {}_1 I^X_{ji}\ f^M_{ij}\ ;UReV$$

r?2`$I^M_{ij}$ /2MQi2b }`Köb bQm`+BM; /2+BbBQM 2?B+? Q[m H b QM2 B7 }`K bQm`

Q`B;BM M/ x2`Q Qi?2`rBb2- $I^X_{ki}$ /2MQi2b }`Köb b H2b /2+BbBQM r?B+? Bb[m KH`F2

QM2 B7 }`K b2HHb iQ /2biBM iBQM K QM2 Qi?2`rBb2X

LQi2 i? i i?2 irQ F2v T ` K2i2`b BM Qm_1 -KQ/2H ;Q2p2`M i?2 K ;M

im/2 Q7 i?2 #BH i2` H 2+QMQK$_0$B2b 7Q` bQm`+BM; M/ b2HHBM; 7`QK +QmM

}`Köb }t2/ +Qbi Q7 2tTQ`iBM; iQ i?2 b K2 +Q$_1$mMi`v #v 2t2`iBM;

+QmMi`v /2+`2 b2b bQm`+BM; }t2/ +Qbib BM i?2 b K2 +Q$_0$;2$_1$+QmMi`v #v

}`Köb /2+BbBQM iQ 2tTQ`i iQ bT2+B}+ +QmMi`v +QKTH2K2Mib

b K2 +QmMi`v- M/ pB+2 p2`b X h?Bb Bb i?2 `2 bQM r?v Qm` KQ/2H

BM/2T2M/2M+2 #2ir22M }`Köb bQm`+BM; M/ b H2b /2+BbBQMbX

jX9 1[mBHB#`BmK

q2 MQr /2}M2 i?2 ;2M2` H 2[mBHB#`BmKX h?2 K`F2i bi`m+im`2 Bb

H2p2H Bb TBMM2/ /QrM BM i2`Kb Q7 MQM@K Mm7 +im`BM; ;QQ/

BM J2HBix UkyyjV- r2 bbmK2 7`22 2Mi`v 7Q` }`K H@;QQ/b T`Q/m+2`b-

2Mi` Mi Bb `2p2 H2/ QMHv 7i2` Bi T v $f_e$bX7Q` 2Mi`v- 2 +? 2Mi`

firm will enter the market until the expected profit reaches zero [illegible]

$$\int_{\tilde{\varphi}_i}^{1} [\;_i(\varphi)]\, dG_i(\varphi) = w_i f_{ei}; \qquad (17)$$

where (φ) is defined in eq [illegible] (the cutoff productivity for su[illegible] determines the measure of produc[illegible] down unknowns of aggregate [illegible] equilibrium (A.1 [illegible]).

The labor market clearing condition delivers the equilib[illegible]

$$N_i = \frac{L_i}{f_i} \qquad (18)$$

where

$$f_i \int_{\tilde{\varphi}_i}^{1} \Big[\sum_{k\in s(\varphi)} f^X_{ki} + \sum_{j\in J(\varphi)} f^M_{ij} + \sum_{h\in s(\varphi)\cap J(\varphi)} ({}_0 f^X_{hi} + {}_1 f^M_{ih}) \Big] dG_i(\varphi) + f_{ei}$$

is the total fixed costs payment [illegible] given $N_i^A = N_i[1 - G_i(\tilde{\varphi}_i)]$.

We conclude this section by defining the general equilib[illegible]

Definition 1. [illegible] the [illegible] w_i [illegible] L_i [illegible] the other exog[illegible] parameters, the general equilibrium consists of firm's optim[illegible] sourcing [illegible] $s(\varphi)$ [illegible] $J(\varphi)$, the cutoff productivity [illegible] B_i, and measure of potential [illegible] N_i [illegible] solve firm's pro[illegible] maximization [illegible] firms enter the market until [illegible] free [illegible] holds, and (iii) labor market [illegible] condition

5 Connecting Model to Data

In this section, we discuss how to connect the model to d[illegible] assumptions that help to conduct quantitative analysis.

5.1 Specification of the Fixed Costs

Following [illegible] Eaton, Kortum, and [illegible] (2011) [illegible] Antràs, Fort, and Tintelnot (2017) [illegible] assume firms face heterogeneous fixed costs in [illegible] of sourcing and exporting [illegible] follows.

$$\log f^M_{fij} = {}^M_C + {}^M_d \log Dist_{ij} + {}^M_{disp}\,{}^M_{fij}; \qquad (19)$$

$$\log f^X_{fji} = {}^X_C + {}^X_d \log Dist_{ji} + {}^X_{disp}\,{}^X_{fji}: \qquad (20)$$

h?2 +QMbi M ;i2`K BM b+ H2 T ` K2i2` K2 bm`2b i?2 K ;MBim/2 Q7
BMi2`M iBQM H i` /2 MH Q?2 B2 i ;K H2Q; .Bb i M T2m`2b i?2 +QmMi`v
bT2+B}+ # ``B2`b BM BKTQ`iBM; 7`QK mM/2` Q2 ;M Ti?B +Q bMi v
//BiBQM- i?2 }`K@+QmMi`v@bT2+B}+ /2`rBQ 7`QK #Bp `B i2 bi M/
MQ`K H /Bbi`B#miBQM rBi? K2 M 2 M/ i?2 bi M/ `/ 2`i}t2/ +Qbi Q7 b2HHBM;
7`QK i?2 /QK2biB+ K `F2i UBX2X- *?BM V iQ x2`QX h?2 #Qp2 bT
iQ ;2M2` i2 bK HH@bBx2 2tTQ`i2`b M/ BKTQ`i2`bX 6m`i?2`KQ`2
7Qm` ivT2b Q7 }`Kb Q#b2`p2/ BM i?2 / i X AM i?2 / i - 7Q` Mv 7
7Qm` b2ib Q7 *?BM2b2 }`Kb, Tm`2 2tTQ`i2`b- Tm`2 BKTQ`i2`b- i
}`KbX qBi?Qmi }`K@+QmMi`v@bT2+B}+ }t2/ +Qbib- bi`B+i ?B2` `
BKTQ`iBM; BKTHB2b QMHv i?`22 ivT2b Q7 }`Kb + M +Q@2tBbiX A
i?2M i?2 KQ/2H rQmH/ 7 BH iQ ;2M2` i2 Tm`2 BKTQ`i2`b- #2+ mb2
iQ BKTQ`i rBHH HbQ 2tTQ`i UBX2X- #2+QK2b irQ@r v i` /2`VX

9Xk *? HH2M;2b BM JQ/2H aQHmiBQM M/ 1biBK iBQ

PM2 r2HH@FMQrM +? HH2M;2 BM i?2 HBi2` im`2 HB2b BM bQHp
;2Mib rBi? ?2i2`Q;2M2Qmb +? ` +i2`BbiB+b- b i?2 ó#`mi2 7Q`+
iB HHv 2tTHQ/BM; +?QB+2 b2ibX C BU y V B b i i Q M T H M Q B T B +`2 Q' b#v@
+QKTH2K2Mi `Biv M/ /QTi ób M/rB+?ô H;Q`Bi?K- r?B+? b2[m2
M/ HQr2` #QmM/b Q7 i?2[R8] +?QB+2 F B b - 1 + F 2 U k - y k W / a Q B b i? i
bBKBH ` b[m22xBM; H;Q`Bi?K rQ`Fb 7Q` i?2 + b2 r?2M /Bb+`2i2
Qi?2`X h` /2 2+QMQKBbib ? p2 rB/2Hv mb2/ bm+? H;Q`Bi?K- #mi
2tTQ`i /2+BbBQMb U2X;X- hBMi2HMQi ` BKTQ`i /2+BbBQMb U- M/ h k y R k H M Q i
b2T ` i2HvX h?2 7 +i i? i Qm` KQ/2H ? b i` /2 /2+BbBQMb QM #Q
H2M;2 `2; `/BM; r?2i?2` i?Bb H;Q`Bi?K + M #2 TTHB2/ BM i?Bb
S`QTQbBiBQM Bi biBHH rQ`FbX

S`QTQbBiBQM 2 R X> 1 M/ 0 < $_0$; $_1$ < 1- }`Kö b T`Q}i K tBKBx iBQM T`
BM 2[m iBQM i? ?2i2`Q;2M2Qmb }t2/ +Qbib 2t?B#Bi $B^X_{ki}$ $B^X_{ji}$ M+`2 bBM
I^X_{ki};I^M_{ij} - M/ I^M_{ik};I^M_{ij} 7Q` k/i;j 2JX

LQi2 BM i?2 #Qp2 T`QTQbBiBQM- bmT2` `b i?2 T`QT2`iv Q7 BM+`2 bBM
i?2 T`Q}i 7mM+iBQM M/ i?2`27Q`2 K F2b }`Kö b 2tTQ`i M/ BKTQ
iQ 2 +? Qi?2`X q2 b?Qr i?2 +QKTH2K2Mi `Biv T`QT2`iv Bb M 2K
Qm` H i2` M Hvb BbX b 2tTQ`i M/ BKTQ`i /2+BbBQMb `2 +QKT
S`QTQbBiBQM i?2`2 Bb BM+`2 bBM; /B $_{ki}$;$I^M_{ij}$ M/ $I^X_{ki}$;$I^X_{ij}$ T`Q`iv BM
i?2 M HvbBb Q` bM 6Q`i- M/ h k y R k H M Q H F B b - 1 + F 2 U k - y k W - / i?2B
ób M/rB+?ô H;Q`Bi?K TTHB2b BM Qm` 2MpB`QMK2Mi- r?B+? #v

[R8] h?2 B/2 Bb iQ b[m22x2 i?2 +?QB+2 b2i #v F22TBM; i?2 Kmbi@BM+Hm/2/
i?2 Kmbi@2t+Hm/2/ Bi2Kb 7`QK #Qp2X h?2M r2 2M/ mT rBi? +QKTmi iBQM
+QMi BMb i?2 QTiBK H bQHmiBQMX a22 *?2MX/a2BHT2`2M 2t BTiBQM Q7 i?2 H;Q`Bi?KX

9Xj 6BM H@:QQ/b S`Q/m+2`b

}M H ;QQ/b }`Kb- M/ r2 HbQ +QM/m+i `Q#mbiM2bb 2t2`+Bb2 #v
i?2 mTbi`2 K BM/mbi`B2bX

9X9 :` pBiv

q2 MQr /2`Bp2 i?2 KQ/2H@BKTHB2/ ;` pBiv 2[m iBQMb 7Q` #Qi? M//Bb+mbb i?2 BKTHB+ iBQM Q7 Qm` K2+? MBbK QM #BH i2` H *QM/BiBQM H QM }`Köb QTiBKsH i M/JB(M);-bBìbiB2 ;wTmi Tm`+? b2 7 Q`Bj;BBM 1) ij(') 7` +iBQM Q7 }`Köb T`Q}i-

$$M_{ij}(') = (\quad 1)' \quad 1 \quad \frac{1}{} \quad {}^{M}_{i}(') \quad \frac{1}{} \quad 1 \quad {}^{X}_{i}(') \quad T_j({}^{M}_{ij} w_j) \quad ; \qquad \text{UkRV}$$

7Q`2 J(') M/ x2`Q Qi?2`rBb2X M/ Bib b H2b B`b2 ;B2pM2M2#vM K `F2i

$$X_{ki}(') = ' \quad 1 \quad {}_{i}(')^{M} \quad \frac{1}{} \quad {}^{X}_{ki} \quad 1 \quad B_k; \qquad \text{UkkV}$$

7Qk`2 s(') M/ x2`Q Qi?2`rBb2X
amKKBM; 2[m kR VBQpM2 U HH }`Kb ;Bp2b i?2 ;;`2; i2 BKTQ`i Q7 BM
7`QK Mv Q`B ;BM HHQrb,

$$M_{ij} = N_i \int_{'_{-i}}^{1} M_{ij}(')dG_i(') = (\quad 1) \frac{1}{} N_i T_j({}^{M}_{ij} w_j) \quad {}^{M}_{ij}; \qquad \text{UkjV}$$

r?2`2

$$ {}^{M}_{ij} \int_{'_{-i}}^{1} I^{M}_{ij}(')' \quad 1 \quad {}^{M}_{i}(') \quad \frac{1}{} \quad 1 \quad {}^{X}_{i}(')dG_i(') \qquad \text{Uk9V}$$

Bb BM+`2 bBM; BM i?2 MmK#2`BQKTQ`KiBM7+jQXKm WviBM BkjV-M U r2 K v /2`Bp2 i?2 7QHHQrBM; ;` pBiv 2[m iBQM 7Q` i` /2 BM BMi2`
"Xj7Q` i?2 /2i BH2/ /2`Bp iBQMbVX

$$M_{ij} = \frac{E_i}{P_i^{1} \; /N_i} \quad \frac{Q_j}{\sum_{h=1}^{J} \frac{E_h}{P_h^{1} \; /N_h} \; {}^{M}_{hj} \qquad {}_{hj}} \quad {}^{M}_{ij} \qquad {}^{M}_{ij}; \qquad \text{Uk8V}$$

r?2`2

$$P_i^{1} \; /N_i \quad \sum_{k=1}^{J} b_k P_{ki}^{1} \; /N_i \qquad \text{UkeV}$$

Bb i?2 r2B;?i2/ p2` ;2 Q7 +QmMi`vöb K2 M 2tTQ`i T`Bb2 k= BM/2t +
$\frac{B_k}{\sum_{i=1}^{J} B_i}$ Bb i?2 /2K M/ b? `2 Q7 +QmMi`vH#XN$_i$ R1 p$_{ki}$(')1 dG$_i$(') Bb i?2
2tTQ`i T`B+2 BM/2t 7Q` }`Kb 7`QK +QmMi`v 2F 2 $\sum_{h=1}^{J} M_{hj}$ Bb i?2 iQi H
BMi2`K2/B i2 BMTmi T`Q/m+2/ #v Q`B;BM

hm`MBM; iQ i?2 #BH i2` H i` /2 Q7 }M H ;QQ/b- i?2 i ;i;Q2; i2 2
K `F2i b

$$X_{ki} = N_i \int_{'_{-i}}^{1} X_{ki}(')\,dG_i(') = N_i \,{}^{-1} B_k \; {}^{X}_{ki} \; {}^{1} \; {}^{X}_{ki};\qquad \text{UkdV}$$

r?2`2

$$^{X}_{ki} \int_{'_{-i}}^{1} I^{X}_{ki}(')\,'^{\,1}\; {}^{M}_{i}(')^{\,-1}\, dG_i(')\qquad \text{Uk3V}$$

Bb BM+`2 bBM; BM i?2 MmK#2` 2QT7Q}`KBbMB;MQ+K`Q maBH2Ki`BvH `Hv- r2 /2`B
i?2 7QHHQrBM; ;` pBiv 2[m iBQM 7Q` i` /2 BM }M H ;QQ/b,

$$X_{ki} = \frac{E_i}{P_i^{1}\ /N_i}\;\frac{S_k}{P_{h=1}^{J}\frac{E_h}{P_h^{1}\ /N_h}\,(^{X}_{kh})^{1}\;{}^{X}_{kh}}\;{}^{X}_{ki}\,{}^{1}\;{}^{X}_{ki};\qquad \text{UkNV}$$

r?2`2 $S_k = P_{h=1}^{J} X_{kh}$ /2MQi2b i?2 iQi H #bQ`TiBQM Q7 k}X M H ;QQ/b 7Q`
6`QK 2[m iBQM UkNV- Bi Bb +H2 ` i? i i?2 2tBbi2M+2 Q7 #BH i2
b+QT2 BM+`2 b2b ;;`2; i2 i` /2 ~Qrb #v 7 +BHBi iBM; }`Kbö 7Q`2
`2/m+iBQM BM }t2/ +Qbib Q7 2tTQ`i M/ BKTQ`iX

8 Zm MiBi iBp2 AKTH2K2Mi iBQM

AM i?Bb b2+iBQM- r2 T`2b2Mi i?2 [m MiBi iBp2 BKTHB+ iBQMb Q
M/ +QmMi2`7 +im H M HvbBbX h?2 [m2biBQMb i? i r2 BMi2M/ iQ
Q7 i?2 #BH i2` H 2+QMQKB2b Q7 b+QT2 K2+? MBbKbc M/ kV iQ
++QmMib 7Q` i?2 bivHBx2/ 7 +ib /Q+mK2Mi2/ BM i?2 2KTB`B+ H
M HvbBb- r2 HbQ b?Qr K `F2i@bT2+B}+ #BH i2` H 2+QMQKB2
2z2+ib Q7 i?2 i` /2 HB#2` HBx iBQM QM }`Köb 2tTQ`i M/ BKTQ`i
h?2 [m MiBi iBp2 M HvbBb 7i2`r `/b +QMbBbi2MiHv mb2b i?
am`p2v Q7 AM/mbi`B H 1Mi2`T`Bb2 M/ *?BM2b2 +mbiQKb[Rd] b i?2 KTH
Q7 +QmMi`B2b BM Qm` b KTH2 Bb i?2 mMBQM Q7 i?2 iQT jy 2tTQ`
bQm`+BM; Q`B;BMb BM i2`Kb Q7 2tTQ`i M/ BKTQ`i p Hm2 BM kyy
Q7 i?2 +QmMi`B2b Qp2`H Tb M/ i?2 iQi H MmK#2` Q7 +QmMi`B2b
Bib2H7VX GQQFBM; i i?2 i` /2 pQHmK2- i?2 b2H2+i2/ b KTH2
2tTQ`i p Hm2 M/ N8W Q7 iQi H BKTQ`i p Hm2 7Q` *?BM X AM r?
KQ/2H T ` K2i2`Bx iBQM M/ B/2MiB}+ iBQMX q2 i?2M b?Qr i?2 K
M/ MQM@i `;2i2/ KQK2MibX q2 }M HHv BHHmbi` i2 i?2 `2bmHib Q

