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Taking Grubel and Lloyd to dance in the city: Domestic intra-industry trade in China☆

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ABSTRACT

We assess theoretical predictions regarding the determinants of domestic intra-industry trade in large panel data of pairs of 276 cities, as well as 42 sectors, over three years in China. We find that geographical and technological distances are the main impediments of intra-industry trade, being more important than relative endowment differences. This confirms expectations based on new trade theory in a novel data environment.

1. Introduction

The so-called new trade theory delivers three predictions regarding the extent of intra-industry trade between regions and countries, namely that it declines with (i) technology differences, (ii) trade frictions, and (iii) relative endowment differences between these entities (see Helpman and Krugman, 1985; Helpman, 1987). Of those predictions, mainly the last one had been assessed with data, and virtually all of the existing evidence is based on country-level data. Economic theory suggests that technology differences and trade frictions should be particularly important, more so than relative endowment differences, to explain intra-industry trade (see Eaton and Kortum, 2002). The reason is that technology gaps and trade frictions foster the specialization of regions and countries to a larger degree than this is the case for relative endowment differences (see Costinot et al., 2012).

We contribute to the literature as follows. First, we assess the relative importance of technology, frictions, and endowment differences (apart from other factors) for intra-industry trade (IIT). Second, we do so in a novel data set of inter-city sector-level trade for a single country, China. Third, we do so by distinguishing between IIT in intermediates versus final goods. This setting is unique, as the measurement of outcome and determinants is unusually homogeneous.

Grubel and Lloyd (1975) proposed an index (henceforth GLI) which since has been used widely for measuring and explaining IIT. Earlier contributions to the topic include the ones of Falvey (1981), Greenaway and Milner (1983), Havrylyshyn and Civan (1985), Helpman (1987), Bergstrand (1990), Davis (1995) and Hummels and Levinsohn (1995). More recent ones include Markusen and Venables (2000), Melitz (2003), Egger et al. (2007, 2008), Monte (2011), Epifani and Gancia (2017) and Impullitti et al. (2022).

Distinguishing intermediates from final goods trade is interesting as costs versus preferences should matter differently for them. We construct five GLIs for all, final, and intermediate trade between cities over time, according to the basic form in Helpman (1987) and Bergstrand (1990). An inter-city GLI is unity, if the trade of a type within sectors is balanced for a city pair, and it is zero in the absence of any intra-sector two-way trade for a city pair.

We report on the patterns and determinants of five types of GLI between 276 Chinese cities: for all trade flows, for final goods, and for intermediate goods. Among the latter, we distinguish between three types: all intermediate goods trade, within-sector-pair trade in intermediates, and between-sector-pairs trade in intermediates.

Our results document that any GLI declines with any considered distance concept — technology, geography, relative endowments, quality of life, and Hukou status — where geographical distance and technological distance are the main impediments. This highlights the

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importance of technological similarity for IIT, which had been ignored in most of the earlier work on the matter.

2. Definition of overall and intra-industry trade flows with final and intermediate goods

For any pair of cities $\{rr'\}$, consider data of all bilateral sales and purchases ("exports" and "imports" between them, which we referred to broadly as their trade). Let us measure total trade flows of final plus intermediate goods, final goods, and types of intermediate goods trade at the level of making (producing or selling) sectors s and use generic superscript $V \in$ {total, final, inter-all, inter-within, inter-between} to specify export (X) and import (M) flows. Use $X^V_{rr'ss't}$ for V-type exports from rs to $r's'$ and $M^V_{rr'ss't}$ for V-type imports by rs from $r's'$ at time t with V pertaining to total, final, or intermediate goods. This permits defining

$$\begin{aligned}
&X^{\text{final}}_{rr't} = \textstyle\sum_{s=1}^S X^{\text{final}}_{rr'st} && M^{\text{final}}_{rr't} = \textstyle\sum_{s=1}^S M^{\text{final}}_{rr'st}\\
&X^{\text{inter-between}}_{rr't} = \textstyle\sum_{s\neq s'} X^{\text{inter}}_{rr'ss't} && M^{\text{inter-between}}_{rr't} = \textstyle\sum_{s\neq s'} M^{\text{inter}}_{rr'ss't}\\
&X^{\text{inter-within}}_{rr't} = \textstyle\sum_{s=1}^S X^{\text{inter}}_{rr'sst} && M^{\text{inter-within}}_{rr't} = \textstyle\sum_{s=1}^S M^{\text{inter}}_{rr'sst}\\
&X^{\text{inter-all}}_{rr't} = X^{\text{inter-within}}_{rr't} + X^{\text{inter-between}}_{rr't} && M^{\text{inter-all}}_{rr't} = M^{\text{inter-within}}_{rr't} + M^{\text{inter-between}}_{rr't}\\
&X^{\text{all}}_{rr't} = X^{\text{final}}_{rr't} + X^{\text{inter-all}}_{rr't} && M^{\text{all}}_{rr't} = M^{\text{final}}_{rr't} + M^{\text{inter-all}}_{rr't}.
\end{aligned} \tag{1}$$

