Impact of Trade on Industry-Level Output

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Abstract

Does a country's trade significantly increase industry-level output? Are the impacts larger for differentiated industries than for homogeneous industries? To empirically answer these questions, we extend in two ways the Frankel and Romer (1999) method, which uses the geographical component of trade as an instrument. First, while Frankel and Romer look at impacts on the country-level output, we look at those on the industry-level output. Second, we introduce the index of an industry's differentiation based on Rauch (1999). Using a two-stage least square estimation and data for 20 manufacturing industries and 99 countries in 2015, we find that a country's trade significantly positively affects industry-level output and output per worker and the impacts are larger for the more differentiated industries.

JEL classification: F1, F4, O4

Keywords: Trade, Industry-level output, Differential impacts

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1. Introduction

1.1 Motivation

Whether trade causes growth has been an important and well-debated question in the trade literature for several decades. A number of studies have empirically answered this question by examining the impact of trade on output at the country level. However, establishing a causal relationship between trade and income has been difficult due to the endogeneity issue that aggregate trade causes growth in national income or rich countries trade more because of a high level of production. Frankel and Romer (1999) investigate the effect of trade on income at the country level for 63 countries in 1985, accounting for the endogeneity of trade. They estimate a cross-country regression of income per person on geographic components of countries' trade and conclude that the trade has a significant positive impact on the national income. Building upon the Frankel-Romer econometric methodology, Irwin and Terviö (2002) test the trade–income relationship using the data for the pre-World War I, the interwar, and the different post-war periods and confirm that even after accounting for the endogeneity of trade, countries that trade more have higher incomes.

The aforementioned studies examine the impact on the country-level output. However, when policy makers debate trade liberalization, the worry could be not only over the increase in aggregate output but also over the unequal impacts across industries.[1] In fact, recent trade studies imply that trade can increase output at the industry level and the impacts can differ across industries. The Melitz (2003) model implies that, through intra-industry reallocation of resources, trade can increase the aggregate productivity of industry and thus increase the output at the industry level. Moreover, Chaney (2008) shows, using an extended Melitz model, that the effect of trade liberalization is larger for differentiated industries than for

[1] We share the similar spirit with Kehoe et al. (2015). Although their interest is in the impact on exports of trade liberalization, Kehoe et al. (2015) argue that policy makers' worry is not over the aggregate increase but over the unequal impacts across industries.

homogeneous industries. Impacts of a country's trade on industry-level output, however, have been uncharted in the empirical literature of trade and growth.

1.2. Research Question

Thus, motivated by Melitz (2003) and Chaney (2008), this paper now raises the following questions:

i. Does a country's trade significantly increase industry-level output?

ii. Are the impacts larger for differentiated industries than for homogeneous industries?

To empirically answer these questions, this paper estimates the impact of *country-level* trade on *industry-level* output using data for 99 countries and 20 manufacturing industries for the year 2015. To evaluate the possibly different trade impacts across industries, we construct and include in our regressions an index that measures the degree of differentiation in each industry. This allows us to examine if the trade impacts on industry output are larger for industries with higher differentiation.

To address the endogeneity in the trade, we follow Frankel and Romer (1999)'s two-stage least square (2SLS) estimation strategy that uses the geographical component of trade as an instrument variable. To be specific, the key instrument variable, the predicted trade share in GDP of a country, is constructed from estimating a gravity equation of bilateral trade with the geographical characteristics and then aggregating the estimates over its trade partners. Then we use the predicted trade share and its interaction with the industry differentiation index to instrument our endogenous trade variable and its interaction with the index. As a robustness check, we also conduct an industry-by-industry estimation by applying the cross-country regression for each of the 20 manufacturing industries.

1.3. Main Results

Our main results are as follows.

i. All the geographical variables are theoretically consistent and significant, implying that results are conventional. The areas of a country and its trading partner negatively and significantly affect bilateral trade implying high intra-country trade, whereas the populations of both countries affect the bilateral trade positively and significantly.

ii. A country's constructed trade share in GDP from the gravity model is a strong instrument for the actual overall trade share in GDP. This implies that geographical location plays a critical role in shaping the actual trade volume.

iii. The impact of a country's trade on industrial output is positive and significant. One percent point increase in the trade/GDP ratio increases industrial output by 3.008%.

iv. The impact of a country's trade on industrial output per worker is also positive and significant. One percentage point increase in the trade/GDP ratio increases industrial output per worker by 1.698%.

v. The impacts of a country's trade on industrial output and industrial output per worker increase with the degree of differentiation in the manufacturing industries.

1.4. Literature Review and Value-added

There are several empirical studies that examine growth and international trade at the country level. It, however, is difficult to establish a causal relationship between trade and income due to an endogeneity problem. Frankel and Romer (1999) use a geographic instrument to identify a positive impact of trade on income.[2] Their cross-sectional estimates for the year 1985 for 63 countries suggest that the impact of geography-based differences in trade is quantitatively large. Moreover, they compare the regression estimates from the OLS with the instrumental variable least square (IVLS) estimates of trade–income relationships and find that OLS estimates do not overstate the impact of trade. Irwin and Terviö (2002) confirm the validity of the findings of Frankel and Romer (1999) for the pre-World War I, the inter-war, and the post-war periods and find that countries that trade more as a proportion of their GDP

[2] Sachs and Warner (1995), Dollar (1992), and Edwards (1998) are also prominent studies that find a positive relationship between trade and income, although it is difficult to know the direction of causality.

have higher incomes controlling for the endogeneity of trade. They also conclude that OLS estimates are not the upward biased indicators of the trade's impact on the income.