[Rd]q2 +?QQb2 kyyd b i?2 # b2 v2 ` iQ bim/v }`Köb i` /2 /2+BbBQMb iQ pQB/
*?BM öb qhP 2Mi`v M/ kyy3 }M M+B H +`BbBbX

8XR JQ/2H S ` K2i2`Bx iBQM

h?Bb b2+iBQM bT2+B}2b KQ/2H T ` K2i2`Bx iBQMX 6`QK MQr QM
Bb /` rM 7`QK S `2iQ /Bbi`B#miBQM rBi? b? T2 T ` K2i2` Mm+im` H
` K2i2`b 7Q` i?2 # b2HBM2 KQ/2H BMiQ i?`22 bm#+ i2;Q`B2bX h?
S `2iQ b? T2 T ` K2i2` r?B+? Bb bbB;M2/ 2ti2`MiHHv 7QHHQrBM
hBMi2`K R9dX h?2 b2+QM/ ;`QmT Q7 T ` K2i2`b BM+Hm/2 +QmMi`v
i2MiB H BM 2[m iBQM 3 UV- i?2 /2K M/ 2H biB+BiB2b 7Q` +BM;2H b
UVX 6QHHQrBM; i?2 /Bb+mbbBQM BM b2+iBQM M #2 2biBK i2/
/2MiHv 7`QK `2/m+2/@7Q`K `2;`2bbBQMbX h?2 i?B`/ ;`QmT +QM
T ` K2i2`b- r?B+? `2 +?Qb2M iQ K i+? i?2 Q#b2`p2/ i` /2 T ii2`M
2biBK i2 i?Bb b2i Q7 T ` K2i2`b mbBM; i?2 bBKmH i2/ K2i?Q/ Q7

S ` K2i2`b 1biBK i2/ 7`QK _2/m+2/@6Q`K _2;`2bbBQMb 2biBK
iBQM Q7 +QmMi`vöb b H2b M/ bQm`+BM; TQi2MiB Hb 7`QK i?2 T
+ M #2 b2T ` i2Hv B/2MiB}2/ i FBM; i?2 Q#b2`p2/ }`Kbö 2tTQ`i M
QTiBK H bQHmiBQMX h?2 2biBK iBQM mb2b i?2 B/2 i? i +QmMi`
b?QmH/ #2 `2~2+i2/ #v }`Köb b H2b M/ bQm`+BM; b? `2 M/ Qbb +Q
URVX q2 MQ`K HBx2 2[m iBQM Ud#V #v }`Köb b H2b M/ bQm`+BM; b? `2
+QmMi`v `2bT2+iBp2Hv- i F2 HQ;b QM #Qi? bB/2b- M/ i` Mb7Q`K
#v //BM; `2bB/m H 7Q` HQrb,[R3]

$$HQ \frac{M}{fij} \quad HQ \frac{M}{fii} = HQ \frac{M}{ij} + \frac{M}{fij} \qquad UjyV$$

M/

$$HQ \frac{X}{fki} \quad HQ \frac{X}{fii} = HQ \frac{X}{ki} + \frac{X}{fki}; \qquad UjRV$$

r?2`2 $M_{fij}$ /2MQi2b }`Köb bQm`+BM; b?`2 BM X_{fki} M/ ϵ H2b b? `2 BM K `F
k- M/ i?2 ?Qbi +QmMi`v iQ *?BM X >2`2 r2 MQ`K HBx2 i?2 BM/b H
TQi2MiB H iQ #2 QM2X

6B`Köb /QK2biB+ BMi2`K2/B i2 BMTmi p Hm2 Bb Q#i BM2/ 7`Q
K2/B i2 BMTmi 7`QK Bib iQi H QT2` iBM; BMTmiX q2 i?2M + H+mH
7Q` 2 +? }`K #v bm#i` +iBM; 2tTQ`i `2p2Mm2 7`QK Bib iQi H b H2
;2i }`Köb bQm`+BM; M/ b H2b b? `2b +`Qbb *?BM M/ 7Q`2B;M
BM i?2 b KTH2 +Q``2bTQM/bQm`+BM; Ub H2bV b? `2 7`QK 7Q`2B;M
7Q`2B;M K `F2i- M/ #v Bib /QK2biB+ bQm`+BM; Ub H2bV b?
Ub H2bV p Hm2 BM i? i 7Q`2B;M +QmMi`vX q2 i?2M 2biBK i2 2[m iBQM

[R3]PM2 bi`m+im` H BMi2`T`2i iBQM Q7 i?2 `2bB/m H Bb }`Kb 7 +2 B/BQbvM+`
BXBX/X +`Qbb }`Kb M/ K `F2ib- M/ Bb `2 HBx2/ 7i2` i?2 2Mi`v /2+BbBQMb
/2+BbBQMb `2K BMb mM z2+i2/ b HQM; b i?2 2t@TQbi T`272`2M+2 b?Q+F p
7mM+iBQMX HbQ MQi2 i? i i?2 T`272`2M+2 b?Q+F- QM+2 `2 HBx2/- BMi`Q/m

Pp2` HH- 6B;m`2 j, a H2bfaQm`+BM; i? i i?2 *?BM2b2 }`Köb 2tTQ`i /2+BbBQMb `2K
Q7 b2HHBM; iQ 7Q`2B;M K `F2ib r?BH2 i?2 bQm`+BM; /2+BbBQM
;2iiBM; ++2bb iQ 7Q`2B;M BMTmi bmTTHB2`b- r?B+? Bb 2biBK i2

6B;m`2 j, a H2bfaQm`+BM; SQi2MiB Hb M/ i?2 LmK#2` Q7 1t

LQi2h,?Bb };m`2 b?Qrb i?2 +Q``2H iBQM #2ir22M +QmMi`vöb UHQ;V b H2
#2` Q7 *?BM2b2 2tTQ`i2`b US M2H V M/ i?2 +Q``2H iBQM #2ir22M +Q
M/ i?2 UHQ;V MmK#2` Q7 *?BM2b2 BKTQ`i2`b US M2H "VX AM S M2H
rBi? @p Hm2 yXyyX AM S M2H "- i?2 bHQT2 Q7 i?2 H2 bi@b[m `2b }i HBM2 Bb yXyN8 rBi?
b2/ QM *?BM öb iQT jy bQm`+BM; Q`B;BMb M/ iQT jy 2tTQ`i /2biBM i
iQ je 7Q`2B;M +QmMi`B2bX "Qi? b H2b M/ bQm`+BM; TQi2MiB Hb `2
bQm`+BM; TQi2MiB Hb `2bT2+iBp2HvX

1biBK iBQM Q7 .2K M/ 1H biB+BiB2b Q7 i?2 *1a T`272`2M+2
HBbiB+ +QKT2iBiBQM bi`m+im`2 KQM;}M H@;QQ/b T`Q/m+2`b B
K `FmT Qp2` K `;BM H+Qbi- K`F2ib BKTHB2b i? i r2 + M mb2 i?2
K `FmTb iQ BM72` i?2 /2K M/ 2H biB+Biv T ` K2i2`X IbBM; i?2 }`
}`Köb K `FmT #v i?2 .2GQ2+F2` M/ q `KvMbF2 ?Q/b2T ` i2Hv 7Q` 2
7Qm`@/B;Bi BM/mbi`v H2p2HX hQ HH2pB i2 i?2 2z2+i Q7 2ti`2K
i i?2 #QiiQK jW M/ i?2 iQT jWX h?2 i?2 K2 M Q7 Qm` 2biBK i2/ K
K2/B M H2p2H Bb RXk3X h?2 K2/B M H2p2H Q7 }`K K `FmTb-
Bb bHB;?iHv ?B;?2` i? M i?2 2biBK i2 Q7 RXkj 7Q` i?2 lX3X #v mbBM;
/ i Q7 lXaX }`KbVX h?2 `2bmHi `2~2+ib HQr2` K `FmT +? `;2/ #v

jy

Q7 i?2 lXaX LQi2 i?bii?2 i` /2 2H biB+Biv [RN] 7Q` }M H ;QQ/bX

1biBK iBQM Q7 aQm`+BM; 1H biB+BiB2b- q2 2biBK i2 i?2 i` /2 2H biB+Biv 7Q /B i2 ;QQ/b X /B i2 ;QQ/b Q /Q bQ- r2 mb2 i?2 /2}MBiBQM 7Q` bQm`+BM; TQi2MiB

$$ {}^{M}_{ij} = T_j \, {}^{M}_{ij} w_j \quad ; \qquad (jkV) $$

h FBM; HQ; QM #Qi? bB/2b M/ //BM; `2bB/m H i2`K vB2H/b M 2K

$$ HQ\hat{}^{M}_{ij} = {}_0 + {}_1 HQ; \_j + {}_2 HQ; + TBi H T2`rQ`F2`Mm K\#2`_j Q7 }`Kb $$

$$ HQ^{M}_{ij} w_j + {}_g \quad :` pBiv_{ij} \; ; $$

r?2`2 r2 BM+Hm/2 Q?2`_BM biQ+F- + TBi H T2`rQ`F2` M/ MmK\#2` Q +QmMi`v 2{+B2M+v BM BMTmi X `Q(Q) +BbQM2 HQm;K M@+ TBi H /D r ;2i F2M 7`QK 'BQHb M/ EQ2MB; H^{M}Q ; Bb i?2 2biBK i2/ bQm`+BM; TQi2 i?2 T`2pBQmb b2+iBQM X B2/ \#v i?2 mMr2B;?i2/ J6L i `Bz BKTQb2 BKTQ`i2/ BMi2`K2/B i2 BMTmib- AM 7`QK +QBMM;ii`v2 `2;`2bbBQMb- r2 Q7 ;` pBiv p `B \#H2b iQ +QMi`QH 7Q` i?2 MQM@i `Bz i` /2 \# ``B2

h \#H2 d T`QpB/2b i?2 2biBK iBQM `2bmHiX AM +QHmKM URV M/ bQm`+BM; TQi2MiB H b i?2 /2T2M/2Mi p `B \#H2X h?2 `2;`2bbBQ 2H biB+Biv Q7 RXydk BM +QHmKM UkV r?2`2 T2`2M2BM bQm`+BM; M;iMi iQ rBi? TQi2MiB H +Q``2H iBQM Q7 r ;2b +`Qbb +QmMi`B2b BM MK2 b 6Q`i- M/ hBM2 UkyRdVX 2biBK i2/ Bb bHB;?iHv HQr2` i? M i?2 Q BM i?2B` T T2` URXd3NVX AM HBM2 rBi? i?2 6h `2bmHib- i?2 2 }`K@H2p2H / i Bb HQr2` i? M i? i Q\#i BM2/ 7`QK [kV] mbBM; bi`2; i2 KQ`2 /BbT2`b2/ T`Q/m+iBpBiv /Bbi`B\#miBQM KQM; BMTmi bmTT

Hi2`M iBp2Hv- QM2 K v 2biBK i2 BMTmi i` /2 2Hjb iB+Biv ;` `2bmHi Bb `2TQ`i2/ BM +QHmKM UjV M/ U9VX q2 mb2 i?2 Q\#b2`p bQm`+BM; Q`B;BMb b /2T2M/2Mi p `B \#H2 - NM^{M}_{ij} r?2`2 HQ;QiB7 QM` /QK2biB+ BMTmi Tm`+?b2 Q7 HH *?BM2b2 }`Kb [kR] 2biBK i2/ i` /2 2H biB+Biv Q7 BMi2`K2/B i2 ;QQ/b b RXkdj BM +

[RN] q2 +QM/m+i b2MbBiBpBiv +?2+F- iQ 6Bb?2 2ibp HQr2` QK `FmT +? `;2/ \#v *?BM2 =1:21V- +HQb2 iQ i?2 mTT2` \#QmM/ p Hm2 \#v 2iBK i2 Bb ii Bi` M/ U_2kkyRdVX h?2 T ` K2i2`b Q7 B_0 M/ B_1 \#2+QK2 bHB;?iHv bK HH2` i? M \# b2HBM2- M/ Qm ` MF@` MF +Q``2H iBQM [mBi2 *X27] HQK Q22 /2T2M/2Mi bX

[ky] 6Q` BMbiM+2- M/ EQ`iimK Q\#i BM M 2biBK i2/ i` /2 2H biB+Biv jXey mbBM QMHvX

[kR] LQi2 i? i r2 MQ`K HBx2 /QK2biB+ bQm`+BM; TQi2MiB H iQ \#2 QM2X h?2 /Q BKTQ`iBM; 7`QK bQm`+BM;

$$ N_i \int_{'_i}^{1} I^{M}_{ij}(')(1)^{-1}' \; {}^{1}({}_i(')) {}^{-1} \; {}^{1} X_i(') \; {}^{M}_{ii} \, dG_i(') = (1)^{-1} N_i \, {}^{M}_{ij} ; $$

r?2`2 ^{M}_{ii} = 1 X

h #H2 d, 1biBK iBM; aQm`+BM; 1H biB+Biv

	HQ^M_j;		HQ; ;;`2; i2$_j$BKTQ`i	
	PGa	Ao	PGa	Ao
	URV	UkV	UjV	U9V
HQ$^M_{ij}$;w$_j$	@RXyN9	@RXydk	@RXdek	@RXkd
	UyX9ReV	UyX8y3V	UyX88dV	UyXejN
HQ; /Bb$_{ij}$i M+2	@yX89y	@yX8jd	@yX988	@yXj3d
	UyXkdeV	UyXk9kV	UyXj3jV	UyXj9RV
*QMiB$_{ij}$mBiv	@yXN3d	@yXN3R	@RXyyN	@yX3N
	UyX8eyV	UyX9NyV	UyXeeyV	UyX8jy
HQ; :.S T2`$_j$+ TBi	yX9y3	yXj39	RXReN	yXejR
	UyXe9kV	UyXeNyV	UyXddNV	UyXNy
AM+QK2$_{ij}$;`QmT	@RXjdk	@RXjed	@RX9Ry	@RXk3
	UyXjNdV	UyXje3V	UyX3ydV	UyXeNe
_h$_{ij}$	@yXRyN	@yXRRy	@yXy8jR	@yXyd
	UyX998V	UyXjdeV	UyXNe8V	UyX3kN
HQ; _$_j$.	@yXy9NN	@yXy8Rk	@yXy3ye	@yXR
	UyXRkdV	UyXRy9V	UyXkj9V	UyXkyk
HQ; + TBi H T$_j$2` rQ` F2`	yXk89	yXkej	@yXyR93	yXR33
	UyX9jyV	UyX9ykV	UyX88RV	UyX88e
HQ; MmK#2`$_j$ Q7 }`Kb	yXRkR	yXRkR	yXjy9	yXjyj
	UyXRddV	UyXR8yV	UyXRNNV	UyXR
HQ; /QK2bi$_j$B+ BMTmi		yXN39	yXN38	
		UyXkk3V	UyXR3NV	
*QMbi Mi	@3X3Rd	@3Xd8d	@RyXR3	@3X39
	URXdjyV	URX3RdV	U9Xd9eV	U9XkR
6@ai iBbiB+	@	R8Xejd	@	R3X3j9
P#bX	je	je	je	je
_^{2}	yX8ke	yX8ke	yX3ey	yX38e

LQi2, h?Bb i #H2 b?Qrb i?2 2biBK iBQM `2bmHib 7Q` bQm`+BM; 2H biB+ 2tTQ`i /2biBM iBQMb M/ iQT jy bQm`+BM; Q`B;BMb 7Q` *?BM BM v2 +QmMi`B2bX 6QHHQrBM; M/ 6Mb`b QMi`b- M/ h BKyM2H2M2 HQ; TQTmH iBQM bBx2 b 7Q` HQ$^M_{ij}$w$_j$; BM +QHmKMb UkV M/ U9VX _Q#mbi bi M/ `/ 2``Q`b `2 BM i?2 Q7 bi2`BbF BM/B+ i2b bB;MB}+ M+2 i RWU V- 8WU V M/ RyWU V H

BMbi`mK2Mi b BM +QHmKM UkVX J2 Mr?BH2- i?2 2biBK i2/ +Q2 Tm`+? b2 UyXN39 BM +QHmKM UjV M/ yXN38 BM +QHmKM U9V i?2Q`2iB+ H T`2/B+iBQM XQjWXBM 2+[mQ bQ2MR@ yXydk BM +QHmKM UkV b 7Q`BM Qm` [m MiBi iBp2 M HvbBbX LQi2 i? i Qm`X2b+BK`iBQMb iQ S`QTQbBiBQM i` /2 /2+BbBQMb +`Qbb bQm`+BM; Q`B;BMb M +QKTH2K2Mi `v iQ 2 +? Qi?2`- BKTHvBM; i?2 MH#Q2` BHTKB2M BM +QMi2tiX

$$\hat{=} \quad ;\mathrm{KBM}() \quad J^{d\ 0}\hat{q}\ J() \quad J^{d}\ ; \qquad \mathrm{UjjV}$$

7` +iBQM Q7 2tTQ`i2` M/ BKTQ`i2`bX h?Bb Bb #2+ mb2 H `;2`
;2iiBM; HQr2` }t2/ +Qbi /` rbX h?2 irQ T ` K2i2`b ;Qp2`MBM; i?2
b+QT2 K2+? MBbK TH v M BKTQ`i Mi `QH2 BM z2+iBM; i?2 `2H
#2+QK2 2tTQ`i2`b- M/ +QMp2`b2Hv- i?2 /p Mi ;2 Q7 2tTQ`i2`b i
BM+`2 bBM; BM i?2 BX2K2ii?2 +Q``2H iBQM +Q2{+B2Mi #2ir22M i
+ M HbQ H2 / iQ BM+`2 b2b BM i?2b2 /p Mi ;2bX

