Korea and the World Economy, Vol. 19, No. 1 (April 2018) 23-50

Ricardian Comparative Advantage and Value Added in Exports*

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Incorporating the literature on value added in exports and Ricardian comparative advantage, this paper tests empirically whether the importance of Ricardian comparative advantage is valid for value added in exports. We decompose gross exports at the industry level into various value-added components, covering 40 countries and 14 manufacturing industries for the period of 1995-2011. Using a panel data model with three dimensional fixed effects (exporter-importer-year, importer-industry-year, and exporter-industry fixed effects), we find that comparative advantage is an important determinant of the patterns of trade in a world with global value chains. Furthermore, we also find the evidence that developed countries have greater scope for intra-industry comparative advantage. Finally, we also find that Ricardian comparative advantage determines the patterns of trade in Korean manufacturing.

JEL Classification: F10, F11

Keywords: comparative advantage, domestic value added in exports, global value chains, world input output table, production fragmentation

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* Received November 9, 2017. Revised March 19, 2018. Accepted April 2, 2018. This paper is a revised and extended version of Choi and Park (2016).

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1. INTRODUCTION

The fragmentation of production across countries has become a prominent feature in recent decades. The emergence of global value chains has contributed to the structural interdependence of the world economy (Baldwin 2013) and it has become more and more attractive for firms to distribute certain stages of their production abroad, as trade costs fall. Production stages or tasks are increasingly fragmented and distributed across firms and countries. As global value chains are deepening, firms tend to source the intermediate inputs increasingly from foreign countries. Consequently, the share of domestic value added in gross exports tends to shrink when foreign intermediate inputs contribute more to the gross value of exports.

These fundamental changes in the global trade environment and components of gross exports, however, have been neglected in empirical tests of Ricardian comparative advantage. The work of Eaton and Kortum (2002), Costinot, Donaldson, and Komunjer (2012) ("CDK (2012)") provide the theoretical foundations to guide the empirical analysis and a number of empirical studies examined the importance of Ricardian comparative advantage, including Bombardini *et al*. (2012), Burstein and Vogel (2010), Kerr (2013), Levchenko and Zhang (2016), and Morrow (2010). Despite recent theoretical advances, these empirical studies still use the dependent variable measured by gross exports at the industry level.[1)]

As Grossman and Rossi-Hansberg (2007) put it, the measurement of trade as the gross values of imports and exports was perhaps appropriate at a time when trade flows comprised mostly finished goods. Therefore, such measures are inadequate to investigate the importance of Ricardian comparative advantage in a world with global value chains. With deepening global value chains allowing goods to cross borders many times, gross exports at the industry level include foreign intermediate inputs that do

1) An exception is CDK (2012), in which the dependent variable is gross export that is disaggregated by exporting and importing countries and adjusted for differences in levels of "openness" to account for trade-driven selection.

not create domestic value added and, thus, do not appropriately reflect the actual domestic production of a country. Thus, export performance measures using gross exports containing this double-counting problem are inadequate to examine the importance of comparative advantage.

One way to deal with this problem is to decompose gross exports into various domestic value-added components by sources at the industry level. Based on the methodology of Koopman *et al*. (2014) and using the World Input-Output Table (Timmer *et al*., 2015), we build a comprehensive data set on bilateral domestic value added in exports covering 40 countries and 14 manufacturing industries, corresponding roughly to two-digit ISIC for the period 1995-2011. We show the evolution of various domestic value-added components at the country and industry level in detail and how different features are generated when we measure export performance by gross exports versus domestic value added in exports.

Incorporating the literature on value added in exports and studies on comparative advantage, this paper tests empirically the importance of Ricardian comparative advantage using value added in exports as the dependent variable rather than gross exports. To our knowledge, this is the first study to investigate the validity of Ricardian comparative advantage for value added in exports by country and industry. Using a panel data model with three dimensional fixed effects (exporter-importer-year, importer-industry-year, and exporter-industry fixed effects), we find strong support for the importance of Ricardian comparative advantage for domestic value added in exports. Furthermore, the theories of Eaton and Kortum (2002) and CDK (2012) suggest that the parameter governing the relationship between productivity and exports in this Ricardian model reflects the extent of intra-industry heterogeneity. We test this implication by building alternative samples in which exporter and importer are consisted of only developed and developing countries, respectively. The empirical results show large intra-industry heterogeneity for developed country pairs relative to developing country pairs, confirming the theoretical prediction.