Rodriguez and Rodrik (2000) criticize that the results of Frankel and Romer (1999) are not robust to controlling for omitted variables, such as latitude (distance from equator).[3] On the other hand, Hall and Jones (1999), Frankel and Rose (2001), and Noguer and Siscart (2005) find that the geographic-determined portion of trade has a significant impact on income even after controlling for latitude. Irwin and Terviö (2002) show mixed results for the inclusion of latitude: the significance remains for the OLS coefficient but disappears for the 2SLS coefficient.

Feyrer (2019) finally solves this omitted variable problem by generating a time-varying geographic instrument. Country pairs with relatively short air routes compared to sea routes benefit more from improvements in aircraft technology. He thus uses this heterogeneity to generate a geography-based instrument for trade that varies over time. His results suggest that Frankel and Romer's (1999) basic results hold.

In this line of research, by extending Frankel and Romer (1999) we empirically investigate the impact of country-level trade on industry-level output using the data for 99 countries and 20 manufacturing industries for the year 2015. We contribute to the literature in two ways. First, while past studies look at impacts on the country-level output, we look at those on the industry-level output.[4] This allows us to investigate unequal impacts across industries, in particular, across 20 industries in our case. Second, we introduce the index of an industry's differentiation based on Rauch (1999) to an industry-level version of the Frankel and Romer (1999) regression. This makes it possible to investigate whether the impacts are larger for

[3] See also Rodrik et al. (2004).

[4] Using the data for 50 countries, Mashal (2020) empirically investigates the impact of the industry-level (not country-level) trade on the industry-level output, for each of the paper and textile industries and for each of the years 2008–2017.

differentiated industries than for homogeneous industries. Thus, our paper would be a good complement to the past country-level studies.

1.5. Organization of the Paper

The remainder of this paper is organized as follows. Section 2 explains our regression specification and data. Section 3 presents our empirical results. Section 4 concludes this study.

2. Regression Specification and Data

2.1. Regression Specification

In the trade and growth literature, such as Frankel and Romer (1999) and Irwin and Terviö (2002), the cross-country regression equation is written as follows:

$$ln\, Y_j = \beta_0 + \beta_1 T_j + \beta_2 ln\, A_j + \beta_3 ln\, P_j + \mu_j, \quad (1)$$

where Y_j is the output of country j, T_j is the total trade/GDP ratio of country j, P_j is the population of country j, and A_j is the area of country j.

This paper now evaluates the impact of trade on *industry-level* output and also uncovers the *heterogeneous effects* related to the differentiation degree of an industry. To do so, we modify equation (1) as follows.

$$ln\, Y_{ij} = \emptyset_0 + \emptyset_1 T_j + \emptyset_2 ln\, A_j + \emptyset_3 ln\, P_j + \emptyset_4 Index_i + \emptyset_5 Index_i * T_j + \epsilon_{ij}. \qquad (2)$$

Here, i varies from 1, 2, …, 20 for industries and j varies from 1, 2, …, 99 for countries. The variable $Index_i$, measured between zero and one, captures the degree of differentiation in each industry i. We explain the construction of this index of differentiation in Section 2.2.2. The variables A_j and P_j denote the area and population of country j.

The parameters of interest are the coefficient $\emptyset_1$, which measures the effect of country-level trade on industry-level output, and the coefficient $\emptyset_5$, which measures how this effect varies with the degree of differentiation of an industry. If estimates of both $\emptyset_1$ and $\emptyset_5$ are significantly positive, we have affirmative answers to both research questions raised at the beginning of Section 1.2, that is, a country's trade significantly increases industry-level output, and this effect becomes more pronounced for more differentiated industries.

In addition to regression (2), we also estimate the impact of trade on output per worker using the following specification:

$$ln\,\frac{Y_{ij}}{L_{ij}} = \vartheta_0 + \vartheta_1 T_j + \vartheta_2 ln\,A_j + \vartheta_3 ln\,P_j + \vartheta_4 Index_i + \vartheta_5 Index_i * T_j + \rho_{ij}\,. \quad (3)$$

The theoretical ground to investigate the heterogeneity of the effect of trade on industry-level output is based on Chaney (2008), which predicts the impact of trade liberalization to be larger for differentiated industries than for homogeneous industries. His reason is as follows. Homogeneous goods are identical and therefore have a high elasticity of substitution, whereas differentiated goods may differ in quality or functional features or design and therefore have a low elasticity of substitution. Now, suppose that trade barriers are reduced. Then it causes new and less productive firms to enter the export market. If the elasticity of substitution is high, low-productivity firms are at a severe disadvantage and these low-productive firms can capture only a small share in the export market. The impact of these new entrants on aggregate trade is thus small. On the other hand, if the elasticity of substitution is low, each firm is sheltered from competition and the new entrants can capture a large share in the export market. The impact of these new entrants on aggregate trade is thus large. Hence, a lower elasticity makes the extensive margin of exports more sensitive to trade liberalization; that is, the impact of trade liberalization is larger for differentiated industries having a low elasticity than for homogeneous industries having a high elasticity.