For any trade concept, we can then define a corresponding intra-industry trade index in the spirit of Grubel and Lloyd (1975):

$$\text{GLI}^V_{rr't} = 1 - \frac{\sum_{s=1}^S |X^V_{rr'st} - M^V_{rr'st}|}{\sum_{s=1}^S (X^V_{rr'st} + M^V_{rr'st})} \in [0,1], \tag{2}$$

where $V \in$ {total, final, inter-all, inter-between, inter-within}. In what follows, we report on those concepts based on data for 276 cities and 42 sectors for the years 2012, 2015, and 2017 in China.

3. Data

We use data from the following sources.

3.1. Intercity-and-sector trade data for China

Our main data source is the China City-Level Multi-Regional Input-Output (MRIO) Database, published by the Institute of Carbon Emission Accounts and Databases (CEADs). It contains bilateral sales data for 42 sectors (covering agriculture, manufacturing, and services) and 309 cities in China for the years 2012, 2015, and 2017.[1]

These data inform the aforementioned five measures of intra-industry indices with inter-city and year variation, $\text{GLI}^V_{rr't}$ for $V \in$ {total, final, inter-all, inter-between, inter-within}.

3.2. Determinants of intra-industry trade (IIT) links

IIT should depend positively on the size of production locations due to economies of scale, it should depend negatively on factor endowment differences (see Helpman, 1987), and it should depend negatively on technology differences (see Gilroy and Broll, 1988; Davis, 1995). Trade frictions should reduce all forms of trade (see Bergstrand, 1990). To explore these hypotheses for the different definitions of IIT, we make use of data from not only the MRIO Database but also the China Urban Statistical Yearbook. First, we condition on city-time fixed effects to capture size effects.[2] We focus on distance variables in terms of (i) technology, (ii) relative endowments, and (iii) trade frictions between pairs of cities in explaining the GLI as well as the volume of inter-city trade in the MRIO data.

We first utilize data from the China City-Level MRIO Database to construct the 1×3 vector of cost-share parameters in all regions and sectors and years, C_{rst}. The row sum of the latter is unity for each $\{rst\}$, as cost shares sum up to one. Hence, there is no need for standardization of the latter, as all shares live in the same domain. However, we define trade weights across sectors s for a given pair of regions $\{rr'\}$, $W^V_{rr'st} = \frac{X^V_{rr'st}}{\sum_{s=1}^S X^V_{rr'st}}$ for all concepts $V \in$ {total,final,inter,inter-plus}. This obtains[3]

$$\text{DTECH}^V_{rr't} = \sum_{s=1}^S W^V_{rr'st}(C_{rst} - C_{r'st})(C_{rst} - C_{r'st})',$$
$$V \in \{\text{total, final, inter, inter-plus}\}. \tag{3}$$

Moreover, we employ data from the China Urban Statistical Yearbook to define a 1×3 vector of primary factor-endowment variables for each region and year, F_{rt}. The three columns in this vector pertain to the logarithm each of skilled labor (measured in quantity), unskilled labor (measured in quantity), and land (measured in square meters). We standardize these factors to make them comparable. For this, use the $R \times 3$ matrix of stacked endowments for all regions in year t, F_t, and define the variance–covariance matrix $\Sigma_{Ft} = R^{-1}F_t'F_t$ as well as the square root of its inverse, $\Sigma_{Ft}^{-1/2}$. This permits defining the vector of standardized endowments for each region r as $\tilde{F}_{rt} = F_{rt}\Sigma_{Ft}^{-1/2}$ and the scalar of squared scaled relative endowment differences between regions as[4]

$$\text{LDENDOW}_{rr't} = (\tilde{F}_{rt} - \tilde{F}_{r't})(\tilde{F}_{rt} - \tilde{F}_{r't})'. \tag{4}$$

Finally, we use the log of the great-circle distance between the cities based on their latitude and longitude in some of the regressions and refer to it by, $\text{LDIST}_{rr'}$.[5] Furthermore, we use three indicator variables reflecting high-speed-railway (HSR) network access. We define $\text{SAMEHSR}_{rr't}$ indicating whether cities r and r' are located on the same HSR line at year t. $\text{BOTHHSR}_{rr't}$ indicates whether cities r and r' are located both on an HSR line but not the same one at year t. $\text{ONEHSR}_{rr't}$ indicates whether either city r or city r' are located on an HSR line but not both at year t. These indicators are derived from the Chinese High-speed Rail and Airline Database (CRAD).