The rest of this paper is organized as follows. Section 2 presents the decomposition of gross exports into various domestic value-added components and shows the evolution of the relation between value added in exports and gross exports. In section 3, we test whether the importance of Ricardian comparative advantage is valid for value added in exports, using IV techniques to deal with an endogeneity bias. We also test the robustness of our empirical results using alternative samples and the cross-sectional data set of CDK (2012). Furthermore, we test the importance of comparative advantage for Korean manufacturing. Finally, the last section provides our conclusions.

2. DOMESTIC VALUE ADDED IN EXPORTS

2.1. Ratios of Domestic Value Added in Exports to Gross Exports

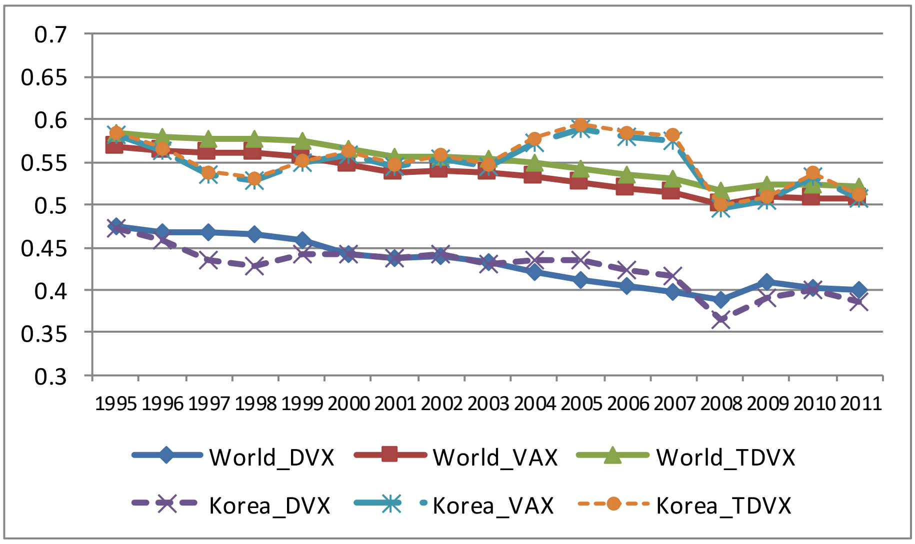
The growing recent literature on global value chains suggests methodologies to compute the domestic value added in exports, including Hummels, Ishii, and Yi (2001), Daudin, Rifflart, and Schweisguth (2011), Johnson and Noguera (2012a, 2012b) and Stehrer, Foster, and de Vries (2012), Koopman *et al*. (2010), Kowalski (2014), Stehrer (2013), and Koopman *et al*. (2014). In particular, Koopman *et al*. (2014) provides a framework to decompose gross exports into various components of domestic value added as shown in table 1.

Table 1 Decomposition of Gross Exports

Gross Exports	Total Domestic Value Added in Exports (TDVX)	Direct value added exports (DVX)
		Indirect value added exports (IVX)
		Exported in intermediates that return home (RVX)
	Foreign value added	

Source: Koopman *et al*. (2014).

Figure 1 Evolution of Value Added Ratios between 1995 and 2011



Source: Author's calculation using the World Input-Output Table.

Gross exports are composed of total domestic value added in exports (TDVX) and foreign value added. Total domestic value added in exports can be further decomposed into direct value added in export (DVX), indirect value added (IVX) originating from domestic intermediates and domestic value added that returns home (RVX). Based on the methodology of Koopman *et al*. (2014) and using the World Input-Output Database (WIOD), we compute domestic value added in exports at the industry level from gross exports. Our study covers 40 countries and 14 manufacturing industries (list in Appendix).

Figure 1 presents how the ratios of domestic value added in exports relative to gross exports for 40 countries as a whole and for Korean manufacturing have evolved over the period 1995-2011. DVX ratio is measured by the sum of direct value added in exports divided by the sum of gross exports across all countries and manufacturing industries. Following Johnson and Noguera (2012b), we define VAX ratio as the sum of direct and indirect value added (DVX+IVX) divided by the sum of gross exports, and

TDVX ratio as the sum of DVX, IVX and RVX relative to the sum of gross exports.