To address endogeneity in the relationship between trade and output in equation (2), we use geographic variables to construct an instrument for trade in the same fashion as Frankel and

Romer (1999). To be specific, we first estimate the bilateral trade flow using the gravity model.

$$ln\left(\frac{T_{jk}}{GDP_j}\right) = \alpha_0 + \alpha_1 ln\left(D_{jk}\right) + \alpha_2 ln\left(P_j\right) + \alpha_3 ln\left(P_k\right) + \alpha_4 ln\left(A_j\right) + \alpha_5 ln\left(A_k\right)$$
$$+ \alpha_6\left(border_{jk}\right) + \alpha_7\left(landlocked_j + landlocked_k\right) + e_{jk}. \quad (4)$$

This equation explains that the bilateral trade of country j with country k relative to country j's GDP depends on the distance between the two trading countries $\left(D_{jk}\right)$, the population (P) and area (A) of each country, whether the trading partners have a common border, and if either one or both countries are landlocked. The left-hand side variable, bilateral trade relative to GDP, is measured as the sum of country *j*'s exports to and imports from country *k* in US thousand dollars. To incorporate the argument that trade with the neighboring countries is more favorable, we include the distance between the countries which is measured as the distance between the capital cities of the two trading countries. The population of each country is quantified in millions and the area of the country is taken in square kilometers, whereas the border and landlocked variables are the qualitative variables of geographic characteristics taken as dummy variables. The above gravity equation is estimated to find the fitted values of bilateral trade. As the above gravity equation takes the trade share and the geographical factors, such as distance, area, and population, in log form, the coefficients α_1 to α_5 express the trade elasticities with respect to distance, area, and population, respectively.

We next aggregate the estimated values of country *j*'s trade with country *k* over all partner countries k. We thus obtain $\widehat{T}_j$, which is country *j*'s constructed trade share in GDP calculated as $\widehat{T}_j = \sum_{k \neq j} e^{\widehat{\alpha} x_{jk}}$.

Now, we estimate our regression model (2) to quantify the impact of trade on industry-level output in 2SLS. In the first stage, we regress a country's actual trade share in GDP on the constructed trade share $\widehat{T}_j$ from the gravity equation. This gives the estimate of the fact that geographical variables account for a major part of the variation in trade share across all the countries. The first-stage equations can be expressed as follows:

$$T_j = c_0 + c_1\hat{T}_j + c_2 Index_i * \hat{T}_j + c_3 ln\, A_j + c_4 ln\, P_j + c_5 Index_i + u_j, \quad (5)$$

$$Index_i * T_j = d_0 + d_1\hat{T}_j + d_2 Index_i * \hat{T}_j + d_3 ln\, A_j + d_4 ln\, P_j + d_5 Index_i + v_j. \quad (6)$$

The endogenous variables are country j's actual trade relative to GDP and its interaction with the index. The instruments are the estimated geographical component of trade $\hat{T}_j$ and its interaction with the index. Other controls include the population and the area of country j.

In the second stage, the predicted values of regressions (5) and (6) are substituted into the main regression (2) (and (3)) in place of the endogenous terms T_j and $Index_i * T_j$ to estimate the parameters $\emptyset_1$ and $\emptyset_5$.

2.2. Data

2.2.1 Trade and Output Data

To evaluate our research questions, our key data requirement is data on industrial output and output per worker of the manufacturing industries and the bilateral trade data for all the countries for the year 2015. We extracted the data on industrial output and the number of employees (labor) working in 20 manufacturing industries across 99 countries from the statistical database of the United Nations Industrial Development Organization (UNIDO). The data on bilateral imports has been taken from the IMF's Direction of Trade Statistics (DOTS). To generate the trade variable for 99 countries, the bilateral import data for each trading partner has been added as Trade = M_{ij} + M_{ji} where "M" refers to "Goods, Value of Imports, Cost, Insurance, Freight (CIF)" in US Dollars. Note that the data on "Goods, Value of Imports, Free on Board (FOB)" is missing for many countries, so we use "Goods, Value of Imports (CIF)." The data for country-level GDP is taken from the World Bank's World

Development Indicators (WDI), and the data on geographical characteristics is obtained from the *Centre d'Études Prospectives and d'Informations Internationales* (CEPII) database.[5]

The selected 20 manufacturing industries are given in Appendix A. The classifications are based on the two-digit International Standard Industrial Classification (ISIC) Rev3.1. Based on the Competitive Industrial Performance Index (CIP) published by UNIDO, this study chose 99 countries listed in Appendix A, who are at least in lower-middle rank industry competitiveness. We started with 101 countries, but the countries for which the industry-level output was not available were dropped. The final estimation is thus based on 99 countries.

2.2.2 The Differentiation Index of Industry

We construct the differentiation index of industry i $Index_i$ as follows. Rauch (1999) classifies the trading products into two categories. The first category is "homogeneous products," which include products traded on an organized exchange (w) and reference priced products (r), and the second category is "differentiated products" (n). Using the classification of Rauch (1999), we characterize the chosen 20 manufacturing industries into differentiated vs. homogeneous industries.[6] Rauch's classification is at the four-digit Standard International Trade Classification (SITC) Rev. 2. We match it with our two-digit ISIC Rev. 3.1 classification and then calculate the share of the four-digit differentiated products in each of our two-digit 20 industries.