Courant and Deardorff (1992) addressed a country's lumpiness — in the sense of an uneven distribution of factors across its regions — as a determinant of trade. Moreover, Courant and Deardorff (1993) suggest that the distribution of amenities within countries matters beyond the one of endowments. This could motivate an empirical analysis about the distribution of factors *within* countries (or regions) and their bilateral trade. We argue that a similar reasoning pertains to the trade

[1] See Zheng et al. (2022) for more details. The MRIO Database is fully consistent with the China Provincial Single-Regional Input-Output (SRIO) Tables, the China Urban Statistical Yearbook, and the Customs Database. Of the 309 cities principally available, for only 276 of them information on technology and endowments is available. Those are the ones we use.

[2] Helpman (1987) proposed using country joint size and similarity in terms of GDP to account for scale effects. It turns out that, conditional of city-time fixed effects, such variables do not contribute significant explanatory power and, therefore, we suppress them in what follows.

[3] A large body of work on technological differences anchors those in total-factor productivity (see Eaton and Kortum, 2002; Caliendo and Parro, 2015, and Costinot et al., 2012). However, doing so requires imposing tight assumptions on the model structure. Working with differences in factor-cost shares permits ignoring structural model assumptions, while considering some aspect of technology differences between the regions.

[4] Some earlier work on intra-industry trade used per-capita-income figures to measure capital-labor ratios (see Helpman, 1987 or Hummels and Levinsohn, 1995). We opt for a more direct metric and a larger set of endowment factors in comparison.

[5] We use Google Maps to capture the coordinates of each city and then calculate the log of great-circle distance between city pairs.

Table 1
Descriptive statistics.

	Mean	Std.dev.	Min.	Max.
Grubel–Lloyd indices:				
$\mathrm{GLI}^{\text{total}}_{rr't}$	0.299	0.153	0.000	0.935
$\mathrm{GLI}^{\text{final}}_{rr't}$	0.143	0.160	0.000	1.000
$\mathrm{GLI}^{\text{inter-all}}_{rr't}$	0.156	0.101	0.000	0.869
$\mathrm{GLI}^{\text{inter-between}}_{rr't}$	0.298	0.137	0.000	0.931
$\mathrm{GLI}^{\text{inter-within}}_{rr't}$	0.319	0.151	0.000	0.939
Intercity distance variables:				
$\mathrm{LDENDOW}_{rr't}$	5.978	6.029	0.000	84.118
$\mathrm{DTECH}^{\text{total}}_{rr't}$	0.208	0.077	0.003	0.911
$\mathrm{DTECH}^{\text{final}}_{rr't}$	0.211	0.078	0.000	0.697
$\mathrm{DTECH}^{\text{inter-all}}_{rr't}$	0.202	0.106	0.007	1.112
$\mathrm{LDIST}_{rr'}$	6.975	0.716	1.974	8.409
$\mathrm{SAMEHSR}_{rr't}$	0.016	0.125	0.000	1.000
$\mathrm{BOTHHSR}_{rr't}$	0.238	0.426	0.000	1.000
$\mathrm{ONEHSR}_{rr't}$	0.463	0.499	0.000	1.000
$\mathrm{QOLDIFF}_{rr't}$	0.429	1.000	0.000	7.892
$\mathrm{HUKOUDIFF}_{rr't}$	0.851	1.000	0.000	6.354

Note: See Sections 2 and 3.2 for definitions of each variable.

between regions or a country as large as China. Specifically, we argue that a high quality-of-life (QOL) index and a desirable Hukou status for a city positively related to a region's lumpiness, as high average amenity levels often go hand in hand with their dispersion within a region. The results in Courant and Deardorff (1992) suggest that differences in interregional lumpiness are associated with more trade but less IIT. The analysis in Courant and Deardorff (1993) suggests that bigger amenity differences — which are a source of interregional labor mobility — lead to bigger gains from cross-regional specialization and, hence, more trade but less intra-industry trade. To this end, we use $\mathrm{QOLDIFF}_{rr't}$ as the (by the standard deviation) standardized difference in the quality-of-life index between cities r and r' at year t, sourced from the Chinese Research Data Services Platform (CRDSP). Similarly, we use $\mathrm{HUKOUDIFF}_{rr't}$ as the (by standard deviation) standardized difference in the Hukou registration index between cities r and r' at year t, derived from the China Household Finance Survey (CHFS) and introduced in Zhang et al. (2019). The latter two variables reflect the ease with which individuals can move between Chinese cities for institutional reasons.