S M2H * Q7 3b#Q2b i?2 `2bmHib 7Q` i?2 2biBK i2/ T ` K2i2`bX h
i?2 2tBbi2M+2 Q7 H `;2 }t2/ +Qbib BM 2tTQ`iBM; M/ BKTQ`iBM;X
Q7 2tTQ`iBM; Bb- QM p2` ;2- kX93 KBHHBQM 1UW Q?2`Q2 M/2jey-
2tTQ`i2` b H2bV- M/ i? i Q7 i?2 bQm`+BM; }t2/ +Qbi Bb RXkN K
la. UQ81W Q7 i?2 p2` ;2 }`Köb bQm[k8] +BMQ`/ BH miK2 UQm` 2biBK i2b
`2H iBp2Hv KQ`2 /B{+mHi 7Q` *?BM2b2 }`Kb iQ 2tTQ`i iQ 7Q`2B;
7Q`2B;M Q`B;BMbX h?2 T`2b2M+2 Q7 H `;2 }t2/ +Qbib HbQ BKTH
`2/m+BM; i?2K +QmH/ ? p2 bm#bi MiB H BKT +i QM }`Köb ;HQ#
bm;;2bib i? i bQm`+BM; 7`QK 7Q`2B;M +QmMi`v + M- QM p2`
2tTQ`iBM; iQ i?2 b K2 +QmMi`v #v #Qmi 9yW UQ` 2[mBp H2MiHv
}`Kb /2+B/2b iQ 2tTQ`iV- M/ i?Bb +Qbi `2/m+iBQM 2z2+i Bb bBKB
r v `QmM/ U #Qmi jdW BM T2`+2Mi ;2 Q` 2[mBp H2MiHv- yX8 KBH
b p2/ B7 }`Kb /2+B/2b iQ 2tTQ`ib iQ Bib bQm`+BM; Q`B;BMVX h?
bHB;?iHv T+bB7BpQ`2H iBQMb #2ir22M i?2 }t2/ +Qbib?Q+FbX 6
/BbT2`bBQM Q7 }t2/ +Qbib QM #Qi? i?2 2tTQ`i M/ BKTQ`i bB/2 +
iQ K i+? i?2 bm#bi MiB H ?2i2`Q;2M2Biv BM i2`Kb Q7 }t2/ +Qbib 7
BKTQ`i2`bX

[k8]. b- _Q#2`ib- M/ hvv#Q i?Qr i?2 2biBK i2/ 2tTQ`i }t2/ +Qbi 7Q` *QHQK#B }
9yy-yyy la. X``b- 6Q`i- M/ h2M2THi2Mi i?2 2biBK i2/ BKTQ`i }t2/ +Qbi 7Q`
#Qmi 8y-yyy la.

6B;m`2 9, C +Q#B M J i`Bt

LQi2ḫ?Bb };m`2 `2TQ`ib i?2 KQ/2H B/2MiB}+ iBQM `2bmHi #v b?QrBM;
?Q`BxQMi H tBb `2T`2b2Mib i?2 T ` K2i2`b M/ i?2 p2`iB+ H tBb `2T`
i?2 KQK2Mi Ub?QrM b i?2 iBiH2 Q7 2 +? T M2HV rBi? `2bT2+i iQ i?2 +Q

h #H2 3, S ` K2i2` bbB;MK2Mib, " b2HBM2

S ` K2i2`b	avK#QHb	" b2HBM2	aQm`+2
S M2H , bbB;M2/			
S `2iQ b? T2		9Xk8	GBi2` im`2
S M2H ", _2/m+2/@7Q`K `2;`2bbBQMb			
.2K M/ 2H biB+Biv		9Xkj	1biBK iBQM
aQm`+BM; 2H biB+Biv		RXyd	1biBK iBQM
S M2H *, aJJ			
.2K M/ b+ H2	$\tilde{B}_i$	jX99 UyXR8yV	1biBK iBQM
*Qbi `2/m+iBQM UBKTQ`i@BM/m+2/V	θ_0	yX9R UyXy98V	1biBK iBQM
*Qbi `2/m+iBQM U2tTQ`i@BM/m+2/V	θ_1	yXRd UyXyk8V	1biBK iBQM
*Q``2H iBQM Q7 }t2/ +Qbib		yXyd UyXyy9V	1biBK iBQM
AKTQ`i, +QMbi Mi i2`K	M_C	RXk9 UyXy8yV	1biBK iBQM
AKTQ`i, /Bbi M+2 T ` K2i2`	M_d	RX3e UyXyyjV	1biBK iBQM
AKTQ`i, bi M/ `/ /2pB iBQM	M_{disp}	RX38 UyXyRjV	1biBK iBQM
1tTQ`i, +QMbi Mi i2`K	X_C	kX93 UyXy88V	1biBK iBQM
1tTQ`i, /Bbi M+2 T ` K2i2`	X_d	RX9y UyXyR9V	1biBK iBQ
1tTQ`i, bi M/ `/ /2pB iBQM	X_{disp}	kXee UyXykyV	1biBK iBQM

LQi2, h?Bb i #H2 HBbib i?2 T ` K2i2` p Hm2b 7Q` i?2 bbB;M2/ M/ i?2 QM `2;`2bbBQM Q` 7`QK i?2 bBKmH i2/ K2i?Q/ Q7 KQK2Mib UaJJV K2i?Q/ Q#i BM2/ #v #QQibi` TTBM; i?2 / i M/ i?2 bi M/ `/ 2``Q`b `2 `2TQ`i2/

8Xk 6Bi Q7 i?2 " b2HBM2 M/ Hi2`M iBp2 JQ/2Hb

h #H2 N b?Qrb i?2 KQ/2H }i 7Q` #Qi? i `;2i2/ M/ MQM@i `;2i2/ KQK KQK2Mib Bb i?2 b? `2 Q7 BKTQ`i2`b M/ i?2 b? `2 Q7 2tTQ`i2`b im`BM; }`KbX h?2 KQ/2H T`2/B+ib `QmM/ M mM+QM/BiBQM H h?2b2 MmK#2`b `2 #`Q /Hv +QMbBbi2Mi rBi? i?2 / i - r?2`2 i?2 7 M/ i?2 7` +iBQM Q7 2tTQ`i2` Bb QMHv NWX AM i?2 / i - i?2 bB M/ BKTQ`i2`b `2 ?B;?Hv bF2r2/X 6QHHQrBM; 6h- r2 mb2 i?2 7` `2 #2HQr K2/B M iQ /Bb+BTHBM2 T ` K2i2`b bbQ+B i2/ iQ i?2 K mb2 i?2 7` +iBQM Q7 BKTQ`i2`b M/ 2tTQ`i2`b KQM; }`Kb #2HQr /BbT2`bBQM T ` K2i2` Q7 }t2/ +Qbi /Bbi`B#miBQMbX h?2 KQ/2H BM b H2b BX2X 9XdW BM KQ/2H p2`bmb eXRW BM / i 7Q` BKTQ p2`bmb dXjW 7Q` 2tTQ`iBM;X 6BM HHv- i?2 KQ/2H + Tim`2b i?2 2tTQ`i M/ BKTQ`i T`Q}H2b UyX93 pXbX yX9yV M/ i?2 2tTQ`i2`öb TQ`i U2tTQ`iV T `iB+BT iBQMX AM i?2 / i ik-r? pB+Mn K2 MQ2/fBK hQ# 2tT2`B2M+2 BM +QmMi`v Bb bbQ+B i2/ iQ `QmM/ N iBK2b ?B; BKTQ`i2`f2tTQ`i2` BM i?2 b K2 +QmMi`vX h?2 KQ/2H HB;Mb r2H /p Mi ;2 UNXyd pXbX NXjkV M/ T`2/B+ib bHB;?i Qp2`b?QQi 7Q` pXbX NXy8VX

"2bB/2b i?2 i `;2i2/ KQK2Mib- i?2 2biBK i2/ KQ/2H HbQ + Tim

S ` K2i2`b	JQ/2H . i
S M2H , h `;2i2/ KQK2Mib	
a? `2 Q7 BKTQ`i2`b	yXRk yXRR
a? `2 Q7 2tTQ`i2`b	yXRk yXyN
a? `2 Q7 BKTQ`i2`b U#2HQr K2/B M b H2bV	yXy9d yXyeR
a? `2 Q7 2tTQ`i2`b U#2HQr K2/B M b H2bV	yXy8j yXydj
a? `2 Q7 }`Kb rBi? +im H K2/B M /QK2biB+ BMX8k i Tm`8+y? b2	
qBi?BM@}`K 2tTQ`i@BKTQ`i +Q``2H iBQM	yX93 yX9y
_ iBQ #fr b? `2 Q7 2tTQ`i2`b KQM; BKTQ`i2`b M/ MQM@BKT	
_ iBQ #fr b? `2 Q7 BKTQ`i2`b KQM; 2tTQ`i2`b M/ MQM@2tTQ	
S M2H ", LQM@i `;2i2/ KQK2Mib	
a? `2 Q7 irQ@r v i` /2`b	yXy9 yXy9
a? `2 Q7 irQ@r v i` /2`b KQM; 2tTQ`i2`b	yXj8 yX99
a? `2 Q7 irQ@r v i` /2`b KQM; BKTQ`i2`b	yXj9 yXje
LmK#2` Q7 2tTQ`i /2biBM iBQMb- irQ@r v i` /2` Qp2` Tm`2 2tT	
LmK#2` Q7 bQm`+BM; Q`B;BMb- irQ@r v i` /2` Qp2` Tm`2 BKTQ	

LQi2h?Bb i #H2 b?Qrb KQ/2H }i QM i `;2i2/ M/ MQM@i `;2i2/ KQK2Mib
/2i BHb QM i?2 +QMbi`m+iBQM Q7 KQK2MibX

bbQ+B i2/ iQ irQ@r v i` /2`bX aT2+B}+ HHv- i?2 KQ/2H ;2M2`
b? `2 Q7 irQ@r v i` /2` M/ BM / i - i?2 b? `2 Bb `QmM/ 9XyWX
Q#b2`p2/ B7 r2 HQQF i +QM/BiBQM H KQK2Mib, BM / i - i?2 b?
+QM/BiBQM H QM #2BM; 2tTQ`i2`b M/i? iBbj8W QM #2BM; BKTQ
Bb jeW M/ j9W- `2bT2+iBp2HvX AM #Qi? i?2 KQ/2H M/ i?2 / i - ir
2tTQ`i iQr `/b KQ`2 K `F2ib URX9e BM i?2 KQ/2H M/ RX8y BM i?2
bQm`+2 7`QK KQ`2 Q`B;BMb URX9N BM i?2 KQ/2H M/ RX8y BM i?
r2 HbQ +?2+F i?2 ?B2` `+?v T ii2`Mb BM bQm`+BM; M/ 2tTQ`iBM
/Q2b `2 bQM #Hv ;QQ/ DQ# BM K i+?BM; i?2 Q#b2`p2/ ?B2` `+?

_2bi`B+i2/ JQ/2H bi?Bb b2+iBQM- r2 +QMbB/2` i?`22 Hi2`M iBp2
` i2Hv $H_0 = 0$ - $_1 = 0$ M/ #Qi? b2i iQ #2 x2`QX aT2+B}+ HHv- 7Q` 2
`2bi`B+i2/ KQ/2Hb- r2 `2@2biBK i2 i?2 KQ/2Hb mbBM; i?2 b K2 b
HBM2 KQ/2HX q?2M `2@2biBK iBM; i?2 }`bi irQ KQ/2Hb- r2 /`QT i
b? `2b KQK2Mib- BX2X 2tTQ`i2`öb /p Mi ;2 BM BKTQ`i T `iB+BT
BM 2tTQ`i T `iB+BT iBQMX 6Q` i?2 H bi KQ/2H r?2`2 i?2 722/# +
#Qi? bB/2b- r2 HbQ /`QT i?2 }`K@H2p2H +Q``2H iBQM KQK2MiX
KQ/2Hb `2 MQi /2bB;M2/ iQ `2T`Q/m+2 i?2b2 7 +ibX "v /`QTTBM;
iBQM pQB/b bi +FBM; i?2 /2+F ; BMbi i?2 # b2HBM2 KQ/2H- M/ r
Hi2`M iBp2 2biBK iBQM T`Q+2/m`2 r?2M HH i?2 7Qm` ivT2b Q7
;2iBM; i?2 b K2 b2i Q7 KQK2Mi b BM i?2 # b2HBM2 KQ/2H- M/ r

[m MiBi iBp2 BKTHB+ iBQMb `2 bBKBH `X

h #H2 Ry, S ` K2i2` bbB;MK2Mib M/ JQK2Mib

S ` K2i2`bfJQK2Mib	" b2HBM2=0 0=0 _2bi`B+i2/ aQm`+2f. i
S M2H , bbB;M2/	
S `2iQ b? T2	9Xk8 9Xk8 9Xk8 9Xk8 GBi2` im`2
S M2H ", _2/m+2/@7Q`K `2;`2bbBQM	
.2K M/ 2H biB+Biv	9Xkj 9Xkj 9Xkj 9Xkj 1biBK iBQM
aQm`+BM; 2H biB+Biv	RXyd RXyd RXyd RXyd 1biBK iBQM
S M2H *, aJJ	
.2K M/ b+ H2	jX99 jXkd jX99 jXed 1biBK iBQM
	UyXR8yV UyXy8yV UyXykRV UyXy9dV
*Qbi `2/m+iBQM UBKTQ`i@BM/m+2/ 2tTQ`iV	yX9R yXkN yXyy yXyy 1biBK iBQM
	UyXy98V UyXyj3V U V 1biBK iBQM
*Qbi `2/m+iBQM U2tTQ`i@BM/m+2/ BKTQ`iV	yXjd yXyy yXj3 yXyy 1biBK iBQM
	UyXyk8V U V UyXyR9V 1biBKViBQM
*Q``2H iBQM Q7 }t2/ +Qbib	yXyd yXRR yXRj yXRj 1biBK iBQM
	UyXyy9V UyXyy8V UyXyydV UyXyRRV
AKTQ`i, +QMbi Mi2`K	RXk9 RXej RX39 RXN9 1biBK iBQM
	UyXy8yV UyXyRkV UyXyR3V UyXyR3V
AKTQ`i, /Bbi M+2 T ` K2i2`	RX3e RXjj RXy8 RXye 1biBK iBQM
	UyXyy3V UyXyyjV UyXyyjV UyXyy9V 1
AKTQ`i, bi M/ `//2pB iBQM	RX38 RXN3 RXN8RXNy 1biBK iBQM
	UyXyRjV UyXyy3V UyXyyNV UyXyRyV
1tTQ`i, +QMbi Mi2`K	kX93 kXek kXej kXk8 1biBK iBQM
	UyXy88V UyXykeV UyXykkV UyXyk9V
1tTQ`i, /Bbi M+2 T ` K2i2`	RX9y yXNk yXdj yXd9 1biBK iBQM
	UyXyR9V UyXyRyV UyXyydV UyXyydV
1tTQ`i, bi M/ `//2pB iBQM	kXee kXej kX8y kXjk 1biBK iBQM
	UyXykyV UyXyRkV UyXyRyV UyXyRRV
S M2H ., h `;2i2/ KQK2Mib	
a? `2 Q7 BKTQ`i2`b	yXRk yXR9 yXR9 yXRk yXRR
a? `2 Q7 2tTQ`i2`b	yXRk yXRe yXRe yXRe yXyN
a? `2 Q7 BKTQ`i2`b U#2HQr K2/B M b H2bV	yXy9d yXy8j yXyy8X yXy9k yXyeR
a? `2 Q7 2tTQ`i2`b U#2HQr K2/B M b H2bV	yXy8j yXyd9 yXyydX yXyed yXydj
a? `2 Q7 }`Kb rBi? +im H K2/B M /QK2biB+ BMTmX8km`+?X82	yX8k yX9d yX8y
qBi?BM@}`K 2tTQ`i@BKTQ`i +Q``2H iBQM	yX93 yXkk yXk3 yXR3 yX9y
_ iBQ #fr b? `2 Q7 2tTQ`i2`b KQM; BKTQ`i2`b M/ MQM@BKTQ`i2`b	NXy8
_ iBQ #fr b? `2 Q7 BKTQ`i2`b KQM; 2tTQ`i2`b M/ MQM@2tTQ`i2`b	NXjk

LQi2h?Bb i #H2 b?Qrb T ` K2i2`Bx iBQM 7Q` i?2 # b2HBM2 M/ i?2 i?`
b2+QM/ +QHmKM b?Qrb i?2 `2bmHib 7Q` # b2HBM2X h?2 i?B`/ +QHmKM
r?2`2 r2 $b_1$=i0 X AM i?2 2biBK iBQM- r2 /`QT i?2 KQK2Mi QM i?2 b? `2 Q7 2
QM BKTQ`i2` pbX MQM@BKTQ`i2`- BX2X- i?2 KQK2Mi rBi? M bi2`BbP
+QMbB/2`b bvKK2i`B+ + b_0=r0?X `h2?r2 }b7i? +QHm $_1$=M bM/ b_0 = 0 X h?2
bi M/ `/2``Q`b `2 `2TQ`i2/ BM T `2Mi?2b2bX