2.1.1. World

For the world, all ratios of domestic value added in exports to gross exports including DVX, VAX, and TDVX ratio, declined from 1995 to 2011. In particular, DVX ratio declined from 0.474 in 1995 to 0.399 in 2011. This change corresponds to about 15.7%. VAX ratio and TDVX ratio decline by 11.08 and 11.07% from 1995 to 2011, respectively. There was an increase in these ratios in 2009, coincident with a sharp drop in world trade. The overall trend is consistent with recent literature such as Johnson and Noguera (2012b) and Kummritz (2014).

2.1.2. Country level

We turn to the level of individual countries. Table 2 presents TDVX, VAX and DVX ratios of 40 countries in 1995 and 2011. There are significant heterogeneities across countries in the initial level of all ratios, the magnitude of changes, and change directions. All three ratios declined in almost all countries. However, Romania, Greece, and Ireland experienced increases in DVX ratio. Furthermore, it is notable that not only many emerging markets (e.g., Latvia, Poland) showed large declines, but also some developed countries such as France, Japan, and Germany.

Additionally, there were some countries that experienced increases in TDVX and VAX ratios, but declines in DVX ratio. These include Cyprus, Portugal, and Slovenia. This means that increases in IVX and RVX (value added that returns home) for these countries were large enough to offset declines in DVX. In addition, although Japan experienced large falling DVX ratios, the level of DVX ratio in 2011 is still the highest among 40 countries.

Table 2 TDVX, VAX and DVX Ratios by Country

	TDVX ratio			VAX ratio			DVX ratio		
	1995	2011	% change	1995	2011	% change	1995	2011	% change
Australia	0.569	0.543	–4.70	0.568	0.540	–4.93	0.467	0.411	–11.85
Austria	0.604	0.498	–17.46	0.600	0.494	–17.57	0.469	0.356	–24.06
Belgium	0.418	0.317	–24.18	0.412	0.313	–23.91	0.323	0.226	–29.86
Brazil	0.603	0.530	–12.18	0.602	0.527	–12.35	0.485	0.404	–16.67
Bulgaria	0.443	0.404	–8.75	0.443	0.404	–8.81	0.360	0.302	–15.99
Canada	0.476	0.514	7.96	0.469	0.505	7.77	0.413	0.421	2.10
China	0.609	0.594	–2.45	0.606	0.577	–4.75	0.531	0.475	–10.51
Cyprus	0.431	0.453	5.30	0.431	0.453	5.24	0.394	0.360	–8.54
Czech Republic	0.532	0.401	–24.62	0.525	0.398	–24.27	0.399	0.285	–28.61
Denmark	0.491	0.414	–15.74	0.490	0.413	–15.72	0.411	0.324	–21.31
Estonia	0.434	0.420	–3.22	0.434	0.420	–3.25	0.341	0.314	–7.75
Finland	0.604	0.471	–21.99	0.602	0.470	–21.97	0.463	0.331	–28.53
France	0.488	0.360	–26.18	0.478	0.353	–26.12	0.389	0.272	–30.15
Germany	0.627	0.542	–13.62	0.606	0.521	–14.04	0.500	0.400	–19.89
Greece	0.492	0.551	11.94	0.491	0.549	11.79	0.415	0.430	3.51
Hungary	0.524	0.397	–24.21	0.523	0.396	–24.42	0.408	0.287	–29.67
India	0.459	0.366	–20.35	0.459	0.364	–20.65	0.395	0.297	–24.73
Indonesia	0.648	0.605	–6.61	0.647	0.603	–6.81	0.547	0.468	–14.51
Ireland	0.465	0.482	3.65	0.464	0.481	3.69	0.384	0.387	0.89
Italy	0.556	0.473	–14.86	0.550	0.468	–14.95	0.461	0.360	–21.96
Japan	0.785	0.716	–8.72	0.772	0.707	–8.53	0.648	0.539	–16.81
Korea	0.585	0.512	–12.52	0.581	0.507	–12.71	0.472	0.387	–18.18
Latvia	0.707	0.481	–31.96	0.706	0.479	–32.15	0.540	0.360	–33.32
Lithuania	0.450	0.449	–0.25	0.450	0.448	–0.44	0.357	0.344	–3.69
Luxembourg	0.485	0.473	–2.51	0.484	0.472	–2.44	0.350	0.308	–12.11
Malta	0.315	0.435	38.12	0.315	0.435	38.20	0.251	0.328	30.65
Mexico	0.434	0.410	–5.52	0.431	0.406	–5.96	0.375	0.344	–8.14
Netherlands	0.431	0.339	–21.38	0.425	0.336	–21.12	0.337	0.256	–24.06
Poland	0.584	0.405	–30.65	0.583	0.402	–30.99	0.456	0.294	–35.42
Portugal	0.440	0.474	7.78	0.438	0.472	7.59	0.374	0.360	–3.64
Romania	0.559	0.661	18.20	0.559	0.659	17.92	0.450	0.494	9.66
Russia	0.522	0.521	–0.23	0.504	0.497	–1.37	0.424	0.390	–8.20
Slovak	0.545	0.400	–26.63	0.539	0.398	–26.20	0.396	0.272	–31.27
Slovenia	0.483	0.486	0.64	0.482	0.485	0.64	0.392	0.352	–10.10
Spain	0.546	0.440	–19.42	0.542	0.435	–19.65	0.445	0.332	–25.43
Sweden	0.556	0.447	–19.62	0.553	0.444	–19.62	0.436	0.330	–24.25
Taiwan	0.450	0.385	–14.56	0.449	0.382	–14.77	0.374	0.271	–27.54
Turkey	0.621	0.485	–21.92	0.620	0.482	–22.22	0.525	0.370	–29.44
UK	0.600	0.504	–16.05	0.590	0.497	–15.74	0.481	0.387	–19.56
USA	0.703	0.692	–1.65	0.642	0.648	0.91	0.556	0.525	–5.44