4. Descriptive statistics, estimating equation, and regression results

In Table 1, we report on the various measures of $\mathrm{GLI}^{V}_{rr't}$ as well as the other variables defined in the previous section. The table suggests that about 30% of all trade between cities in China is within sectors. Interestingly, intra-industry links are particularly strong for intermediates ($\mathrm{GLI}^{\text{inter-all}}_{rr't}$) relative to final goods ($\mathrm{GLI}^{\text{final}}_{rr't}$) and particularly so within maker-buyer sector pairs ($\mathrm{GLI}^{\text{inter-within}}_{rr't}$).

Regarding the distance variables, it should be noted that the means and standard deviations are substantially lower for the technology (cost-share) distance measures than for geographical distance or endowment differences between cities.

For the subsequent analysis, we specify the estimating equation

$$\begin{aligned}\mathrm{GLI}^{V}_{rr't}, \mathrm{X}^{V}_{rr't} &= \exp(Z^{V}_{rr't}\beta^{V})U^{V}_{rr't},\\ Z^{V}_{rr't} &= \mathrm{LDENDOW}_{rr't}, \mathrm{DTECH}^{V}_{rr't}, \mathrm{LDIST}_{rr'}, \mathrm{SAMEHSR}_{rr't},\\ &\quad \mathrm{BOTHHSR}_{rr't}, \mathrm{ONEHSR}_{rr't}, \mathrm{QOLDIFF}_{rr't}, \mathrm{HUKOUDIFF}_{rr't}.\end{aligned}$$

where we account for $\{rr'\}$-specific fixed effects in some regressions, which then does not permit including $\mathrm{LDIST}_{rr'}$ in the regressions. We generally include city-time (rt- and $r't$-) fixed effects and estimate regressions using Poisson Pseudo-maximum Likelihood (PPML) estimation, following Correia et al. (2020) and Weidner and Zylkin (2021).

In Table 2, we report on regressions for the GLIs at the top, and for export volumes at the bottom. As the GLIs are symmetric (i.e., they are the same for observations $rr't$ and $r'rt$), we use the lower triangular of the annual bilateral trade matrix for them, while using all city-pair-time observations for export volumes.

The results suggest that the GLIs decline with any considered distance concept — relative endowments, technology, geography, quality of life and Hukou status — conditional on region-time fixed effects. This corroborates the results for inter-country trade found in Helpman (1987) regarding factor endowments. Moreover, that intra-industry trade accounts for a larger share between technologically more similar and geographically closer sub-national regions is novel and interesting in the light of and consistent with the theory on comparative advantage, especially, the comparative advantage arising from technological differences in Ricardo's theory and from differences in endowments in Heckscher-Ohlin's theory.[6] Conditional on distance in railway-network access does not play a role for the GLIs. Differences in quality of life and Hukou provisions tend to reduce intra-industry trade. The latter is consistent with labor movements and their impact on IIT between cities of similar quality of life and Hukou status, where such movement is easier for institutional reasons.

That city-pair trade volumes decline with geographical distance and factor-endowment differences suggests that these measures affect trade in a friction-type way, akin to other trade costs, and beyond unilateral effects embodied in prices.

When normalizing coefficients in Table 2 with the standard deviations of the distance variables in Table 1, we would conclude that the geographical neighborhood is most important for intra-industry relations, but technological similarity is more important than factor endowments for intra-sectoral links. As mentioned in the introduction, this is consistent with expectations based on Helpman and Krugman (1985) or Helpman (1987), although they had not been explored there.

Regarding inter-city trade volumes, endowment differences and geographical distance are detrimental across the board, but technology differences raise final goods and total trade while reducing intermediate goods trade. Similar to the finding for the GLIs, railway-network access does not significantly influence city-pair trade volumes. The results regarding quality of life suggest that bigger differences in QOL are associated with more trade but with a lower share of IIT. The latter is consistent with Courant and Deardorff (1993). The ones regarding

[6] It is also consistent with the principle that relative differences in geography are a key assumption of the theory of comparative advantage.