To do so, first the four-digit products in each of our two-digit 20 industries are subcategorized as per the Rauch category of reference price (r), products traded on an organized exchange (w), and differentiated products (n). Table 1 shows the percentage distribution of the products into homogeneous (r and w) vs. differentiated (n) in each of 20 industries. Rauch gives "Liberal" as well as the "Conservative" classification of products. As shown in Table 1,

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[5] http://www.cepii.fr/CEPII/en/bdd_modele/bdd.asp

[6] The classification is available at https://econweb.ucsd.edu/~jrauch/rauch_classification.html

however, there are no prominent differences in both ways of classification. For this study, we rely on the conservative classification to create the differentiation index of an industry. Table 1 shows that for the Food & Beverages industry, out of all the products produced and traded only 26.56% matches the definition of differentiated products (n), whereas 40.63% of products are produced and sold at a reference price (r) and 32.81% of products have a proper exchange market (w). However, the 8 industries, namely, Wearing Apparel & Fur, Publishing & Printing, Machinery & Equipment, Office Accounting & Computing Machinery, Electrical Machinery & Apparatus, Motor Vehicles, Trailers & Semi-Trailers, Other Transportation Equipment, and Fabricated Metal Products, are producing fully differentiated products (n).

Table 1: Differentiated vs. Homogeneous Products in Each Manufacturing Industry based on Rauch (1999)

ISIC Classified Industry	**Conservative Classification**			**Liberal Classification**		
	Differentiated	**Homogeneous**		**Differentiated**	**Homogeneous**	
	n (%)	**r (%)**	**w (%)**	**n (%)**	**r (%)**	**w (%)**
Food & Beverages	26.56	40.63	32.81	18.75	42.19	39.06
Tobacco Products	11.11	22.22	66.67	11.11	22.22	66.67
Textile	58.3	26.2	15.5	54.8	23.8	21.4
Wearing Apparel & Fur	100	-	-	100	-	-
Wood Products excluding Furniture	54.55	45.45	-	54.55	9.09	36.36
Paper & Paper Products	20	80	-	20	70	10
Publishing & Printing	100	-	-	100	-	-
Coke, Refined Petroleum Products & Nuclear Fuel	26.32	42.11	31.58	21.05	47.37	31.58
Chemicals & Chemical Products	8.77	89.47	1	8.77	84.21	7.02

Rubber & Plastics Products	96	4	-	84	16	-
Non-Metallic Mineral Products Industries	87.88	12.12	-	78.79	15.15	6.06
Basic Metal	18.75	28.13	53.13	12.5	25	62.5
Machinery & Equipment	100	-	-	100	-	-
Office Accounting & Computing Machinery	100	-	-	100	-	-
Electrical Machinery & Apparatus	100	-	-	78.57	21.43	-
Motor Vehicles, Trailers & Semi-Trailers	100	-	-	100	-	-
Other Transportation Equipment	100	-	-	100	-	-
Furniture Manufacturing	92.59	-	7.41	92.59	-	7.41
Leather, Leather Products & Footwear	66.67	11.11	22.22	55.56	22.22	22.22
Fabricated Metal Products	100	-	-	95.65	4.35	-

Note: The table shows the shares (%) of differentiated (n) and homogeneous products (r and w) in each of the 20 manufacturing industries, based on Rauch's (1999) conservative and liberal classifications.

Next, relying on the conservative classification of Rauch, we use the values of "n" as the degree of differentiation of an industry as it shows the share of the four-digit differentiated industries in each of the two-digit 20 industries. To convert this value into index form, we transform the values of 0-100 in terms of 0-1 by dividing the values by 100. The variable

$Index_i$ depicts the degree of differentiation of industry i from 0 to 1. Closer to 1 means a more differentiated industry and vice versa. The differentiation index of an industry is shown in Table 2.

Table 2: Differentiation Index

ISIC Classified Industry	Differentiation Index	Conservative Classification		
		Differentiated	Homogeneous	
		n (%)	r (%)	w (%)
Food & Beverages	0.266	26.56	40.63	32.81
Tobacco Products	0.111	11.11	22.22	66.67
Textile	0.583	58.3	26.2	15.5
Wearing Apparel & Fur	1.000	100	-	-
Wood Products excluding Furniture	0.546	54.55	45.45	-
Paper & Paper Products	0.200	20	80	-
Publishing & Printing	1.000	100	-	-
Coke, Refined Petroleum Products & Nuclear Fuel	0.263	26.32	42.11	31.58
Chemicals & Chemical Products	0.088	8.77	89.47	1
Rubber & Plastics Products	0.960	96	4	-
Non-Metallic Mineral Products Industries	0.879	87.88	12.12	-

Basic Metal	0.188	18.75	28.13	53.13
Machinery & Equipment	1.000	100	-	-
Office Accounting & Computing Machinery	1.000	100	-	-
Electrical Machinery & Apparatus	1.000	100	-	-
Motor Vehicles, Trailers & Semi-Trailers	1.000	100	-	-
Other Transportation Equipment	1.000	100	-	-
Furniture Manufacturing	0.926	92.59	-	7.41
Leather, Leather Products & Footwear	0.667	66.67	11.11	22.22
Fabricated Metal Products	1.000	100	-	-

3. Empirical Results

3.1. Main Findings

The descriptive statistics of the data that is used to estimate the gravity model of trade in equation (3) is presented in Table 3. Here, bilateral trade (T_{jk}) is measured in US dollars, and nominal GDP is also taken in US dollars. The area of each country (*A*) is measured in square kilometers, population (*P*) is measured in millions, and distance (D_{jk}) is calculated as the distance between populous cities measured in kilometers. The border is a dummy taking value 1 if a trading partner has a common border, and landlocked is a dummy taking value 1 if either one or both trading countries are landlocked.