Source: Author’s calculation using the World Input-Output Table.

2.1.3. Industry level

Table 3 shows TDVX, VAX and DVX ratios at the industry level and their changes between 1995 and 2011. There is also significant heterogeneity among the industries. TDVX ratio of leather, leather products and footwear, and food and beverage were the lowest in 1995, indicating their production processes were highly fragmented in 1995. There are less fragmented

Table 3 TDVX, VAX and DVX Ratios by Industry

Industry	TDVX ratio			VAX ratio			DVX ratio		
	1995	2011	% change	1995	2011	% change	1995	2011	% change
Food, Beverages and Tobacco	0.38	0.40	4.0	0.38	0.39	3.6	0.35	0.36	0.8
Textiles and Textile Products	0.50	0.47	–6.5	0.49	0.46	–6.0	0.43	0.41	–4.9
Leather, Leather Products and Footwear	0.39	0.42	6.6	0.39	0.41	6.5	0.35	0.37	5.6
Wood and Products of Wood and Cork	0.67	0.86	27.3	0.66	0.84	26.9	0.56	0.67	19.8
Pulp, Paper, Paper Printing and Publishing	0.93	0.94	0.6	0.90	0.91	0.7	0.73	0.71	–3.7
Coke, Refined Petroleum and Nuclear Fuel	0.49	0.33	–32.2	0.48	0.32	–32.9	0.40	0.25	–37.2
Chemicals and Chemical Products	0.66	0.55	–16.5	0.64	0.53	–16.5	0.49	0.40	–19.0
Rubber and Plastics	0.86	0.73	–15.7	0.83	0.70	–15.7	0.68	0.54	–20.9
Other Non-Metallic Mineral	0.86	0.81	–5.9	0.84	0.79	–6.0	0.72	0.64	–10.9
Basic Metals and Fabricated Metal	0.94	0.81	–13.7	0.90	0.78	–13.7	0.70	0.56	–19.9
Machinery	0.53	0.52	–2.8	0.52	0.51	–2.9	0.46	0.42	–9.3
Electrical and Optical Equipment	0.53	0.48	–9.3	0.51	0.46	–9.5	0.42	0.36	–15.7
Transport Equipment	0.41	0.36	–13.1	0.40	0.35	–12.0	0.35	0.29	–17.3
Manufacturing, Nec; Recycling	0.46	0.44	–4.8	0.46	0.43	–5.3	0.41	0.37	–10.4

Source: Author’s calculation using the World Input-Output Table.