Table 2
Regression results.

Panel A: City-pair-year Grubel–Lloyd Index outcome					
Inter-city distance variable	$GLI^{total}_{rr't}$	$GLI^{final}_{rr't}$	$GLI^{inter\text{-}all}_{rr't}$	$GLI^{inter\text{-}between}_{rr't}$	$GLI^{inter\text{-}within}_{rr't}$
$LDENDOW_{rr't}$	−0.006***	−0.018***	−0.007***	−0.003***	−0.005***
	(0.000)	(0.001)	(0.001)	(0.000)	(0.000)
$DTECH^{V}_{rr't}$	−0.771***	−2.066***	−0.290***	−0.123***	−0.182***
	(0.037)	(0.075)	(0.048)	(0.027)	(0.031)
$LDIST_{rr'}$	−0.160***	−0.456***	−0.156***	−0.062***	−0.103***
	(0.003)	(0.007)	(0.004)	(0.003)	(0.003)
$SAMEHSR_{rr't}$	0.056	0.057	0.054	0.035	0.021
	(0.073)	(0.111)	(0.079)	(0.070)	(0.071)
$BOTHHSR_{rr't}$	−0.016	−0.046	−0.021	−0.033	−0.052
	(0.075)	(0.114)	(0.081)	(0.071)	(0.072)
$ONEHSR_{rr't}$	−0.006	−0.005	−0.016	−0.016	−0.026
	(0.038)	(0.057)	(0.041)	(0.036)	(0.036)
$QOLDIFF_{rr't}$	−0.017**	−0.060***	−0.063***	−0.010*	−0.014**
	(0.008)	(0.023)	(0.014)	(0.006)	(0.006)
$HUKOUDIFF_{rr't}$	−0.007***	−0.012**	−0.011***	−0.005**	−0.005**
	(0.002)	(0.006)	(0.003)	(0.002)	(0.002)
Obs	114,395	112,218	114,395	114,395	114,395
Pseudo R^2	0.033	0.096	0.041	0.025	0.028
Panel B: City-pair-year export outcome					
Inter-city distance variables	$X^{total}_{rr't}$	$X^{final}_{rr't}$	$X^{inter\text{-}all}_{rr't}$	$X^{inter\text{-}between}_{rr't}$	$X^{inter\text{-}within}_{rr't}$
$LDENDOW_{rr't}$	−0.030***	−0.026***	−0.030***	−0.027***	−0.040***
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
$DTECH^{V}_{rr't}$	0.420**	2.969***	−4.203***	−3.173***	−7.127***
	(0.214)	(0.232)	(0.214)	(0.216)	(0.237)
$LDIST_{rr'}$	−1.339***	−1.377***	−1.312***	−1.318***	−1.291***
	(0.019)	(0.019)	(0.018)	(0.018)	(0.019)
$SAMEHSR_{rr't}$	0.130	0.043	0.139	0.162	0.107
	(0.263)	(0.289)	(0.255)	(0.261)	(0.243)
$BOTHHSR_{rr't}$	−0.145	−0.253	−0.116	−0.116	−0.088
	(0.269)	(0.297)	(0.260)	(0.267)	(0.250)
$ONEHSR_{rr't}$	0.045	0.059	0.037	0.058	−0.006
	(0.136)	(0.150)	(0.132)	(0.136)	(0.127)
$QOLDIFF_{rr't}$	0.254***	0.246***	0.249***	0.276***	0.199***
	(0.029)	(0.029)	(0.028)	(0.033)	(0.024)
$HUKOUDIFF_{rr't}$	−0.126***	−0.117***	−0.116***	−0.106***	−0.137***
	(0.020)	(0.020)	(0.020)	(0.021)	(0.018)
Obs	228,802	228,802	228,802	228,802	228,802
Pseudo R^2	0.708	0.702	0.719	0.703	0.753

* $p < 0.1$.
** $p < 0.05$.
*** $p < 0.01$.
Note: Values in parentheses are robust standard errors for clustering adjustment at the city-pair level. All regressions include $rt-$ and $r't-$ fixed effects.

the Hukou-index differences point are consistent with a notion of this variable capturing mobility costs. With this interpretation, the respective findings are consistent with the predictions voiced in Courant and Deardorff (1993).

Data availability

Data will be made available on request.

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