Table 3: Descriptive Statistics for the Gravity Model					
Variables	Obs.	Mean	S D	Min	Max
Imports	9177	1.61e+09	1.04e+10	3	4.82e+11
Trade	9177	3.23e+09	1.93e+10	3	6.27e+11
GDP	9177	7.57e+11	2.22e+12	6.40e+09	1.80e+13
Trade/GDP	9177	.007	.025	0	.871
Distance	9177	6734.087	4514.887	59.617	19772.34
Population	9177	68.336	196.667	.423	1371.22
Area	9177	1150000	2630000	316	1.71e+07
Border	9177	3.1%	.173	0	1
Landlocked	9177	32%	.464	0	1

Table 4 presents the result of the gravity model expressed in equation (3). The gravity model results show that the impact of the distance between the countries on the trade share is negative and significant and the trade elasticity with respect to distance is greater than 1 in absolute terms. This means that bilateral trade is more likely to be high with neighboring countries than with distant countries. The countries' bilateral trade is positively and significantly affected if the trading partner shares the common border. However, in our data, very few countries have a common border. Bilateral trade share has a negative relationship with the areas of both partner countries *j* and *k*, whereas the trade share elasticity with respect to population is greater than zero and the population of both the trading partners significantly and positively affects the bilateral trade share of countries. Moreover, if any of the countries are landlocked, the bilateral trade to GDP share of the country decreases.

Table 4: Estimation of Gravity Equation	
Variables	$ln\ (T_{jk}/GDP_j)$
$ln\ (A_j)$	-0.123***
	(0.0164)

$ln\ (A_k)$	-0.171***
	(0.0165)
$ln\ (P_j)$	0.133***
	(0.0221)
$ln\ (P_k)$	0.860***
	(0.0221)
$ln\ (D_{jk})$	-1.170***
	(0.0293)
$border_{jk}$	0.972***
	(0.144)
$(landlock_j + landlock_k)$	-1.088***
	(0.0503)
Constant	3.599***
	(0.306)
Observations	9,177
R-squared	0.347

Note: Robust standard errors in parentheses.

*** p<0.01, ** p<0.05, * p<0.1

The results of our gravity model are as expected and consistent with theoretical implications, signifying that geographical characteristics are the key determinants of the bilateral trade to GDP share. The R-squared of the gravity model is 0.347, which means that around 35% variation in bilateral trade is explained by the geographical characteristic included in the model. Given the fact that the results are from cross-sectional data, the value of R-squared is sufficiently good. To avoid the chances of heteroscedasticity, the robust standard errors are calculated and shown in Table 4.

The above regression coefficients are used to find the constructed bilateral trade to GDP ratio by taking the exponential power of the predicted values and adding all the values country-wise for all the trading partners to construct aggregate trade share $\hat{T}_j$ for each country. The constructed instruments $\hat{T}_j$ and $Index_i * \hat{T}_j$ are then used in the first-stage equations (5) and (6). We find the minimum eigenvalue statistic in the first stage to be 115.2, which confirms the relevance of the instruments.

The estimated results of main regressions (2) and (3) are presented in Table 5.

Table 5: Impact of Trade and Differentiation Degree on the Industry-level Output and Output per Worker

Variables	$ln\, Y_{ij}$ Output	$ln\, \frac{Y_{ij}}{L_{ij}}$ Output per Worker
$\tilde{T}_j$	3.008***	1.698***
	(0.684)	(0.434)
$Index_i * \tilde{T}_j$	1.309*	0.777*
	(0.780)	(0.435)
$ln\, P_j$	1.122***	0.0835**
	(0.0587)	(0.0351)
$ln\, A_j$	0.203***	0.177***
	(0.0675)	(0.0445)
$Index_i$	-1.560***	-1.512***
	(0.565)	(0.312)
Observations	1,561	1,522
R-squared	0.225	0.129

Note: Robust standard errors in parentheses.

*** p<0.01, ** p<0.05, * p<0.1

We summarize the main findings as follows: (1) The impact of a country's trade on industrial output is positive and significant. One percent point increase in the trade/GDP ratio increases industrial output by 3.008%. (2) The impact of a country's trade on industrial output per worker is also positive and significant. One percentage point increase in the trade/GDP ratio increases industrial output per worker by 1.698%. (3) The impacts of a country's trade on industrial output and industrial output per worker increase with the degree of differentiation in the manufacturing industries.

3.2 An Alternative Approach: Industry-by-industry Estimation

This section employs an alternative strategy to investigate the effect of a country's trade on industry-level output. We estimate the following regressions by 2SLS for each industry i separately and obtain the industry-level trade impact β_{1i} (and δ_{1i}) for i =1, 2, …, 20.

$$ln\, Y_{ij} = \beta_{0i} + \beta_{1i} T_j + \beta_{2i}\, ln\, A_j + \beta_{3i} ln\, P_j + \mu_{ij}. \quad (7)$$

$$ln\, \frac{Y_{ij}}{L_{ij}} = \delta_{0i} + \delta_{1i} T_j + \delta_{2i} ln\, A_j + \delta_{3i} ln\, P_j + \eta_{ij}. \quad (8)$$

For each industry i, i = 1, 2, …, 20, we run cross-country regression to estimate the impacts of the trade, area, and population of the country on the industrial output. By comparing the estimated coefficients of all industries, we can analyze whether the impact of trade is the same for all the industries or it varies across the industries. Moreover, we compare the OLS estimates with the IVLS estimates of the relationship between the country-level trade and industrial output.