AM h #Ry2?2 `2TQ`i i?2 T ` K2i2` 2biBK iBQMb M/ KQ/2H }i Q7 #
M/ `2bi`B+i2/ KQ/2HbX Ai Bb +H2 ` i? i i?2 `2bi`B+i2/ KQ/2Hb-
bQ+B i2/ rBi? K `F2i@bT2+B}+ #BH i2` H 2+QMQKB2b Q7 b+QT2
KQK2Mib bm+? b i?2 2tTQ`i2` M/ BKTQ`i2` b? `2bX h?2 T2`7Q`
i? i HH i?2b2 KQ/2Hb `2 #mBHi QM i?2 6h 7` K2rQ`F M/ i?mb
T`QT2`iB2b 7`QK BiX 6Q` 2t KTH2- i?2 MQM@K `F2i@bT2+B}+ 7
bi`B+i2/ KQ/2Hb `2 BKTQ`i Mi BM + Tim`BM; i?2 `2H iBp2 MmK#2
UR9W BM KQ/2H M/ RRW BM / i VX "v 2biBK iBM; i?2b2 `2bi`B-
+ M BbQH i2 Qm` KQ/2H K2+? MBbK 7`QK i?2 bi M/ `/ 6h 7` K2r
KmiBM; i?2 K `F2i@bT2+B}+ #BH i2` H 2+QMQKB2b Q7 b+QT2X

8Xj _ MF@_ MF *Q``2H iBQM

AM i?Bb b2+iBQM- r2 bb2bb KQ/2Höb #BHBiv iQ `2THB+ i2 i?2 /Q 7 2tTQ`i /2biBM iBQMb M/ bQm`+BM; Q`B;BMbX hQ Mbr2` i? / i iQ +QKTmi2 i?2 MmK#2` Q7 2tTQ`i2`b M/ BKTQ`i2`b BM 2 +? 7 ivT2b Q7 KQ/2Hb- r2 b+ ii2`@THQi i?2 2tTQ`i M/ BKTQ`i ` MFB h?2 `2bmHi Bb T`2b2Mi2/ B2MHQBQm`2i?2 +QM/BiBQM Hb KTH2 Q7 UBX2X- }`Kb b2HH iQ iH2 biQM2 7Q`2B;M K `F2i M/ ii?2 b K2 7Q`2B;M Q`B;BMV 7Q` #Qi? i?2 / i M/ i?2 KQ/2HbX

AM i?2 / i i? i +QMi BMb iQT i` /BM; T `iM2`b rBi? *?BM - r?2I iBM iBQM KQp2b mT #v QM2- i?2 ` MF Q7 i?Bb +QmMi`v QM i?2 2 QM p2` ;2 BM+`2 b2b #v yXd8X h?2 # b2HBM2 KQ/2H UBM S M2 `2H iBQMb?BT- rBi? bHB;?iQp2`b?QQi UyXd3 7Q` i?2 KQ/2HVX

h?2 TQbBiBp2` MF@` MF `2H iBQMb?BT `BbBM; 7`QK i?2 # b #v Qi?2` +? MM2Hb i? irQ`F BM/2T2M/2MiHv 7`QK i?2 K `F2i@b 6Q` 2t KTH2- i?2 +Q``2H iBQM #2ir22M +QmMi`vöb bQm`+BM; T 6B;mj`2 M H2 / iQ bBKBH ` Q#b2`p iBQMbX hQ BbQH i2 i?Bb TQb i?2 ` MF@` MF `2H iBQMb?BT 7Q` i?2 i?`22 `2bi`B+i2/ p2`bBQMb 2tTQ`i UBX2=X0Y MHv 2tTQ`i@BM/m+2/0BKTQMi/UBX2XM2 M?2v 2 #Qi? 2z2+i `2 Kmi2/X "2+ mb2 i?2 QMHv /Bz2`2M+2 +`Qbb i?2b2 `2 #BH i2` H- mMBH i2` H- Q` MQM@K `F2i bT2+B}+ 2+QMQKB2 iQ BbQH i2 Qm`+? MM2Hb T `iX

S M2H " b?Qrb i? irBi?Qmi Mv }t2/ +Qbi `2/m+iBQM K2+? MBb 2tTH BMb `QmM/ 9yW UyXkNfyXd8V Q7 i?2 bHQT2b BM i?2 / i - #BH i2` H +Qbi `2/m+iBQM K2+? MBbK ++QmMib 7Q` #Qmi i?2 . Hi2`M i2Hv BMi`Q/m+2 mMBH i2` H 2+QMQKB2b Q7 b+QT2 K2+ QM2@bB/2/ +Qbi `2/m+iBQM bi`2M;i?2Mb i?2 TQbBiBp2 `2H iBQ 2tTQ`i M/ yX9k 7Q` i?2 Qi?2` r v `QmM/V- #mi Bb BMbm{+B2Mi / i X

---

[k] AM TT2MXBX2 +?2+F i?2 `Q#mbiM2bb Q7 Qm``2bmHi #v ` MFBM; i?2 bQm` /2biBM iBQMb QM HH }`Kb- BX2X- BM+Hm/BM; Tm`2 2tTQ`i2`b- Tm`2 BKTQ b KTH2- i?2 KQ/2H /2HBp2`b bHB;?iHv HQr2` UyXdRV +Q``2H iBQMb i? M i?2

LQi2h ?Bb };m`2 THQib i?2 ` MF@` MF `2bmHi 7Q` i?2 b2H2+i2/ iQT jy
2tTQ`i K `F2ib +QmMi`B2b BM kyydX h?2 ` MFBM;b Q7 bQm`+BM; Q`B;
#v i?2 MmK#2` Q7 *?BM2b2 BKTQ`i2`b M/ 2tTQ`i2`b- `2bT2+iBp2Hv- 7Q
T M2Hb b? `2 i?2 b K2 tBb H #2HbX

AM //BiBQM- i?2b2 ` MF@` MF `2H iBQMb?BTb +QmH/ HbQ #
#2ir22M i?2 K `F2i@bT2+B}+ }t2/ +Qbi /` rbX Pm` 2biBK iBQM 7
U=0:07V +Q``2H iBQMX h? i M im` HHv H2 /b iQ i?2 Bbbm2 `2; `/B
#B b Q7 i?2 }t2/ +Qbib +Q``2H iBQM T* X 9Xk 2tT2+iQ`b M/ +T 2M/Bt
M HvbBb r?2`2 r2 +? M;2 i?2 +Q``2H iBQM Q7 i?2 +Qbi /` r T ` K
`2;BK2 r?2`2 i?2 }t2/ +Qbi /` rb `2 BM/2T2M/2Mi iQ i?2 QM2 r?
Qp2`H TX S M2H Q7 i?2 i #H2 b?Qrb i?2 ` MF@` MF `2H iBQMb?
M/ BKTQ`i2`bV 7Q` HH 7Qm` ivT2b Q7 KQ/2HbX q2 2tT2`BK2Mi
2 f 0:0; 0:2; 0:4; 0:6; 0:8g - M/ HH i?2 `2bip Hm2b Q7 i?2 KQ/2H `2i F2M 7
h?2`2 `2 irQ TQBMib iQ MQi2X 6B`bi M/ T2`? Tb MQi bm`T`BbBM
T ` K2i2` /Q2b K F2 i?2 KQ/2H iQ #2ii2` + Tim`2 i?2 ` MF@` MF
T ii2`M H `;2Hv ?QH/b 7Q` HH 7Qm` ivT2b Q7 KQ/2HbX 6Q` 2t KT
UBKTQ`i iQ 2tTQ`iV- i?2 ` MF@` MF +Q``2H iBQM BM i?2 b2 7Q

+QMbi`m+i2/ i` /2 +Q[k3] bi2+i? 2M; 7 b 2X/ i?2 KQ/2H rBi? i?Bb T`2@b?Q+

M/ bQHp2 i?2 KQ/2H- r?BH2 F22TBM; Qi?2` KQ/2H T ` K2i2`b +Q

+QmMi`vöb bQm`+BM; M/ b H2b TQi2MiB Hb M/ }t2/ +Qbib `2 i

KQ/2H i? i H2 / }`Kb iQ b?B7i i?2B` bQm`+BM; M/ 2tTQ`iBM; bi`

hQ /2+QKTQb2 *?BM2b2 }`Kbö 7Q`2B;M K `F2i ++2bbBQM BMiQ

iBQM- r2 /2MQi2 i?2 +? M;2 BM $x_{\#QT?}$ B7 r2 7Bt 2 #Q`/2` # Qi? BKTQ`i M/ 2tTQ`

+Qbi `2/m+iBQMb iQ i?2 KQ/2H BM $x_{BKTQ`i}$ B7 r2 Bt 2 `2/m+iBQM BM BKTQ`

`2/m+iBQMX h?2M i?2 +QMi`B#miBQM Q7 BKTQ`i HB#2` HBx iBQ

h?2M i?2 /Bz2`2M+2 #2ir22M $x_{\#QT?}$ M/ $x_{BKTQ`i}$ Bb ii`B#mi2/ iQ i?2 2tTQ`i@bB/2

h #H2 RR, 1ti2MbBp2 J `;BM Q7 h` /2 GB#2` HBx iBQ

	AKTQ`i HB#2` HBx iBQM	1tTQ`i HB#2` H
S M2H , " b2HBM2		
LmK#2` Q7 2tTQ`i2`b	yXy9j	yXN8d
LmK#2` Q7 BKTQ`i2`b	yXN8N	yXy9R
S M2H ", _2bi`B+i2/		
LmK#2` Q7 2tTQ`i2`b	yXyR8	yXN38
LmK#2` Q7 BKTQ`i2`b	yXN3d	yXyRj

LQi2, h?Bb i #H2 /2+QKTQb2b i?2 2ti2MbBp2 K `;BM Q7 i` /2 BMiQ HB#
2tTQ`iBM; bB/2X h?2 }`bi +QHmKM b?Qrb i?2 +QMi`B#miBQM UBM T2`-
BKTQ`i2` 2Mi`vX

h #H2 RR b?Qrb i?2 /2+QKTQbBiBQM `2bmHi 7Q` +? M;2b BM i?2 Mm

M/ BKTQ`i2`bX *QHmKM URV b?Qrb i?2 +QMi`B#miBQM Q7 BKTQ

i `Bz M/ }t2/ +Qbi `2/m+iBQMbV QM +? M;2 BM i?2 MmK#2` Q7 2tT

UkV `2TQ`ib i?2 +QMi`B#miBQM Q7 2tTQ`i HB#2` HBx iBQM r?B+

Q7 BKTQ`i HB#2` HBx iBQM BM +QHmKM URVX q2 HbQ +QM/m+

KQ/2H r?2`2 $\tilde{e}_1 = 0$- BX2X- i?2 #BH i2` H 2+QMQKB2b [kN] b?Q7 2bb+QHi2 `

Bb b?QrM BM S M2H X AM i?2 # b2HBM2 KQ/2H- bQm`+BM; HB#2

BKT +i QM i?2 2tTQ`i2` 2Mi`v i? M i?2 `2bi`B+i2/ KQ/2H U9XjW p

i?2 # b2HBM2 KQ/2H HbQ bm;;2bib H `;2` +QMi`B#miBQMb Q7 2t

Q7 BKTQ`i2`b U9XRW pXbX RXeWVX

h?2 TQbBiBp2 2z2+i Q7 mMBH i2` H BKTQ`i HB#2` HBx iBQM Q

/Q+mK2Mi2/X AM+`2 b2/ ++2bbB#BHBiv iQ 7Q`2B;M bQm`+BM; Q

i?`Qm;? i2+?MQHQ;v M/ [m HBiv mT;` /BM; 7Q` 2tTQ`i2`b UpBM;- GB- M/ ar2MbQM

kyRV- M/ T`QKQi2/ BMMQp iBQM M/ *Bbi`B+i? i2 H 2 MB - Mi`vX 6 MbBQ

*QMbBbi2Mi rBi? i?2 2KTB`B+ H HBi2` im`2- r2 b?Qr i? i i?`Qm;?

[k3] _2+ HH i? i +QmMi`vöb bQm`+BM; TQi2MiB H M/ b H2b TQi2MiB H `2 7mM
`2bT2+iBp2HvX

[kN] AM TT2M/Bt 6Xe- r2 `2TQ`i i?2 /2+QKTQbBiBQM `2bmHi 7Q` i?2 Qi?2` irQ KQ/2
+Qbi `2/m+iBQM- BX2X- $\tilde{e}_1 = 0$ M/ $\tilde{e}_2 = 0$X

bT2+B}+ #BH i2` H 2+QMQKB2b Q7 b+QT2 TH vb M BKTQ`i Mi `Q
BKTQ`i HB#2` HBx iBQM QM 2tTQ`i +iBpBiv BM *?BM X L2;H2+
i?2 2z2+i Q7 BKTQ`i HB#2` HBx iBQMX

h?2 J2+? MBbKQ 7m`i?2`mM/2`bi M/i?2 K2+? MBbKb #2?BM/i?2 /2
r2 b2T ` i2Hv b?Q+F i?2 # b2HBM2 M/i?2 `2bi`B+i2/ KQ/2H #v i`
i `Bz M/ }t2/ +QbibV 7Q` bQm`+BM; M/ 2tTQ`iBM;- M/ r2 `2 B
*?BM2b2 }`Kbö 7Q`2B;M K `F2i T `iB+BT iBQM UBX2X- i?2 MmK#
/2biBM iBQMbVX h?2 }`bb?Qm 7Q`2B;M `2+i2z2+i Q7 i` /2HB#2` HI
r2 +? `i i?2 +? M;2BM i?2 MmK#2` Q7 bQm`+BM; Q`B;BM 7i2` B
+? M;2BM i?2 MmK#2` Q7 K `F2ib 7i2` 2tTQ`i HB#2` HBx iBQM
+H bb2b bQ`i2/ #v i?2B` T`2@HB#2` HBx iBQM iQi H b H2b UrBi
i?2 ?B;?2biVX h?2 bbQ+B i2/ `2bTQMb2 Bb +QMi` bi2/ 7Q` #Qi?
KQ/2HX LQi2 i? i i?2 K ;MBim/2 BM i?2 +? M;2b BM 7Q`2B;M K `
+`Qbb i?2 irQ ivT2b Q7 i?2 KQ/2HbX

h?Bb Bb MiB+BT i2/- b }`Kb BM #Qi? KQ/2Hb `2bTQM/ /B`2+i
iBQMbX h?2 `2bmHi 7Q` i?2 BM/B`2+i 2z2+i- r?B+? Bb bQ2MvBM i
/Bz2`2MiX h FBM; i?2 2tTQ`i HB#2` HBx iBQM Ui?2 i?B`/ T M2H
TH2- 2tTQ`i HB#2` HBx iBQM #`BM;b QM p2` ;2 9W BM+`2 b2 BM
r?2`2 b i?2 `2bTQMb2 Q7 i?2 `2bi`B+i2/ KQ/2H Bb H `;2Hv Kmi2
avKK2i`B+ HHv- BKTQ`i HB#2` HBx iBQM HbQ BM/m+2b `QmM/
i?2 # b2HBM2 M/ RW 7Q` i?2 `2bi`B+i2/X h?2 Q#b2`p2/ /Bz2`2
KQ/2Hb Bb H `;2Hv /2`Bp2/ 7`QK i?2 #BH i2` H +Qbi `2/m+iBQM
HBx iBQM 7`QK QM2 bB/2 BM+2MiBp2b K `F2i T `iB+BT iBQM 7`
}t2/ +Qbi # ``B2`bX

LQi2h?Bb };m`2 THQib i?2 `2bTQMb2 Q7 i` /BM; pQHmK2 U2tTQ`i M/ b
UMmK#2` Q7 /2biBM iBQMb M/ Q`B;BMbV 7Q` }p2 ;`QmTb Q7 }`Kb bQ`i
#2BM; i?2 ?B;?2biVX h?2 #Hm2@+QHQ`2/ # `b `2 7Q` i?2 # b2HBM2 K
`2 7Q` i?2 `2bi`B+i2/ yK@Q /t2BHbX2 bh?`22 BM HQ; /2pB iBQMbX HH 7Qm` T M
tBb H #2HbX

d *QM+HmbBQM

Pm` bim/v ?B;?HB;?ib i?2 HBMF ;2 #2ir22M }`Köb 2tTQ`i M/ BKTQ
K `F2i@bT2+B}+ #BH i2` H 2+QMQKB2b Q7 b+QT2X q2 KQ/2H b
b pBM; BM }t2/ BMp2biK2Mi /m2 iQ bBKmHi M2Qmb 2tTQ`i M/ B
Pm` + HB#` iBQM b?Qrb i?2 +Qbi b pBM; K2+? MBbK Bb [m MiBi
bim/v /2KQMbi` i2b i? ibm+? 7Q`+2 Bb `2H2p Mi BM mM/2`bi M/B
`2H iBQMb?BT b r2HH b BM mM/2`bi M/BM; i?2 BKTHB+ iBQMb
h?2b2 }M/BM;b T`2b2Mi TQi2MiB H p2Mm2b 7Q` 7mim`2 `2b2 `
i` iBQM- i?2 KQ/2H Bb F2Ti BMi2MiBQM HHv T `bBKQMBQmb #v
2` H }t2/ +Qbib bbQ+B i2/ rBi? }`Köb 2tTQ`i M/ BKTQ`i /2+BbBQ