We rely on the same instrument $\hat{T}_j$ constructed in Section 3.1 and run the following first-stage regression

$$T_j = c_0 + c_1 \hat{T}_j + c_2 ln\, A_j + c_3 ln\, P_j + u_j. \quad (9)$$

Then the second stage estimates equations (7) and (8) by replacing T_j with the predicted value obtained from equation (9). The estimates of coefficients β_{1i} and δ_{1i} for all 20 industries are summarized in Table 6. The detailed estimates of equations (7) and (8) for all industries are presented in Appendix B.

Table 6: Summary of Impacts of Trade on Industry-level Output and Output per Worker

ISIC Classified Industry	Industry Output			Industry Output per Worker		
	β_{1i} Coefficients'			δ_{1i} Coefficients'		
	Sign	Significance	Magnitude	Sign	Significance	Magnitude
Food & Beverages	+	***	3.29	+	***	2.10
Tobacco Products	+	*	3.40	+	**	2.93
Textile	+	***	4.59	+	***	3.84
Wearing Apparel & Fur	+	-	2.71	+	***	3.67
Wood Products excluding Furniture	+	***	6.11	+	***	3.15
Paper & Paper Products	+	***	5.31	+	***	2.81
Publishing & Printing	+	***	4.03	+	***	2.40
Coke, Refined Petroleum Products & Nuclear Fuel	+	-	3.27	+	-	2.61
Chemicals & Chemical Products	+	***	6.02	+	***	3.39
Rubber & Plastics Products	+	***	4.29	+	**	3.06

Non-Metallic Mineral Products Industries	+	***	3.21	+	***	1.75
Basic Metal	+	***	4.86	+	***	1.50
Machinery & Equipment	+	***	7.72	+	***	2.01
Office Accounting & Computing Machinery	+	-	3.44	+	**	2.40
Electrical Machinery & Apparatus	+	***	4.81	+	***	2.39
Motor Vehicles, Trailers & Semi-Trailers	+	***	6.15	+	-	1.62
Other Transportation Equipment	+	***	10.32	+	***	3.74
Furniture Manufacturing	+	***	4.73	+	***	2.24
Leather, Leather Products & Footwear	+	-	1.20	+	**	2.11
Fabricated Metal Products	+	***	6.06	+	***	2.30

Note: Blanks in the table indicate that results are insignificant for the industry.

The “industry output” column indicates that the highest impact of a geographical component of aggregated trade share is on the industry of Other Transportation Equipment. The results show that one percentage point increase in predicted trade share increases the output of this industry by 10.32%. For the Non-Metallic Mineral Product industry, on the other hand, one percentage point increase in predicted trade share significantly increases the industry-level output only by 3.21%. On average, the results conclude that the impact of trade on industrial output varies from 3.21% to 10.32% across different industries. Overall, a country's trade positively affects the industrial output of Food & Beverages, Fabricated Metal Products, Tobacco Products, Machinery & Equipment, Textile, Electric Machinery & Apparatus, Non-Metallic Mineral Products, Motor Vehicles, Trailers & Semi-Trailers, Wood Products excluding Furniture, Other Transportation Equipment, Paper & Paper Products, Furniture, Manufacturing, Printing & Publishing, Chemicals & Chemical Products, Rubber & Plastics Products, and Basic Metal. On the other hand, for the industries Office Accounting & Computing Machinery, Wearing Apparel & Fur, Leather, Leather Products & Footwear, and Coke, Refined Petroleum Products & Nuclear Fuel, the impact of trade is positive but not significant.

When output per worker is concerned, the impact of trade is generally smaller. Trade share positively affects the industrial output per worker of Food & Beverages, Fabricated Metal Products, Tobacco Products, Machinery & Equipment, Textile, Office Accounting & Computing Machinery, Wearing Apparel & Fur, Electric Machinery & Apparatus, Leather, Leather Products & Footwear Non-metallic Mineral Products, Wood Products excluding Furniture, Other Transportation Equipment, Paper & Paper Products, Furniture, Manufacturing, Printing & Publishing, Chemicals & Chemical Products, Rubber & Plastics Products, and Basic Metal. However, for the industries Motor Vehicles, Trailers & Semi-Trailers and Coke, Refined Petroleum Products & Nuclear Fuel, the impact of trade on output per worker is positive but not significant. The impact of trade share on the output per worker is highest for the Textile industry, where one percentage point increase in trade share increases the output per worker by 3.84%. For Basic Metal, on the other hand, the magnitude of the impact is significant but the output per worker changes only by 1.5%.

The results of industry-by-industry estimation are in line with our main findings in the previous section with respect to the first research question. It also illustrates the heterogeneity in the effect of a country's trade on industry-level output.

4. Conclusion

By extending Frankel-Romer's (1999) estimation strategy, this paper has investigated the effect of country-level trade on industry-level output for 20 leading manufacturing industries, both for developed and developing countries for the year 2015. Given the argument that there exists an endogeneity in the trade and industrial output relationship, the trade constructed by the geographical variables is used as an instrument for the total trade relative to GDP of countries. The results have indicated that the population and area of the country and the trade volume significantly and positively affect the industrial output and output per worker. Based on Rauch (1999), this paper has characterized the industries into two broader categories as homogeneous and differentiated industries. Our findings also show the heterogeneous trade impacts across industries, which is related to the degree of industry differentiation. It has confirmed that in the differentiated industries, the average impacts of predicted trade share on the industry-level output and output per worker are moderately high as compared to the homogeneous industries.

Appendix.

A. The List of Industries and Countries

Table A.1: List of 20 Manufacturing Industries (ISIC-3)

Food & Beverages	Fabricated Metal Products
Tobacco Products	Machinery & Equipment
Textile	Office Accounting & Computing
Wearing Apparel & Fur	Electrical Machinery & Apparatus
Leather, Leather Products & Footwear	Motor Vehicles, Trailers & Semi-Trailers
Wood Products excluding Furniture	Other Transportation Equipment

Paper & Paper Products	Furniture, Manufacturing
Printing & Publishing	Coke, Refined Petroleum Products & Nuclear Fuel
Chemicals & Chemical Products	Non-Metallic Mineral Products Industries
Rubber & Plastics Products	Basic Metal

Table A.2: List of 99 Countries

Algeria	Argentina	Armenia	Australia	Austria
Azerbaijan	Bahrain	Bangladesh	Belarus	Belgium
Bolivia	Brazil	Vietnam	Bulgaria	Canada
Chile	Brunei Darussalam	China	Colombia	USA
Costa Rica	Croatia	Cuba	Czech Rep	Côte d'Ivoire
Denmark	Ecuador	Egypt	Estonia	Ethiopia
Finland	France	Georgia	Germany	Greece
Hungary	India	Indonesia	Iran	Iraq
Ireland	Israel	Italy	Japan	Jordan
Kazakhstan	Kenya	South Korea	Kuwait	Kyrgyz Rep
Latvia	Lebanon	Lithuania	Luxembourg	Malawi
Malaysia	Malta	Mexico	Moldova	Mongolia
Morocco	Myanmar	Netherlands	New Zealand	Nigeria
Norway	Oman	Pakistan	Panama	Peru
Philippines	Poland	Portugal	Qatar	Romania
Russia	Saudi Arabia	Serbia	Singapore	Slovak Rep
Slovenia	South Africa	Spain	Sri Lanka	Sudan
Sweden	Switzerland	Tajikistan	Tanzania	Thailand
Tunisia	Turkey	Turkmenistan	Uganda	Ukraine
UAE	United Kingdom	Uruguay	Uzbekistan	

B. Detailed Results of Industry-by-industry Estimation

The estimated IVLS results for the impact on industry-level output (equation (7)) are shown in Table B.1.a and Table B.1.b.

Table B.1.a: 2SLS Regression Results: Manufacturing Industrial Output (Log Y_j)

Industries	Food & Beverages	Fabricated Metal Products	Tobacco Products	Machinery & Equipment	Textile	Office Accounting & Computing Machinery	Wearing Apparel & Fur	Electrical Machinery & Apparatus	Leather, Leather Products & Footwear	Non-Metallic Mineral Products Industries
$\tilde{T}_j$	3.292*** (0.866)	6.07*** (1.584)	3.403* (1.721)	7.720*** (2.145)	4.599*** (1.146)	3.441 (2.140)	2.71 (1.573)	4.815*** (1.680)	1.207 (1.266)	3.219*** (0.914)
$ln\ A_j$	0.939*** (0.133)	1.124*** (0.186)	1.471*** (0.265)	1.148*** (0.227)	1.193*** (0.144)	1.770*** (0.294)	1.117*** (0.141)	1.275*** (0.180)	1.281*** (0.158)	0.921*** (0.125)
$ln\ P_j$	0.284** (0.124)	0.246 (0.206)	-0.0841 (0.289)	0.485* (0.281)	0.455*** (0.168)	-0.420 (0.361)	0.0758 (0.176)	0.168 (0.199)	-0.0587 (0.165)	0.207 (0.124)
Constant	15.09*** (1.875)	11.95*** (3.254)	14.05*** (4.384)	7.435 (4.489)	8.636*** (2.728)	18.86*** (5.378)	14.61*** (3.040)	12.53*** (3.371)	15.60*** (2.693)	14.66*** (1.952)
Observations	83	81	53	83	82	68	79	81	79	83

R-squared	0.611	0.388	0.444	0.326	0.621	0.390	0.505	0.471	0.532	0.606

Note: Robust standard errors in parentheses.

*** p<0.01, ** p<0.05, * p<0.1

Table B.1.b:2SLS Regression Results: Manufacturing Industrial Output (Log Y_j)

	Motor Vehicles, Trailers & Semi-Trailers	**Wood Products excluding Furniture**	**Other Transportation Equipment**	**Paper & Paper Products**	**Furniture, Manufacturing**	**Printing & Publishing**	**Chemicals & Chemical Products**	**Coke, Refined Petroleum Products & Nuclear Fuel**	**Rubber & Plastics Products**	**Basic Metal**
$\tilde{T}_j$	6.152*** (1.936)	6.110*** (1.621)	10.32*** (3.424)	5.316*** (1.471)	4.732*** (1.486)	4.034*** (1.152)	6.027*** (1.314)	3.271 (2.072)	4.298*** (1.391)	4.860*** (1.401)
$ln\, A_j$	1.704*** (0.261)	0.677*** (0.216)	1.865*** (0.368)	1.052*** (0.202)	1.192*** (0.165)	0.956*** (0.156)	1.300*** (0.184)	1.226*** (0.225)	1.209*** (0.175)	1.087*** (0.169)
$ln\, P_j$	0.386 (0.284)	0.710*** (0.218)	0.414 (0.450)	0.436* (0.220)	0.170 (0.195)	0.183 (0.161)	0.334 (0.205)	0.0464 (0.272)	0.175 (0.217)	0.522** (0.254)
Constant	7.706* (4.440)	6.007* (3.428)	3.090 (7.194)	9.089*** (3.336)	12.60*** (3.109)	12.97*** (2.445)	10.71*** (3.076)	16.11*** (4.320)	13.23*** (3.298)	9.234** (3.754)

Observations	78	84	74	80	84	80	81	65	80	83
R-squared	0.480	0.319	0.383	0.345	0.461	0.450	0.501	0.352	0.476	0.499

Note: Robust standard errors in parentheses.