`B+?2` b2iiBM; rBi? KQ`2 KB+`Q@7QmM/2/ K2+? MBbK U2X;X-
bB/2/ b2 `+?BM; T`Q+2bbV b?QmH/ Qz2` KQ`2 bi`m+im` H BMi2`
#BH i2` H 2+QMQKB2bX a2+QM/-i?2`2bmHii? imMBH i2` Hi` /2
+QMb2[m2M+2 BKTHB2b Qm` KQ/2H + M #2 2ti2M/2/ iQ bim/v i?2
6Q` 2t KTH2- +Qbi `2/m+iBQM 7`QK +2`i BM bB/2 Q7 i` /2 U2Bi?
+QMbi` BM2/ Q` /22K2/ iQQ +QbiHvX lM/2` i?2b2 +B`+mKbi M+2b
2tT M/2/ #v `2bQ`iBM; iQ i?2 +Q``2bTQM/BM; TQHB+B2b 7`QK i?2
+m``2Mi KQ/2H /Q2b MQi HHQr 7Q` bTBHHQp2`b BM +Qbi `2/m+
i` /2 /2+BbBQMb BM QM2 +QmMi`v +QmH/ z2+ii?2 }t2/ +Qbib Q7
Qi?2` +QmMi`B2b i? i `2 ;2Q;` T?B+ HHv T`QtBK i2- HBM;mBbiB
HHQrBM; 7Q` bm+? K2+? MBbK K v H2 / iQ M2r TQHB+v BKTHB
b i?2 ;;`2; i2 2z2+ib Q7 `2;BQM HfT`272`2MiB H i` /2 ;`22K2M

_ 2 7 2 ` 2 M + 2 b

// - C X M / * Q Q T 2 ` - _ X M U k y B y j V 1 X + Q M Q K B + b , Z m M i B i i B p 2 J 2 i ? Q / i B Q X M h b ? 2 J A h S ` 2 b b X

? M - C X - E ? M / 2 H r H - X E X - M / q 2 B - a X @ C X U k y R R V X h ? 2 ` Q H 2 i ` / 2 X K Q m ` M H Q 7 A M i 2 ` M i B 3 9 M U R V 1 , + d Q M 8 Q X K B + b

H # Q ` M Q x - 6 X - S ` / Q - > X 6 X * X - * Q ` + Q b - : X - M / P ` M 2 H b - 1 X U k C Q m ` M H Q 7 A M i 2 ` M i B 3 M U R V 1 , + R Q d M j Q R K B + b

K B i B - J X - A i b F ? Q F B - P X - M / E Q M B M ; b - C X U k y R 9 V X A K T Q ` i 2 ` / B b + Q M M K 2 + B X + M 1 + Q M Q K - B R + y 9 2 U p d B V 2 , R N 9 k d 3 X

K B i B - J X M / E Q M B M ; b - C X U k y y d V X h ` / 2 H B # 2 ` H B x i B Q M - B M i B i v , 1 p B / 2 M + 2 7 ` Q K K B 2 M B + M 2 h B Q X M Q K - B N + d U 2 p V B 2 , R e R R R e j 3 X

M i ` ¨ b - S X - 6 / 2 2 p - 1 X - 6 Q ` i - h X * X - M / h B M i 2 H M Q i - 6 X U k y k k V X i B Q M H + i B p B i v , m M B } 2 / _ q T Q ¨ F Q B + M ? X S T 2 X ` a 2 ` B 2 b

M i ` ¨ b - S X - 6 Q ` i - h X * X - M / h B M i 2 H M Q i - 6 X U k y R d V X h ? 2 K ` ; B M M / 2 p B / 2 M + 2 7 ` Q K K m 2 b B } + K M b X 1 + Q M Q K - B R + y d 2 U p N B V 2 , k 8 R 9 e 9 X

` F Q H F B b - * X - 1 + F 2 ` i - 6 X - M / a ? B - _ X U k y k k V X * Q K # B M i Q ` B H + Q K T M B 2 b - T H M i } t 2 / + Q b i a a - _ L M q Q K ` F B M ; T S X T 2 X ` a 2 ` B 2 b

" 2 ` M ` / - X " X - C 2 M b 2 M - C X " X - _ 2 / / B M ; - a X C X - M / a + ? Q i i - S X E i ` / 2 X K 2 ` B + M 1 + Q M Q K - B N + N _ U 2 k p V B 2 , 2 i 3 d N j X

" 2 ` M ` / - X " X - C 2 M b 2 M - C X " X - _ 2 / / B M ; - a X C X - M / a + C ? Q m i - M S X H E X Q 7 1 + Q M Q K B + - G 8 B e i U 2 k V m 8 ` e 2 8 e R N X

" B H b - J X M / E H 2 M Q r - S X C X U k y y y V X . Q 2 k 2 b ` + B ? + Q M Q 2 B Q M Y + Q - k m B b + 2 ` ; 2 Q N y U 8 V , R R e y R R 3 j X

" ` M / i - G X - o M " B 2 b 2 # ` Q 2 + F - C X - q M ; - G X - M / w ? M ; - u X U k y T 2 ` 7 Q ` K M + 2 Q 7 + ? B M 2 b 2 K M K m 2 7 B + i m M ` B + M Q M j Q K k B K R + y d 2 U p N B V 2 , k d 3 9 k 3 k y X

" ` M / i - G X - o M " B 2 b 2 # ` Q 2 + F - C X - M / w ? M ; - u X U k y R k V X * ` 2 i / 2 b i ` m + i B Q M \ } ` K @ H 2 p 2 H T ` Q / m + i B p B i v ; ` Q r C ? Q m B M M + ? B Q M 7 2 b 2 2 p k 2 H Q T K 2 M i 1 + Q - M N Q d K U B k + V b j j N j 8 R X

* b i 2 H H M B - . X M / 6 b b B Q - * X U k y R N V X 6 ` Q K M 2 r B K T Q ` i 2 / B M T } ` K @ H 2 p 2 H 2 p B / 2 M + 2 7 ` b ? 2 Q K + b ? r S / Q M B K R V , j k k j j 3 X

*? M2v- hX Ukyy3VX .BbiQ`i2/ ;` pBiv, i?2 BMi2MbBp2 M/ 2ti2Ml
i` /2XK2`B+ M 1+QMQK-BN+3U2pvB,2dyd kRX

*? M2v- hX UkyR9VX h?2 M2irQ`F bi`m+im`2K2Q7BBMi21+MQMBQKB+
_2pB-2Ry9URRV,jeyy jej9X

*?2M- wX- GBm- wX- am€`2x a2`` iQ- CX *X- M/ sm- .X uX UkykR
rBi? +Q`TQ` i2 BM+QK2 i tK+2miB+BMi1?QMQXK-B+R_2UpdV2,rkye8 kRy

*Q``2B - aX UkyR8VX aBM;H2iQMb- +Hmbi2`@`Q#mbi bi M/ `/ 2`
.mF2 lMBp2`bBiv qQXFBM; S T2`

*QbiBMQi- X- _Q/`Q;m2x@*H `2- X- M/ q2`MBM;- AX UkykyVX J
TQHB+v rBi? }`K ?2i2+Q,2QMK2BiBXeV,kdjN kddeX

. b- aX- _Q#2`ib- JX CX- M/ hv#Qmi- CX _X UkyydVX J `F2i 2Mi
;2M2Biv- M/ 2tTQ`i1+vQMKQBK+2biX8U+jV,3jd 3djX

.2 GQ2+F2`- CX M/ q `xvMbFB- 6X UkyRkVX J `FmTk2MB/+}`MK@H2
1+QMQKB+-_2pkBU2eV,k9jd dRX

1 iQM- CX- 1bH p - JX- CBMFBMb- .X- E`Bx M- *X CX- M/ hv#Qm
H2 `MBM;KQ/2H Q7 2tTQ`i/vM KB+bX

1 iQM- CX M/ EQ`imK- aX UkyykVX h2+?MQHQ1+vQM2QK2i`TB?+v-
dyU8V,Rd9R RddNX

1 iQM- CX- EQ`imK- aX- M/ E` K `x- 6X UkyRRVX M M iQKvQ7B
7`QK 7`2M+1+QKMbQXK2iMBU8V,R98j R9N3X

6 M- >X- GB- uX X- M/ u2 TH2- aX _X UkyR8VX h` /2 HB#2` HBx
_2pB2r Q7 1+QMQKB+bNMUaiV,RyjR9X

622Mbi` - _X *X M/ _QK HBb- CX UkyR9VX AMi2`M iBZQM `H@T`B+2
i2`Hv CQm`M H Q-7R1k+NQUMkQK,9Bd+db 8kdX

62M;- GX- GB- wX- M/ ar2MbQM- .X GX UkyReVX h?2 +QMM2+iBQ
BMTmib M/ 2tTQ`ib, 1pB/2M+2 TC`QMK`M?BMQ7b2AMi2biX iBQM H 1
RyR,3e RyRX

: `+B @J +B - .X- >bB2?- *X@hX- M/ EH2MQr- SX CX UkyRNVX
1+QMQK2i3`dBU+8V,R8yd R89RX

:`B2+Q- SX GX- GB- aX- M/ w? M;- >X UkykkVX AMTmi T`B+2b- T
HQM;@`mM 2z2+ib Q7 HB#2` HBx iBQM QMi2?BMQ7b2AMi2biX iBQM H 1
1+QMQ-K8BjUjV,8Re 8eyX

Cz2- X "X URN3eVX h2+?MQHQ;B+ H QTTQ`imMBiv M/ bTBHHQ
Ti2Mib- T`Q}ib M/ K `F2ip Hm2X

CB - SX Ukyy3VX q? i> TT2Mb q?2M q H@J `i *QK2b iQ hQrM, M
i?2 .Bb+QmMi _2i BH1+QMQKB+bX

E b? ` - >X M/ _Q/`B;m2- CX Ukyy3VX .Q2b i?2 mb2 Q7 BKTQ`
T`Q/m+iBpBiv\ TH Mi@H2p2H 2pB/2M+2 7`QK 3HM1+QMQKB+b X

GBm- ZX M/ ZBm- GX .X UkyReVX AMi2`K2/B i2 BMTmi BKTQ`ib
+?BM2b2 }`Kbö T i2Mi BM;b X AMi2`M iBQM H 1+QMQKB+b

J2HBix- JX CX UkyyjVX h?2 BKT +i Q7 i` /2 QM BMi` @BM/mbi`v
BM/mbi`v T`Q/m+iBpBiv1+QMQK2i`B+ eV,ReN8 Rdk8X

JQ` H2b- 1X- a?2m- :X- M/ w ?H2`- X Ukyyj_X
aim/B2bUeV,kee3 kdRkX

Jm?Hb- JX M/ SBbm- JX UkyyNVX AKTQ`ib M/ 2tTQ`ib i?2 H2p2
#2H;BmK X 1+QMQKB+V,eNk dj9X

S p+MBF- LX UkyykVX h` /2 HB#2` HBx iBQM- 2tBi- M/ T`Q/m+
7`QK +?BH2 M2p2` 1+QMQKB+ URV,k9d kdeX

SB2`QH - JX .X- 62`M M/2b- X JX- M/ 6 `QH2- hX UkyR3VX h?2
T2`7Q`K M+2 Q7 1+QMQKB+bV,88y 8dkX

hBMi2HMQi- 6X UkyRdVX :HQ# H T`Q/m+iBQM M/ i`/2 BM i?2 iQi HMi7
1+QMQKB+bV,R8d kyNX

qQQH/`B/;2- CX JX URNNdVX JmHiBTHB+ iBp2 T M2H / i KQ/2H
bbmKTiBQM X 1+QMQKB+b 8V,eed ed3X

qQQH/`B/;2- CX JX UkyRyVX 1+QMQK2i`B+ M HvbBb Q7 +`Qbb b2+iBQM M/ T

um- JX UkyR8VX S`Q+2bbBM; i` /2- i `Bz `2/m+iBQMb M/ }`K T`
+?BM2b2 }`KbX 1+QMQKB+VM9j N33X

Appendices

A Data Appendix

A.1 Data Description

We clean and construct the customs sample from the Chinese Customs Trade Statistics (2000-2015) as follows.

1. First, we restrict attention to records of ordinary trade only, and drop the two categories of processing trade: pure assembly (PA) and import and assembly (IA).

2. Second, the products in Chinese customs database are classified using Harmonized System (HS) code at the 8-digit level across years using different vintages (1996, 2002, 2007 or 2012). We aggregate the sample to firm-country-HS6 (6-digit) level within each year and then convert HS6 codes from different vintages to the 1996 vintage using publicly available correspondences tables from the UN Statistical Division.

3. Both the empirical and the model section focus on the sourcing of intermediates and the export of final goods. Therefore, for export, we only keep the consumption goods at HS6 level identified by Broad Economic Categories Rev. 4 (BEC4), and for import, we focus on the non-consumption goods imported by Chinese firms.

4. Following the method in Ahn, Khandelwal, and Wei (2011), we identify trade intermediaries based on their company names in customs sample and exclude such firms from our analysis.

5. Finally, we restrict our attention to a set of major trading partners with China. For each year from 2000 to 2015, we choose the top 30 export destinations in terms of export value and top 30 import sourcing origins in terms of import value for China. This leads to 59 unique foreign countries which, on average, cover over 93% of the annual export volume and over 96% of the annual import volume. When we conduct reduced-form regressions using the panel data in Fact 2, we choose to keep all 59 foreign countries. When we focus on cross-sectional data of 2007 in Fact 1, Fact 3 and quantitative analysis, we keep only top 30 export destinations and top 30 import sourcing origins, amounting to 36 foreign countries.

A.2 Unobserved Processing Trade

One potential concern about our study is that the correlation between firm's export and import decision in a foreign country may reflect the supply chain or offshoring contract which Chinese firms sign with foreign partner. Throughout the paper, we drop the observed processing trade records from the customs sample. Note that reporting transactions as processing trade exempts firms from tariff duty. Therefore, firm has incentive to over-report processing trade and dropping the observed processing trade records should be sufficient to

exclude such mechanical linkages. To further address the issue of unobserved processing trade, we provide additional evidence as follows.

First, developed countries are more likely to sign supply contract with Chinese firms and we check whether the results are driven by those countries. Here we consider G7 as the major foreign partners of processing trade for China, and we repeat the baseline regressions by adding an interaction term between our variable of interest and dummy for G7. Columns (1)-(2) and (5)-(6) of Table A1 present the results and show that our variables of interest remain stable to taking into account primary supply contractors of China. Second, in the customs sample, some firms engage in both ordinary trade and processing trade. As we only exclude processing trade records from those firms, the resulting sample thus contains two types of firms: those who only do ordinary trade and the hybrid ones who do both. We additionally check whether the hybrid firms drive our empirical findings. We repeat the regression by adding an interaction term between our variable of interest and a dummy for processing trader (equals one if firm has any processing trade records on either export or import side). Columns (3)-(4) and (7)-(8) of Table A1 show that our variables of interest remain largely unchanged. Finally, if a majority of the trade linkages are unobserved processing subcontract, we should expect firms with more trade linkages (such as two-way traders) have lower mark-up compared to those with less trade linkages (such as pure exporter/importers). For example, Yu (2015) shows that Chinese firms with larger processing trade share experienced lower productivity growth after tariff reduction. In the merged sample, we estimate firm-level markup using the De Loecker and Warzynski (2012) method and find that the mean markup of two-way traders and pure exporters is 1.31 and 1.27 respectively, and the difference is statistically significant, suggesting the subcontract issue is not prevalent.

Table A1: Processing Trade and Bilateral Economies of Scope

Dependent Var.:	I Exp.$_{fct}$ > 0				I fIm.$_{fct}$ > 0g			
	LPM	Probit	LPM	Probit	LPM	Probit	LPM	Probit
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
I Imp.$_{fct\ 1}$ > 0	0.013***	0.265***	0.018***	0.184***	0.055***	1.473***	0.055***	1.474***
	(0.002)	(0.004)	(0.002)	(0.006)	(0.004)	(0.004)	(0.004)	(0.004)
. G7 Indicator$_c$	0.010***	0.045***						
	(0.002)	(0.005)						
. Processing Trader$_{ft}$			-0.002	0.133**				
			(0.002)	(0.007)				
I Exp.$_{fct\ 1}$ > 0	0.060***	1.276***	0.060***	1.276***	0.005***	0.255***	0.004***	0.222***
	(0.003)	(0.004)	(0.003)	(0.004)	(0.001)	(0.004)	(0.001)	(0.006)
. G7 Indicator$_c$					0.015***	0.067***		
					(0.003)	(0.005)		
. Processing Trader$_{ft}$							0.006***	0.082***
							(0.001)	(0.006)
Constant	0.122***	-0.897***	0.122***	-0.890***	0.016	-0.875***	0.016	-0.874***
	(0.018)	(0.041)	(0.018)	(0.041)	(0.010)	(0.040)	(0.010)	(0.040)
Export Extended Gravity	YES	YES	YES	YES	NO	NO	NO	NO
Import Extended Gravity	NO	NO	NO	NO	YES	YES	YES	YES
Gravity Variables	YES	YES	YES	YES	YES	YES	YES	YES
Firm-level Controls	NO	YES	NO	YES	NO	YES	NO	YES
Firm-Year FE	YES	NO	YES	NO	YES	NO	YES	NO
Country-Year FE	YES	YES	YES	YES	YES	YES	YES	YES
Firm-Country FE	YES	NO	YES	NO	YES	NO	YES	NO
Obs.	11,650,553	13,244,910	11,650,553	13,244,910	10,515,452	11,764,732	10,515,452	11,764,732
Adj. R^2	0.574	-	0.574	-	0.609	-	0.609	-
Pseudo R^2	-	0.468	-	0.469	-	0.546	-	0.546

i n§0I This table presents additional tests on the unobserved processing trade. G7 indicator denotes whether country c is a G7 country. Processing trader dummy equals one if firm f engages in processing trade on either export or import side in year t. Extended gravity for distance$_{fct\ 1}$ is constructed following Chaney (2014) while the other variables of extended gravity are constructed after Morales, Sheu, and Zahler (2019). Export extended gravity variables are constructed using only firm's past export decisions while import extended gravity variables are constructed using only firm's past import decisions. Standard gravity variables include distance, indicator for contiguity, common continent, common language, common income group and RTA between China and foreign country, and foreign GDP per capita. Standard errors are in the parentheses and clustered at firm and country level. The number of asterisk indicates significance at 1%(***), 5%(**) and 10%(*) level.