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Next, the IVLS results for the impact of trade on output per worker (equation (8)) are presented in Table B.2.a and Table B.2.b.

Table B.2.a: 2SLS Regression Results: Manufacturing Industrial Output Per Worker $\left(\text{Log}\left({}^{Y_j}/_{L_j}\right)\right)$										
Industries	**Food & Beverages**	**Fabricated Metal Products**	**Tobacco Products**	**Machinery & Equipment**	**Textile**	**Office Accounting & Computing Machinery**	**Wearing Apparel & Fur**	**Electrical Machinery & Apparatus**	**Leather, Leather Products & Footwear**	**Non-Metallic Mineral Products Industries**
$\tilde{T}_j$	2.105*** (0.618)	2.304*** (0.564)	2.936** (1.264)	2.01*** (0.733)	3.848*** (0.844)	2.401** (1.189)	3.671*** (0.840)	2.387*** (0.771)	2.112** (0.927)	1.749*** (0.626)
$ln\, A_j$	0.114 (0.0893)	0.193* (0.114)	0.117 (0.239)	0.199* (0.103)	0.0401 (0.110)	0.167 (0.112)	0.0451 (0.110)	0.0807 (0.0911)	0.0441 (0.113)	0.0992 (0.100)
$ln\, P_j$	0.155 (0.101)	-0.0115 (0.135)	0.337* (0.171)	0.0286 (0.117)	0.459*** (0.170)	0.0814 (0.177)	0.325** (0.129)	0.176 (0.115)	0.122 (0.151)	0.0396 (0.0964)
Constant	8.219*** (1.443)	9.462*** (1.677)	5.788* (2.906)	9.121*** (1.716)	2.732 (2.465)	8.681*** (2.786)	4.037** (1.960)	7.656*** (1.801)	7.803*** (2.251)	9.692*** (1.399)
Observations	82	80	51	81	81	67	76	79	75	82
R-squared	0.097	0.125	0.054	0.095	0.144	0.099	0.134	0.072	0.062	0.113

Note: Robust standard errors in parentheses.

*** p<0.01, ** p<0.05, * p<0.1

Table B.2.b: S2SLS Regression Results: Manufacturing Industrial Output Per Worker $\left(\text{Log}\left({}^{Y_j}/_{L_j}\right)\right)$										
Industries	**Motor Vehicles, Trailers & Semi-Trailers**	**Wood Products excluding Furniture**	**Other Transportation Equipment**	**Paper & Paper Products**	**Furniture, Manufacturing**	**Printing & Publishing**	**Chemical & Chemical Products**	**Coke, Refined Petroleum Products & Nuclear Fuel**	**Rubber & Plastics Products**	**Basic Metal**
$\tilde{T}_j$	1.625 (0.987)	3.149*** (0.929)	3.744*** (1.334)	2.817** * (0.723)	2.243*** (0.702)	2.397*** (0.549)	3.395*** (0.850)	2.610 (1.657)	3.060** (1.406)	1.505** (0.741)
$ln\ A_j$	0.171* (0.0999)	0.00418 (0.118)	0.273** (0.136)	0.0140 (0.123)	0.182** (0.0905)	0.0640 (0.0954)	0.221 (0.134)	0.255 (0.170)	0.0952 (0.204)	0.0887 (0.0990)
$ln\ P_j$	0.163 (0.141)	0.352** (0.162)	0.284 (0.184)	0.315** (0.134)	0.0420 (0.118)	0.164* (0.0958)	0.220 (0.158)	0.153 (0.254)	0.0123 (0.256)	0.130 (0.124)
Constant	8.310*** (2.246)	4.747** (2.378)	4.765 (2.987)	5.995** * (1.849)	8.517*** (1.696)	7.393*** (1.318)	6.561*** (2.243)	9.674** (3.913)	9.617*** (3.568)	9.462*** (1.772)
Observations	76	83	70	79	82	78	80	60	79	81
R-squared	0.070	0.088	0.116	0.086	0.128	0.127	0.111	0.042	0.112	0.034

Note: Robust standard errors in parentheses.

*** p<0.01, ** p<0.05, * p<0.1

The first stage regression results estimated by using equation (9) are shown in Table B.3.

Table B.3: First Stage Regression Results

Variables	$\boldsymbol{T_j}$
$\boldsymbol{\hat{T}_j}$	0.717***
	(0.222)
$\boldsymbol{ln\ P_j}$	-0.0487
	(0.0325)
$\boldsymbol{ln\ A_j}$	-0.0514*
	(0.0308)
Constant	1.228***
	(0.350)
Observations	99
R-squared	0.356

Note: Robust standard errors in parentheses.

*** p<0.01, ** p<0.05, * p<0.1

The coefficient of constructed trade share $\hat{T}_j$ is 0.717, which confirms that the constructed share contains enough information about the actual trade share of the countries. A one-unit change in the constructed trade share changes the actual trade share by 0.71 units, and it is significant with the t-value of 3.25, which corresponds to F stats of 10. The results are consistent with those of Frankel and Romer indicating that the geographical component of the trade is a good instrument for actual trade.

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