A.3 Linear Probability Model

We present the estimation results using linear probability model in Table A2 and A3. The advantage of using linear probability model is that we can add firm-year and firm-country fixed effects and use the code *JOX\LTO* developed by Correia (2015) in Stata to estimate the model efficiently.

Table A2: The Effect of Import Choice on Export Decision: LPM

	Dependent Var.: I $Exp._{fct} > 0$							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
I $Imp._{fct\ 1} > 0$	0.117***	0.0722***	0.0722***	0.0169***	0.102***	0.0677***	0.0677***	0.0168***
	(0.0185)	(0.0130)	(0.0128)	(0.00152)	(0.0123)	(0.0108)	(0.0107)	(0.00151)
I $Exp._{fct\ 1} > 0$	0.542***	0.501***	0.501***	0.0600***	0.513***	0.481***	0.481***	0.0597***
	(0.0184)	(0.0136)	(0.0134)	(0.00253)	(0.0135)	(0.0106)	(0.0106)	(0.00280)
Exp. Ext. $Distance_{fct\ 1}$					-0.0218**	-0.0260**	-0.0254**	-0.00158
					(0.0102)	(0.0105)	(0.0104)	(0.00194)
Exp. Ext. $Contiguity_{fct\ 1}$					0.0382***	0.0386***	0.0389***	0.0189***
					(0.0118)	(0.00932)	(0.00921)	(0.00287)
Exp. Ext. $Continent_{fct\ 1}$					-0.00198	-0.00425	-0.00393	-0.00328***
					(0.00738)	(0.00732)	(0.00719)	(0.00115)
Exp. Ext. Com. $Lang._{fct\ 1}$					0.0172*	0.0138*	0.0129*	0.00317
					(0.00936)	(0.00707)	(0.00702)	(0.00243)
Exp. Ext. $Income\ Group_{fct\ 1}$					0.00832	-0.0114**	-0.0141**	-0.00681***
					(0.00566)	(0.00495)	(0.00537)	(0.00208)
Constant	0.210*	0.0489***	0.0502***	0.106***	-0.367**	0.280***	0.276***	0.122***
	(0.122)	(0.00363)	(0.00208)	(0.000318)	(0.174)	(0.0954)	(0.0944)	(0.0176)
Gravity Variables	YES	YES	YES	YES	YES	YES	YES	YES
Firm-Year FE	YES	YES	YES	YES	YES	YES	YES	YES
Country FE		YES				YES		
Country-Year FE			YES	YES			YES	YES
Firm-Country FE				YES				YES
Obs.	13,026,937	13,026,937	13,244,910	11,650,553	12,840,780	13,026,937	13,244,910	11,650,553
Adj. R^2	0.459	0.473	0.473	0.574	0.467	0.477	0.477	0.574

in §0I This table presents the estimation results from specification (1) using linear probability model (LPM). The dependent variable is firm f's export dummy in country c at year t. Extended gravity for $distance_{fct\ 1}$ is constructed following Chaney (2014) while the other extended gravity variables are constructed after Morales, Sheu, and Zahler (2019). Standard gravity variables include distance, indicator for contiguity, common continent, common language, common income group and RTA between China and foreign country, and foreign GDP per capita. Standard errors are in the parentheses and clustered at firm and country level. The number of asterisk indicates significance at 1%(***), 5%(**) and 10%(*) level.

Table A3: The Effect of Export Choice on Import Decision: LPM

	Dependent Var.: I Imp.$_{fct}$ > 0							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
I Exp.$_{fct\ 1}$ > 0	0.0640***	0.0382***	0.0381***	0.00909***	0.0572***	0.0366***	0.0365***	0.00899***
	(0.0130)	(0.00899)	(0.00880)	(0.00123)	(0.0102)	(0.00830)	(0.00816)	(0.00122)
I Imp.$_{fct\ 1}$ > 0	0.605***	0.560***	0.559***	0.0515***	0.588***	0.547***	0.547***	0.0554***
	(0.0174)	(0.0131)	(0.0129)	(0.00403)	(0.0149)	(0.0115)	(0.0114)	(0.00414)
Imp. Ext. Distance$_{fct\ 1}$					-0.00588	-0.00959	-0.00903	0.00561***
					(0.00645)	(0.00623)	(0.00614)	(0.00109)
Imp. Ext. Contiguity$_{fct\ 1}$					0.0404***	0.0425***	0.0428***	0.0171***
					(0.00963)	(0.00865)	(0.00863)	(0.00309)
Imp. Ext. Continent$_{fct\ 1}$					-0.00141	-0.00386	-0.00358	-0.000345
					(0.00498)	(0.00482)	(0.00473)	(0.00108)
Imp. Ext. Com. Lang.$_{fct\ 1}$					0.00885	0.0132**	0.0131**	0.00306
					(0.00877)	(0.00657)	(0.00653)	(0.00214)
Imp. Ext. Income Group$_{fct\ 1}$					0.00175	-0.0130***	-0.0163***	-0.00493***
					(0.00355)	(0.00361)	(0.00411)	(0.00155)
Constant	0.433***	0.0314***	0.0251***	0.0646***	0.0828	0.120**	0.110*	0.0163
	(0.123)	(0.00318)	(0.00165)	(0.000272)	(0.171)	(0.0577)	(0.0569)	(0.0102)
Gravity Variables	YES	YES	YES	YES	YES	YES	YES	YES
Firm-Year FE	YES	YES	YES	YES	YES	YES	YES	YES
Country FE		YES				YES		
Country-Year FE			YES	YES			YES	YES
Firm-Country FE				YES				YES
Obs.	11,712,877	11,712,877	11,905,433	10,515,452	11,543,364	11,712,877	11,905,433	10,515,452
Adj. R^2	0.484	0.498	0.499	0.608	0.488	0.501	0.502	0.609

i n§0I This table presents the estimation results from specification (1) using linear probability model (LPM). The dependent variable is firm f's import dummy in country c at year t. Extended gravity for distance$_{fct\ 1}$ is constructed following Chaney (2014) while the other extended gravity variables are constructed after Morales, Sheu, and Zahler (2019). Standard gravity variables include distance, indicator for contiguity, common continent, common language, common income group and RTA between China and foreign country, and foreign GDP per capita. Standard errors are in the parentheses and clustered at firm and country level. The number of asterisk indicates significance at 1%(***), 5%(**) and 10%(*) level.

A.4 Construction of Extended Gravity Variables

This section constructs the extended gravity variables (recall that in the third and forth line of baseline specification (1), we include firm-country-specific gravity variables constructed from firm's past export or import network which are often referred to as "extended gravity" after Morales, Sheu, and Zahler (2019)). We focus on the construction of export-side extended gravity variables based on firm's past export network and the import-side ones are constructed in a similar way.

Following Chaney (2014), we first include the extended gravity variable of distance, Exp. Ext. Distance$_{fct\ \ 1}$ which measures the average geographic distance between country c and firm's past export network. This is defined as

$$\text{Exp. Ext. Distance}_{fct\ \ 1} \quad \frac{\sum_{c' 2} \text{I}\ \ \text{Exp.}_{fc't\ \ 1} > 0 \quad \ln\left(\text{Distance}_{cc't\ \ 1}\right)}{\sum_{c' 2} \text{I}\ \ \text{Exp.}_{fc't\ \ 1} > 0};$$

where Exp.$_{fc't\ \ 1}$ denotes firm f's export value to country c' in year $t \quad 1$, is the set of countries in our sample and $\ln\left(\text{Distance}_{cc't\ \ 1}\right)$ is log (population weighted) distance between country c and country c' that firm f exported to in year $t \quad 1$. The indicator function $\text{I}\ \ \text{Exp.}_{fc't\ \ 1} > 0$ equals to one if firm f exported to country c' at year $t \quad 1$ and zero otherwise. As in Chaney (2014), we add another control for geographic remoteness of country c which is defined as

$$\text{Remoteness}_{ct\ \ 1} \quad \frac{\sum_{c' 6= \text{G}[\text{i}} \ln\left(\text{Distance}_{cc't\ \ 1}\right)}{N_{c' 6= \text{G}[\text{i}}};$$

where CHN refers to China and $N_{c' 6= \text{G}[\text{i}}$ is the number of foreign countries in our sample. Remoteness$_{ct\ \ 1}$ measures the average distance from country c to the countries other than China. This variable is absorbed in country-year fixed effects.

Following Morales, Sheu, and Zahler (2019), we include other extended gravity variables measuring geographic, cultural and economic similarity between country c and firm's past export network. These extended gravity variables are all dummy variables constructed from whether firm exported to any country that is adjacent to country c (Exp. Ext. Contiguity$_{fct\ \ 1}$), locates in the same continent as country c (Exp. Ext. Continent$_{fct\ \ 1}$), shares common official language with country c (Exp. Ext. Com. Lang.$_{fct\ \ 1}$) or fall into same income group as country c (Exp. Ext. Income Group$_{fct\ \ 1}$). For instance, the extended gravity variable for contiguity, Exp. Ext. Contiguity$_{fct\ \ 1}$, equals to one if firm f exported to any country in year $t \quad 1$ that is adjacent to country c and zero otherwise. The extended gravity variable for common language, Exp. Ext. Language$_{fct\ \ 1}$, equals to one if firm f exported to any country in year $t \quad 1$ that shares a common official language with country c and zero otherwise.

A.5 Construction of Instrument Variables for System GMM

We show the construction of instrument variables used in system GMM estimation in this section. We follow Feng, Li, and Swenson (2016) and use two instrument variables: i) firm-country-specific import and export tariff exposure, and ii) firm-country-specific dummy for processing importer and processing exporters. When we study firm's export probability, the instrument variables used are firm-country-specific import tariff exposure and firm-country-specific dummy for processing importer. In the case when we study firm's import probability, the instrument variables used are firm-country-specific export tariff exposure and firm-country-specific dummy for processing exporter.

First, the firm-country-specific import tariff exposure is defined for some baseline year as follows.

$$\text{Import Tariff}_{fjt} = \sum_{h=1}^{H^M_{fc;t_b}} \left(\frac{\text{Imp.}_{fjh;t_b}}{\sum_{h=1}^{H^M_{fj;t_b}} \text{Imp.}_{fjh;t_b}} \text{Import Tariff}_{jht} \right);$$

where $H^M_{fc;t_b}$ denotes the set of products firm f imports from foreign origin j in the base year t_b, $\text{Imp.}_{fjh;t_b}$ is the associated import value and $\text{Import Tariff}_{jht}$ is applied MFN tariffs on product h from origin j imposed by Chinese government. Similarly, firm-country-specific export tariff exposure is defined as

$$\text{Export Tariff}_{fkt} = \sum_{h=1}^{H^X_{fc;t_b}} \left(\frac{\text{Exp.}_{fkh;t_b}}{\sum_{h=1}^{H^X_{fk;t_b}} \text{Exp.}_{fkh;t_b}} \text{Export Tariff}_{kht} \right);$$

where $H^X_{fc;t_b}$ denotes the set of products firm f exports towards foreign market k in the base year t_b, $\text{Exp.}_{fjh;t_b}$ is the associated import value and $\text{Export Tariff}_{jht}$ is applied MFN tariffs on product h from China imposed by foreign market k. Both tariffs are from the WTO Tariff Database. We choose $t_b = 2001$ as the base year.

Second, the firm-country-specific dummy for processing importer is defined as

$$\text{Processing Importer}_{fct\ 1} = \mathbb{I}\ \ \text{Value of processing import}_{fct\ 1} > 0\ \ :$$

The firm-country-specific dummy for processing exporter is defined in a symmetric way:

$$\text{Processing Exporter}_{fct\ 1} = \mathbb{I}\ \ \text{Value of processing export}_{fct\ 1} > 0\ \ :$$

The rationale for the two instrument variables are as follows. First, import tariff (export tariff) only directly affects firm's import decision (export decision). If market-specific bilateral economies of scope is present, then changes in either export or import tariff would affect firm's trade decision on the other side as well. Second, as in Feng, Li, and Swenson (2016), firm's processing import would arguably encourage only its ordinary import but do

not directly affect its ordinary export. Through our channel, firm who engages in processing trade on import side in a foreign country is more likely to not only do ordinary import from the same country but also do ordinary export towards the same country. Similar assumption applies for processing exporter dummy.

In the baseline estimation of system GMM, we take firm's past trade decisions and all extended gravity variables as GMM-style instrument with maximum lag of 5, and consider standard gravity variables and the aforementioned IVs as IV-style instrument. Our key result of market-specific bilateral economies of scope remains stable to alternative specifications.

B Model Appendix

B.1 Solving the Free Entry Conditions

In this section, we show that J free entry conditions (17) deliver J unique aggregate demands across countries. Our strategy is to prove that taking as given the foreign demands $\{B_k\}_{k\neq i}$, the left-hand side of equation (17) is continuously non-decreasing in B_i. Then its valuation at constant $w_i f_{ei}$ gives us a unique equilibrium B_i. As a result, solving the system of J free entry conditions gives J unique B_i's.

The first step is to show the derivative of the left-hand side of equation (17) respect to B_i is positive. Note that we assume there is no iceberg trade cost or fixed cost of serving the domestic market, i.e. $\tau_{ii}^X = 1$ and $f_{ii}^X = 0$, and the fixed cost for selling in any foreign market is sufficiently large even with import activity. Then all active firms including the least productive one in country i at least serve the domestic market. Combined with the condition that the least productive firm earns zero profit, the derivative of left-hand side of equation (17) with respect to B_i is

$$\int_{\varphi_i^*}^{1} \frac{\partial \left[r_i^M(\varphi) - \frac{1}{\varphi} r_i^X(\varphi) \left(w_i \sum_{k \in \mathcal{S}(\varphi)} f_{ki}^X + w_i \sum_{j \in \mathcal{J}(\varphi)} f_{ij}^M \right) + w_i \sum_{h \in \mathcal{S}(\varphi) \setminus \mathcal{J}(\varphi)} \left(\tau_{hi}^X f_{hi}^X + \tau_{ih}^M f_{ih}^M \right) \right]}{\partial B_i} dG_i(\varphi) > 0. \quad \text{(B.1)}$$

Note that the derivative is positive since raising B_i increases the profit of all firms. First of all, conditional on firms' export and import strategies, a higher domestic demand B_i directly raises total variable profit for all firms through the increases in sales potential $r_i^X(\varphi)$. Secondly, for any levels of increase sales potential, firms' endogenous shift in trade strategies should brings additional gains in profit compared to the case when the trade strategies do not change. Also note that when $B_i \to 0$, firm cannot export to or source from any country and earn zero profit, and when $B_i \to \infty$, all firms include all countries into both export and import profile and earn infinite profit. Next we show the continuity of equation (B.1) by parts and conclude our proof. First, the variable profit is continuously

differentiable for B_i. Its derivative with respect to B_i is

$$\int_{\nu_i}^{\infty} \frac{\partial \left[\theta^{\sigma-1} \left(\tau_i^M(\theta) \right)^{-\sigma} \tau_i^X(\theta) \right]}{\partial B_i} dG_i(\theta) = \int_{\nu_i}^{\infty} \frac{\partial \left[\theta^{\sigma-1} \left(\tau_i^M(\theta) \right)^{-\sigma} B_i + \theta^{\sigma-1} \left(\tau_i^M(\theta) \right)^{-\sigma} \sum_{k \neq i} \tau_{ki}^X{}^{1-\sigma} B_k \right]}{\partial B_i} dG_i(\theta).$$

Note that change in B_i might affect firm profit discontinuously as it changes firm's export and import strategy. Following Antràs, Fort, and Tintelnot (2017), it can be shown that both $\tau_i^M(\theta)$ and $\tau_i^X(\theta)$ are non-decreasing in θ as firm's profit maximization problem (16) features increasing difference in $\{I_{ki}^X; \theta\}$ and in $\{I_{ij}^M; \theta\}$ for any $k; j$. As a result, there is strict hierarchy in firm's export and import decisions: for any $\theta_1 \leq \theta_2$, we have $J(\theta_1) \subseteq J(\theta_2)$ and $S(\theta_1) \subseteq S(\theta_2)$. Therefore, we must also have $\tau_i^M(\theta_1) \geq \tau_i^M(\theta_2)$ and $\tau_i^X(\theta_1) \geq \tau_i^X(\theta_2)$. We can further show that both $\tau_i^M(\theta)$ and $\tau_i^X(\theta)$ are also non-decreasing in domestic demand B_i. In other words, the variable profit $\theta^{\sigma-1} \left(\tau_i^M(\theta) \right)^{-\sigma} \tau_i^X(\theta)$ is a non-decreasing step function in θ and shows jump at different levels of $\theta^{\sigma-1} B_i$. We focus the exhaustive case where there are $2J - 1$ jumps in the profit function. Then firm's variable profit can be written as

$$\theta^{\sigma-1} \left(\tau_i^M(\theta) \right)^{-\sigma} \tau_i^X(\theta) = \begin{cases} \alpha_1 \theta^{\sigma-1} B_i + \beta_1 \theta^{\sigma-1} B_i [\omega_1 - B_i] & \text{if } \theta < b_1 / B_i^{1/(\sigma-1)} \\ \alpha_2 \theta^{\sigma-1} B_i + \beta_2 \theta^{\sigma-1} B_i [\omega_2 - B_i] & \text{if } b_1 / B_i^{1/(\sigma-1)} \leq \theta < b_2 / B_i^{1/(\sigma-1)} \\ \vdots & \\ \alpha_{2J} \theta^{\sigma-1} B_i + \beta_{2J} \theta^{\sigma-1} B_i [\omega_{2J} - B_i] & \text{if } b_{2J-1} / B_i^{1/(\sigma-1)} \leq \theta \end{cases};$$

where α_x denotes firm's sourcing capacity at interval x and ω_x denotes firm's sales capacity at interval x for $x = 1; 2; ...; 2J$.

Intuitively, as we move from less productive firms to more productive ones, previous analysis suggest that firm discontinuously add country to its export or import profile. Hence we can define the expected profit prior to entry as the sum of $2J$ continuous functions. In each one of them, firms with heterogeneous productivities have the same export and import profile. Then it is clear that the sum of those continuous functions which are differentiable with respect to B_i is also continuous in B_i.

As for the total fixed costs paid by firm, it is also continuously differentiable in B_i. Note that its derivative with respect to B_i is

$$\int_{\nu_i}^{\infty} \frac{\partial \left[w_i \sum_{k \in S(\theta)} f_{ki}^X + w_i \sum_{j \in J(\theta)} f_{ij}^M + w_i \sum_{h \in S(\theta) \setminus J(\theta)} {}_0 f_{hi}^X + {}_1 f_{ih}^M \right]}{\partial B_i} dG_i(\theta). \quad \text{(B.2)}$$

An increase in B_i cannot possibly reduce the total fixed costs paid the firm as higher domestic profit induces firm to either export to or import from new country, which comes with additional fixed cost. Using the same logic as before, such derivative can be expressed as

the sum of $2J$ functions continuous in B_i and shows jump at various levels. The derivative on fixed cost is therefore a continuous function on B_i. This concludes the proof that the domestic free entry condition delivers a unique B_i given the foreign aggregate demands.

B.2 Proof of Proposition 1

The following steps show the increasing difference property of firm's profit maximization problem (16) in $\mathrm{I}_{ki}^X; \mathrm{I}_{ji}^X$, $\mathrm{I}_{ki}^X; \mathrm{I}_{ij}^M$, and $\mathrm{I}_{ik}^M; \mathrm{I}_{ij}^M$ respectively, under the parameter constraint. In our context, the increasing difference property corresponds to the single crossing differences in choices (SCD-C) from below introduced by Arkolakis, Eckert, and Shi (2022), which is a pre-requisite to apply the "sandwitch" algorithm in Jia (2008).

Step 1. We show the profit function in (16) features increasing difference in $\mathrm{I}_{ki}^X; \mathrm{I}_{ji}^X$. Ceteris paribus, the marginal benefit of exporting to a market k is an increasing function of firm's decision of exporting to another market j. That is,

$$_i\ \mathrm{I}_{ki}^X = 1; \mathrm{I}_{ji}^X = 1 \quad _i\ \mathrm{I}_{ki}^X = 0; \mathrm{I}_{ji}^X = 1 \ > \ _i\ \mathrm{I}_{ki}^X = 1; \mathrm{I}_{ji}^X = 0 \quad _i\ \mathrm{I}_{ki}^X = 0; \mathrm{I}_{ji}^X = 0 \ :$$

Plugging in the formulas for profits gives

$$\begin{aligned}
&\left(\sum_{j=1}^{} \mathrm{I}_{ij}^M T_j \left(_{ij} w_j\right)\right)^{-\frac{1}{}} \left(\sum_{j^0 \neq j; j^0 \neq k} \mathrm{I}_{j^0 i}^X \ _{j^0 i}^{X\ 1} B_{j^0} + \mathrm{I}_{ji}^X \ _{ji}^{X\ 1} B_j + \mathrm{I}_{ki}^X \ _{ki}^{X\ 1} B_k \right)^{!} \\
&\quad w_i^{1} \ {}_0\mathrm{I}_{ik}^M \ f_{ki}^X(!) + w_i^{\ 1} \ {}_1\mathrm{I}_{ik}^M f_{ik}^M(!) \\
&\quad w_i^{1} \ {}_0\mathrm{I}_{ij}^M \ f_{ji}^X(!) + w_i^{\ 1} \ {}_1\mathrm{I}_{ij}^M f_{ij}^M(!) \\
&\left[\left(\sum_{j=1}^{J} \mathrm{I}_{ij}^M T_j \left(_{ij} w_j\right)\right)^{-\frac{1}{}} \left(\sum_{j^0 \neq j; j^0 \neq k} \mathrm{I}_{j^0 i}^X \ _{j^0 i}^{X\ 1} B_{j^0} + \mathrm{I}_{ji}^X \ _{ji}^{X\ 1} B_j \right)^{!} \right. \\
&\quad \left. w_i^{1} \ {}_0\mathrm{I}_{ij}^M \ f_{ji}^X(!) + w_i^{\ 1} \ {}_1\mathrm{I}_{ij}^M f_{ij}^M(!) \right] \\
&\left(\sum_{j=1}^{} \mathrm{I}_{ij}^M T_j \left(_{ij} w_j\right)\right)^{-\frac{1}{}} \left(\sum_{j^0 \neq j; j^0 \neq k} \mathrm{I}_{j^0 i}^X \ _{j^0 i}^{X\ 1} B_{j^0} + \mathrm{I}_{ki}^X \ _{ki}^{X\ 1} B_k \right)^{!} \\
&\quad w_i^{1} \ {}_0\mathrm{I}_{ik}^M \ f_{ki}^X(!) + w_i^{\ 1} \ {}_1\mathrm{I}_{ik}^M f_{ik}^M(!) \\
&\left[\left(\sum_{j=1}^{} \mathrm{I}_{ij}^M T_j \left(_{ij} w_j\right)\right)^{-\frac{1}{}} \left(\sum_{j^0 \neq j; j^0 \neq k} \mathrm{I}_{j^0 i}^X \ _{j^0 i}^{X\ 1} B_{j^0} \right)^{!} \right]^{3} :
\end{aligned}$$

By cancelling common terms on both sides, it can be shown that the inequality hold. Also note that the above proof allows fixed costs of import and export to vary across firms and markets, which is captured by the $f_{ik}^M(!)$ and $f_{ji}^X(!)$ terms.

Step 2. We show if $0 < {}_0;\ {}_1 < 1$, the profit function also exhibits increasing difference in $\mathrm{I}^X_{ki}; \mathrm{I}^M_{ij}$ for any j and k. That is,

$$ {}_i\ \mathrm{I}^X_{ki} = 1; \mathrm{I}^M_{ij} = 1 \quad {}_i\ \mathrm{I}^X_{ki} = 0; \mathrm{I}^M_{ij} = 1 \ > \ {}_i\ \mathrm{I}^X_{ki} = 1; \mathrm{I}^M_{ij} = 0 \quad {}_i\ \mathrm{I}^X_{ki} = 0; \mathrm{I}^M_{ij} = 0 \ ; $$

other things equal. It is equivalent to show that

$$ \begin{aligned} & {}' \ {}^1 \Bigg(\sum_{j' \neq j} \mathrm{I}^M_{ij'} T_{j'}\left({}_{ij'} w_{j'}\right) + T_j\left({}_{ij} w_j\right) \Bigg)^{\frac{1}{1-}} \Bigg(\sum_{k' \neq k} \mathrm{I}^X_{k'i} \left({}_{k'i}\right)^{1-} B_{k'} + \left({}_{ki}\right)^{1-} B_k \Bigg)^{} \\ & w_i \ 1 \quad {}_0 \mathrm{I}^M_{ik} \ f^X_{ki}(!) + w_i \ {}_1 \mathrm{I}^M_{ik} f^M_{ik}(!) \\ & w_i \ 1 \quad {}_1 \mathrm{I}^X_{ji} \ f^M_{ij}(!) + w_i \ {}_0 \mathrm{I}^X_{ji} f^X_{ji}(!) \quad \mathrm{I}fk = jgw_i \quad {}_0 f^X_{ki}(!) + {}_1 f^M_{ij}(!) \\ & \Bigg[{}' \ {}^1 \Big(\sum_{j' \neq j} \mathrm{I}^M_{ij'} T_{j'}\left({}_{ij'} w_{j'}\right) + T_j\left({}_{ij} w_j\right) \Big)^{\frac{1}{1-}} \Big(\sum_{k' \neq k} \mathrm{I}^X_{k'i} \left({}_{k'i}\right)^{1-} B_{k'} \Bigg] \\ & w_i \ 1 \quad {}_1 \mathrm{I}^X_{ji} \ f^M_{ij}(!) + w_i \ {}_0 \mathrm{I}^X_{ji} f^X_{ji}(!) \quad \mathrm{I}fk = jgw_i \quad {}_0 f^X_{ki}(!) \\ > {}' \ {}^1 & \Bigg(\sum_{j' \neq j} \mathrm{I}^M_{ij'} T_{j'}\left({}_{ij'} w_{j'}\right) \Bigg)^{\frac{1}{1-}} \Bigg(\sum_{k' \neq k} \mathrm{I}^X_{k'i} \left({}_{k'i}\right)^{1-} B_{k'} + \left({}_{ki}\right)^{1-} B_k \Bigg)^{} \\ & w_i \ 1 \quad {}_0 \mathrm{I}^M_{ik} \ f^X_{ki}(!) + w_i \ {}_1 \mathrm{I}^M_{ik} f^M_{ik}(!) \quad \mathrm{I}fk = jgw_i \quad {}_1 f^M_{ij}(!) \\ & \Bigg[{}' \ {}^1 \Big(\sum_{j' \neq j} \mathrm{I}^M_{ij'} T_{j'}\left({}_{ij'} w_{j'}\right) \Big)^{\frac{1}{1-}} \Big(\sum_{k' \neq k} \mathrm{I}^X_{k'i} \left({}_{k'i}\right)^{1-} B_{k'} \Bigg] : \end{aligned} $$

Rearranging the inequality, we have, for $k \neq j$,

$$ \begin{aligned} & {}' \ {}^1 \Bigg(\sum_{j' \neq j} \mathrm{I}^M_{ij'} T_{j'}\left({}_{ij'} w_{j'}\right) + T_j\left({}_{ij} w_j\right) \Bigg)^{\frac{1}{1-}} \left({}_{ki}\right)^{1-} B_k \\ > {}' \ {}^1 & \Bigg(\sum_{j' \neq j} \mathrm{I}^M_{ij'} T_{j'}\left({}_{ij'} w_{j'}\right) \Bigg)^{\frac{1}{1-}} \left({}_{ki}\right)^{1-} B_k \ : \end{aligned} $$

The above formula holds since $1 > 0$, which insures complementarity among firm's export and import decisions if export destination and import origin are not the same country. If $k = j$, we have

$$ \begin{aligned} & {}' \ {}^1 \Bigg(\sum_{j' \neq j} \mathrm{I}^M_{ij'} T_{j'}\left({}_{ij'} w_{j'}\right) + T_j\left({}_{ij} w_j\right) \Bigg)^{\frac{1}{1-}} \left({}_{ki}\right)^{1-} B_k + {}_0 f^X_{ki}(!) + {}_1 f^M_{ij}(!) \\ > {}' \ {}^1 & \Bigg(\sum_{j' \neq j} \mathrm{I}^M_{ij'} T_{j'}\left({}_{ij'} w_{j'}\right) \Bigg)^{\frac{1}{1-}} \left({}_{ki}\right)^{1-} B_k \ : \end{aligned} $$

Therefore, if $0 < {}_0;\ {}_1 < 1$, the inequality holds. The existence of ${}_0;\ {}_1$ affects only the complementarity between export and import decision for the same country.

Step 3. Finally, we show the profit function also exhibits increasing difference in $I_{ij}^M; I_{ik}^M$ for any j and k. That is,

$$_i\ I_{ik}^M = 1; I_{ij}^M = 1 \quad _i\ I_{ik}^M = 0; I_{ij}^M = 1 \ > \ _i\ I_{ik}^M = 1; I_{ij}^M = 0 \quad _i\ I_{ik}^M = 0; I_{ij}^M = 0 \ ;$$

other things equal. It is equivalent to show that

$$\begin{aligned}
&{}' \ 1 \Bigg(\sum_{j' \neq j; j' \neq k} I_{ij'}^M T_{j'}(\ _{ij'} w_{j'}) \ + T_j(\ _{ij} w_j) \ + T_k(\ _{ik} w_k) \Bigg)^{-\frac{1}{}} \Bigg(\sum_{k'=1}^{X} I_{k'i}^X (\ _{k'i})^1 \ B_{k'} \Bigg)^{!} \\
&\quad w_i \ 1 \ \ {}_0 I_{ik}^M \ f_{ki}^X(!) + w_i \ {}_1 I_{ik}^M f_{ik}^M(!) \\
&\quad w_i \ 1 \ \ {}_1 I_{ji}^X \ f_{ij}^M(!) + w_i \ {}_0 I_{ji}^X f_{ji}^X(!) \\
&\left[{}' \ 1 \Bigg(\sum_{j' \neq j; j' \neq k} I_{ij'}^M T_{j'}(\ _{ij'} w_{j'}) \ + T_j(\ _{ij} w_j) \Bigg)^{-\frac{1}{}} \Bigg(\sum_{J'=1}^{X} I_{k'i}^X (\ _{k'i})^1 \ B_{k'} \Bigg)^{!} \right. \\
&\quad \left. w_i \ 1 \ \ {}_1 I_{ji}^X \ f_{ij}^M(!) + w_i \ {}_0 I_{ji}^X f_{ji}^X(!) \right] \\
&{}' \ 1 \Bigg(\sum_{j' \neq j; j' \neq k} I_{ij'}^M T_{j'}(\ _{ij'} w_{j'}) \ + T_k(\ _{ik} w_k) \Bigg)^{-\frac{1}{}} \Bigg(\sum_{k'=1}^{X} I_{k'i}^X (\ _{k'i})^1 \ B_{k'} \Bigg)^{!} \\
&\quad w_i \ 1 \ \ {}_1 I_{ji}^X \ f_{ij}^M(!) + w_i \ {}_0 I_{ji}^X f_{ji}^X(!) \\
&\left[{}' \ 1 \Bigg(\sum_{j' \neq j; j' \neq k} I_{ij'}^M T_{j'}(\ _{ij'} w_{j'}) \Bigg)^{-\frac{1}{}} \Bigg(\sum_{k'=1}^{X} I_{k'i}^X (\ _{k'i})^1 \ B_{k'} \Bigg)^{!} \right. \\
&\quad \left. w_i \ 1 \ \ {}_1 I_{ji}^X \ f_{ij}^M(!) + w_i \ {}_0 I_{ji}^X f_{ji}^X(!) \right] :
\end{aligned}$$

Similarly, it can be shown this is indeed the case if $\frac{-1}{} \ 1$.

B.3 Derivation of Gravity Equations

In this section, we focus on the derivation of the gravity equation for intermediate goods (25), and the one for final goods (29) can be derived in a similar way. Note rearranging equation (23) gives

$$M_{ij} = N_i \ (\ 1) \ ^{-\frac{1}{}} T_j(w_j) \ _{ij}^{M} \ _{ij}^{M} : \tag{B.3}$$

Define origin j's total production of intermediate goods as

$$Q_j \ \sum_k M_{kj} = (\ 1) \ ^{-\frac{1}{}} T_j(w_j) \ \sum_k N_k \ _{kj}^{M} \ _{kj}^{M} : \tag{B.4}$$

Hence, we have

$$(\ 1) \ ^{-\frac{1}{}} T_j(w_j) \ = \frac{Q_j}{\sum_k N_k \ _{kj}^{M} \ _{kj}^{M}} : \tag{B.5}$$

From the free-entry condition (17) and labor market clearing condition (18), we get the equilibrium number of entrants as

$$N_i = \frac{w_i L_i}{\int_{\Omega_{-i}} \left(\tau_i^M(\omega')\right)^{1-\sigma} \left(\tau_i^X(\omega')\right)^{1-\sigma} dG_i(\omega')}. \tag{B.6}$$

Country i's total expenditure on manufacturing sector is given by

$$E_i = w_i L_i. \tag{B.7}$$

Rearranging the denominator of equation (B.6) gives

$$\begin{aligned}
&\int_{\Omega_{-i}} \left(\tau_i^M(\omega')\right)^{1-\sigma} \left(\tau_i^X(\omega')\right)^{1-\sigma} dG_i(\omega') \\
&= \sum_{k=1}^{J} B_k \int_{\Omega_{-i}} I_{ki}^X(\omega') \left(\tau_i^M(\omega')\right)^{1-\sigma} \left(\tau_{ki}^X\right)^{1-\sigma} dG_i(\omega') \\
&= \sum_{k=1}^{J} B_k \frac{1}{(\sigma-1)^{1-\sigma}} P_{ki}^{1-\sigma} / N_i;
\end{aligned}$$

where the ideal export price index of goods exporting from country i to market k is defined as

$$\begin{aligned}
P_{ki}^{1-\sigma} &= N_i \int_{\Omega_{-i}} I_{ki}^X(\omega') p_{ki}^{1-\sigma}(\omega') dG_i(\omega') \\
&= N_i \int_{\Omega_{-i}} I_{ki}^X(\omega') \frac{1}{(\sigma-1)^{1-\sigma}} \left(\tau_i^M(\omega')\right)^{1-\sigma} \left(\tau_{ki}^X\right)^{1-\sigma} dG_i(\omega').
\end{aligned}$$

Therefore

$$\begin{aligned}
N_i &= \frac{E_i}{\sum_{k=1}^{J} B_k \frac{1}{(\sigma-1)^{1-\sigma}} P_{ki}^{1-\sigma} / N_i} \\
&= \frac{E_i}{\frac{1}{(\sigma-1)^{1-\sigma}} \sum_k B_k \sum_{k=1}^{J} b_k P_{ki}^{1-\sigma} / N_i} \\
&\quad \frac{E_i}{\frac{1}{(\sigma-1)^{1-\sigma}} \sum_k B_k P_i^{1-\sigma} / N_i};
\end{aligned} \tag{B.8}$$

where $b_k \equiv \frac{B_k}{\sum_{i=1}^{J} B_i}$ and $P_i^{1-\sigma} \equiv \sum_{k=1}^{J} b_k P_{ki}^{1-\sigma}$.

Finally, plugging $(\sigma-1)^{1-\sigma} T_j(w_j)$ from equation (B.5) and N_i from equation (B.8) back into equation (B.3) yields the gravity equation (25) of intermediate goods.

C Estimation Appendix

C.1 Solution Algorithm

In this section, we list the steps in jointly solving a firm's export and import decisions. The algorithm is based on Proposition 1. The algorithm iterates an indicator vector, which contains all dummy variables that indicate a firm's exporting and sourcing status. Specifically, for firms indexed by $'_i$ and destination-specific exporting and sourcing cost draw $"_i^s; "_i^i$, we implement the following search algorithm:

1. we initialize two indication vectors: both of size 1 $2N$ (with the first 1 N elements representing sourcing status and the remaining $N + 1$ $2N$ elements representing the exporting status). The first vector J_l contains only zeros indicating firms neither export nor import; The second vector J_h contains only ones so that firms import from and export to all destinations.

2. starting from J_l, we sequentially $9LL$ sourcing and exporting destinations, depending on whether this action brings profit. We repeat this step until no room for improvement and label this final vector as $J_l^{\emptyset}$.

3. starting from J_h, we sequentially $L\}nq$ sourcing and exporting destinations depending on whether this action brings profit. We iterate until no room for improvement and label this final vector as $J_h^{\emptyset}$.

4. if $J_l = J_h$, then the optimal decision is obtained, otherwise move to the next step

5. re-initialize $J = J_l^{\emptyset} \setminus J_h^{\emptyset}$, and scan through all the remaining combinations of exporting and sourcing decisions.

C.2 Moment Construction

Using the merged sample between Annual Survey of Industrial Enterprise and Chinese customs sample for the year 2007, we construct the moments as follows. First, it is straightforward to calculate the share of exporters and the share of importers in the sample. The share of exporters and the share of importers for those whose sales income are below median level can be calculated in a similar vein. We also calculate the share of Chinese firms exporting to and importing from each foreign country. The median level of domestic input purchase is directly observed in the data. By definition, the share of firms with domestic input purchase below this level is 0.5. Next, for each two-way trader, we observe its export and import strategies represented by two J-by-one vectors with each element indicating whether the firm exports to or imports from a foreign country. We calculate within-firm export-import correlation using Jaffe (1986)'s "closeness" measure for the two vectors. Then we take a simple average of this correlation across two-way traders as a targeted moment

for $_0$ and $_1$. For the last two targeted moments: ratio between share of exporters among importers and non-importers, and ratio between share of importers among exporters and non-exporters. We use the same calculation as in Table 2. For each foreign country, we calculate the share of Chinese firms exporting to that country among those who import from the same country and among the others who do not. This leads to two conditional shares of exporters. Then we take simple average across foreign countries and calculate the ratio between these two cross-country mean-level conditional shares, i.e. ratio between share of exporters among importers and non-importers. The ratio between share of importers among exporters and non-exporters is calculated in a similar manner.

C.3 SMM Routine

Let $= f\ _1;:::;\ _m g$ represent parameters, and let $\mathsf{J} = f\,\mathsf{K}_1;:::;\,\mathsf{K}_k g$ represent moments. We numerically compute the following matrix containing derivatives of moments with respect to changes in parameters,

$$\frac{\mathsf{J}}{} = \begin{pmatrix} \frac{\mathsf{K}_1}{1} & \frac{@\,\mathsf{K}_1}{@\ _m} \\ :::: & :::: \\ :::: & :::: \\ \frac{@\ _k}{@\,\mathsf{K}_1} & \frac{@\,\mathsf{K}_k}{@\ _m}: \end{pmatrix} \tag{C.1}$$

Then the standard error vector is given by

$$\mathsf{s}\ \overline{\text{Diag}\left(\frac{\mathsf{J}}{}\ ^{0}\ \hat{\mathsf{q}}_{k\ k}\ \frac{\mathsf{J}}{}\right)};\tag{C.2}$$

where

$$\hat{\mathsf{q}} = \begin{pmatrix} \frac{1}{\hat{}_1^2} & & \\ & \ddots & \\ & & \frac{1}{\hat{}_k^2}: \end{pmatrix} \tag{C.3}$$

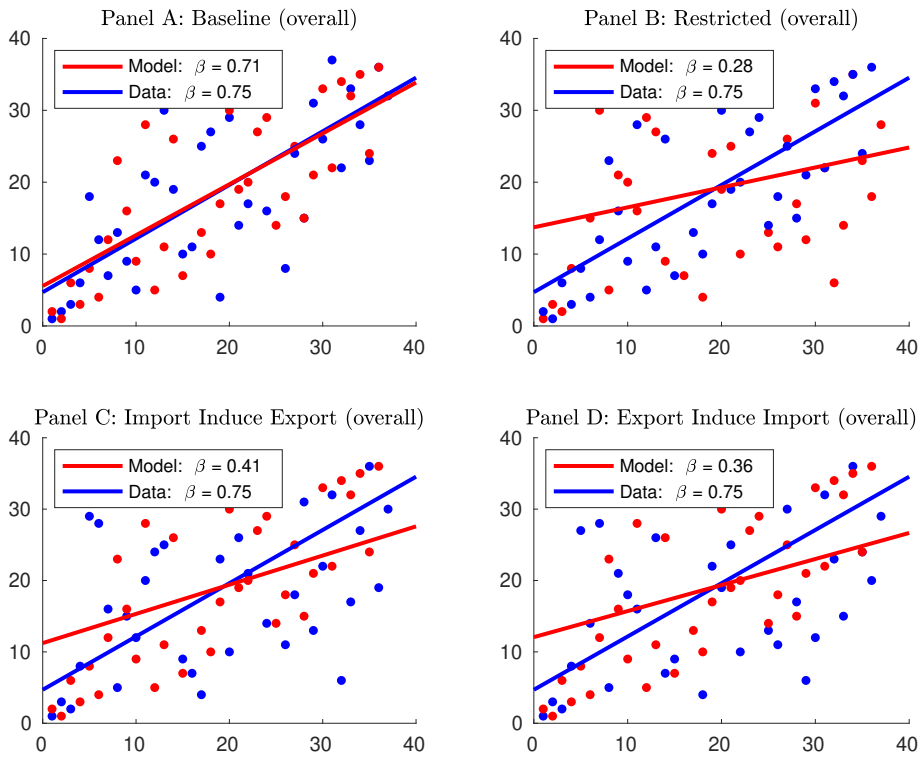
represents the weighting matrix for data. $\hat{}_k$ is the bootstrapped standard error for data moments.

C.4 Robustness of of the Estimation

C.4.1 Rank-Rank for Overall Firms

Figure A1 checks the robustness of the rank-rank correlation. In the text, the ranking of sourcing partners and exporting destinations is by the number of importers and exporters, respectively, and is for two-way traders only. In the following figure, we instead use the full sample including pure exporters and pure importers. We observe similar pattern.

Figure A1: Rank-Rank for Overall Firms



i n§0I This figure plots the rank-rank result. The ranking of sourcing partners and exporting destinations are by the number of importers and exporters, respectively, using overall sample.

C.4.2 Correlation Of Fixed Cost Draws

This section performs a comparative static analysis where we vary the positive correlations between the firm-level fixed cost draws. Table A4 reports the rank-rank correlation for different levels of correlation between the fixed cost draws.

Table A4: Rank-Rank Correlations for Correlated Fixed-Cost Shock Draws

Parameters	Baseline	$_1 = 0$	$_0 = 0$	Restricted	Data
p9j0e 8I i«h@0} nT 0²qn}§0} ¤_hqn}§0} ¡ m®0}9ee 9hqe0					
= 0:00	0.73	0.40	0.33	0.30	0.75
= 0:20	0.74	0.40	0.38	0.29	0.75
= 0:40	0.77	0.41	0.40	0.30	0.75
= 0:60	0.83	0.45	0.47	0.31	0.75
= 0:80	0.87	0.47	0.57	0.32	0.75
p9j0e ?I i«h@0} nT 0²qn}§0} ¤_hqn}§0} ¡ ¦°n]°9´ §}9L0} nje´					
= 0:00	0.76	0.42	0.42	0.31	0.75
= 0:20	0.80	0.49	0.48	0.28	0.75
= 0:40	0.85	0.53	0.56	0.36	0.75
= 0:60	0.90	0.65	0.70	0.44	0.75
= 0:80	0.93	0.74	0.79	0.54	0.75

in§0: This table shows the rank-rank correlation when firms fixed cost draw on sourcing and exporting destinations are correlated.

C.4.3 Hierarchy Entry Pattern

Table A5 shows the hierarchical entry structure for both exporting and sourcing in model and in data.

C.5 Matching Identical Moments Across All Models

Table A6 lists the parameter assignments and estimations when all the four types of models are estimated by targeting the same set of moment (identical to the baseline model). In Figure A2, we plot the rank-rank relationship for the four models using the parameters in table A6.

Table A5: Hierarchy Structure in Importing and Exporting

	Baseline	$_1 = 0$	$_0 = 0$	Restricted	Data
p9j0e 8I ^hqn}§_jX					
1	100	100	100	100	100
1-2	4.32	2.55	2.22	2.01	2.92
1-2-3	0.29	0.19	0.17	0.17	0.57
1-2-3-4	0.048	0.028	0.030	0.028	0.52
1-2-3-4-5	0.012	0.006	0.005	0.006	0.64
p9j0e ?I N²qn}§_jX					
1	100	100	100	100	100
1-2	1.54	0.76	0.52	0.71	2.27
1-2-3	0.044	0.036	0.027	0.034	0.57
1-2-3-4	0.003	0.002	0.003	0.003	0.52
1-2-3-4-5	0.000	0.000	0.000	0.000	0.64

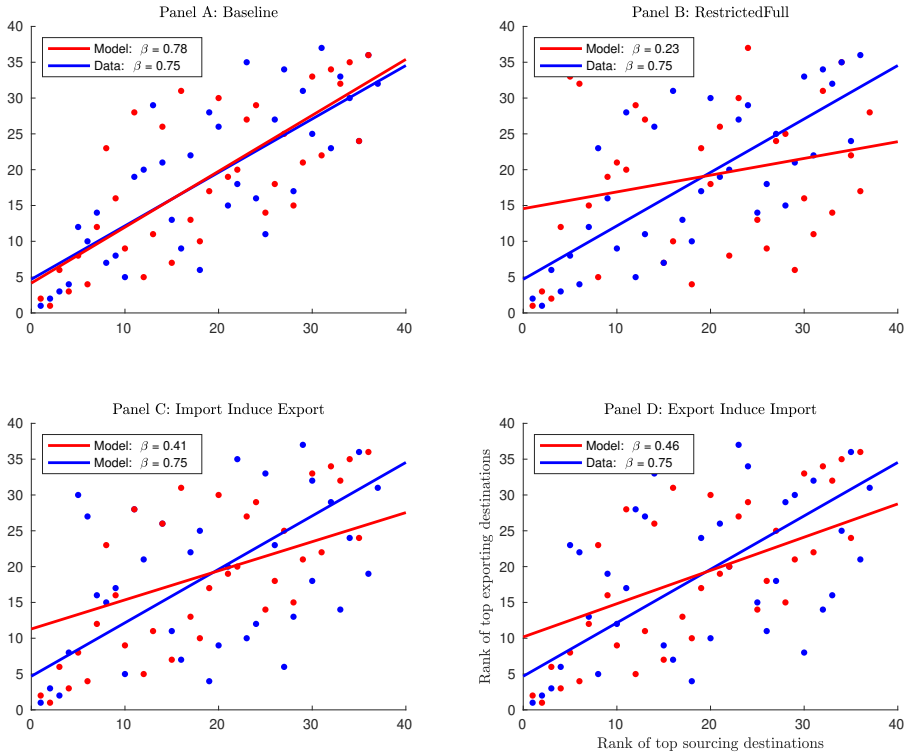
in§0: This table shows the Chinese firms sourcing and exporting pattern from top origins and destinations. Panel A shows sourcing and Panel B shows exporting. The string 1 means importing to/exporting from top one countries but no other, and the string 1-2 means from/to top one and top two but no other; and so forth. All numbers are normalized by the first row.

Table A6: Parameter Assignments (Identical Moments)

Parameters/Moments	Baseline	$_1 = 0$	$_0 = 0$	Restricted	Source/Data
p9j0e 8I 8 _Xj0L					
Pareto shape	4.25	4.25	4.25	4.25	Literature
p9j0e ?I |0L«H0L]Tn}h }0X}0 _nj					
Demand elasticity	4.23	4.23	4.23	4.23	Estimation
Sourcing elasticity	1.07	1.07	1.07	1.07	Estimation
p9j0e GI ~g g					
Demand scale	3.44	2.46	2.59	2.76	Estimation
Cost reduction (import-induced export)	0.41	0.24	0.00	0.00	Estimation
Cost reduction (export-induced import)	0.37	0.00	0.29	0.00	Estimation
Correlation of fixed costs	0.07	0.13	0.14	0.12	Estimation
Import: constant term	1.24	2.03	2.30	2.41	Estimation
Import: distance parameter	1.86	1.66	1.30	1.33	Estimation
Import: standard deviation	1.85	1.49	1.47	1.44	Estimation
Export: constant term	2.48	3.20	2.85	1.81	Estimation
Export: distance parameter	1.40	0.73	0.84	0.56	Estimation
Export: standard deviation	2.66	2.71	2.60	1.99	Estimation
p9j0e KI ¦9}X0§0L hnh0j§					
Share of importers	0.12	0.02	0.02	0.01	0.11
Share of exporters	0.12	0.11	0.11	0.11	0.09
Share of importers (below median sales)	0.047	0.002	0.001	0.001	0.061
Share of exporters (below median sales)	0.053	0.047	0.045	0.032	0.073
Share of firms with actual median domestic input purchase	0.52	0.69	0.67	0.64	0.50
Within-firm export-import correlation	0.48	0.22	0.32	0.20	0.40
Ratio b/w share of exporters among importers and non-importers	12.8	20.9	28.5	25.1	9.05
Ratio b/w share of importers among exporters and non-exporters	9.07	12.5	20.7	19.1	9.32

i n§0: This table shows parameterization for the baseline and the three restricted model. The second column shows the results for baseline. The third column lists the calibration for the model where we set $_1 = 0$. In the estimation, we drop the moment on the share of exporters (conditional on importer vs. non-importer, i.e. the moment with an asterisk superscript); The forth column considers a symmetric case where we set $_0 = 0$. The fifth column sets $_1 = 0$ and $_0 = 0$. The standard errors are reported in parentheses.

Figure A2: Rank-Rank for Two-way Traders (Identical Moments)



i n§0I This figure plots the rank-rank result. The ranking of sourcing partners and exporting destinations is by the number of overall firms. All four panels share the same axis labels.

C.6 Decomposition of Models with Unilateral Economies of Scope

Table A7 shows the decomposition results from the two restricted models of unilateral economies of scope.

C.7 Sensitivity to Higher Demand Elasticity

Table A8 shows the parameter assignment for a larger value of . We re-estimate the model and obtain new parameter values. With this parameter assignment, Figure A3 presents the rank-rank correlation for the baseline model and restricted models.

Table A7: Extensive Margin of Trade Liberalization (Unilateral Scope)

	Import liberalization	Export liberalization
p9j0e 8I $_1 = 0$		
Number of exporters	0.019	0.981
Number of importers	0.988	0.012
p9j0e ?I $_0 = 0$		
Number of exporters	0.030	0.970
Number of importers	0.963	0.037

in§0I This table decompose the extensive margin of trade into liberalization on sourcing and exporting side. The first column shows the contribution (in percent) of sourcing to exporter and importer entry; The second column is the contribution of export liberalization. The third and forth column are shows the associated numbers for the restricted model.

Table A8: Parameter Assignment: Alternative

Parameters	Symbols	Baseline	Source
p9j0e 8I 8 _Xj0L			
Pareto shape.		4.25	Literature
p9j0e ?I |0L«H0L]Tn}h }0X}0 _nj			
Demand elasticity		5.76	Estimation
Sourcing elasticity		1.07	Estimation
p9j0e GI ~g g			
Demand scale	B_i	2.59 (0.12)	Estimation
Cost reduction (import-induced export)	$_0$	0.32 (0.12)	Estimation
Cost reduction (export-induced import)	$_1$	0.28 (.059)	Estimation
Correlation of fixed costs		.063 (.013)	Estimation
Sourcing: constant term	^M_C	1.55 (.053)	Estimation
Sourcing: coefficient of distance	^M_d	2.33 (5e-3)	Estimation
Sourcing: standard deviation	$^M_{disp}$	1.39 (.021)	Estimation
Export: constant term	^X_C	3.09 (.098)	Estimation
Export: coefficient of distance	^X_d	1.75 (.020)	Estimation
Export: standard deviation	$^X_{disp}$	2.60 (.038)	Estimation

in§0I This table shows the estimation of model parameters given a higher value of demand elasticity: 5.76 in this case versus 4.23 in the baseline.