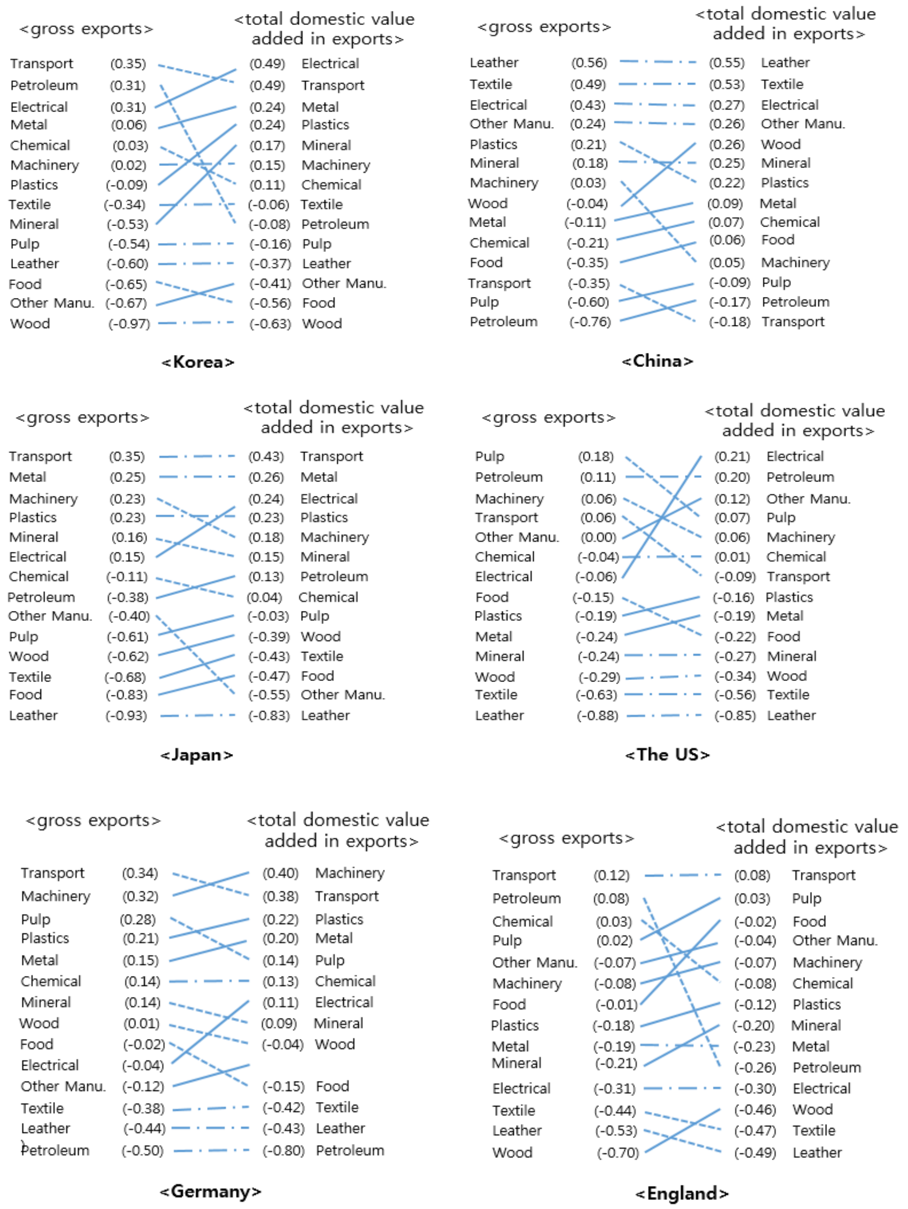
industries including pulp, paper, printing and publishing as well as basic metals and fabricated metal. Moreover, nearly all industries experienced declines in TDVX ratio, but the ratio for wood, products of wood and cork showed a large increase of 27.3%. TDVX and DVX ratios of coke, refined petroleum and nuclear fuel were 0.33 and 0.25, respectively; thus, its production process was the most fragmented in 2011.

2.2. Revealed Symmetric Comparative Advantage

In this section, we illustrate the importance of separating domestic value added in exports from gross exports. Depending on whether gross exports or domestic value added in exports are used in computing the Revealed Comparative Advantage (RCA) index (Balass, 1965), Koopman *et al*. (2014) shows how different policy implications are driven. However, although the RCA index is the most commonly used indicator of a country's trade specialization, many studies indicate that it has some limitations. Hillman (1980) shows that RCA is independent from comparative advantage. Brasili *et al*. (1999) argue that RCA has no clear theoretical foundation and Laursen (1998) also shows that when using the RCA index, it should always be adjusted in such a way that it becomes symmetric. To deal with this problem, Brasili *et al*. (1999) and Dalum *et al*. (1996) proposed the Revealed Symmetric Comparative Advantage (RSCA) index, defined as $RSCA = (RCA-1)/(RCA+1)$, which ranges from –1 to 1. Figure 2 shows the RSCA indexes at the country-sector level for the selected countries based on the total domestic value added in exports and gross exports in the global market in 2011.

When we compare the RSCA indexes using the gross exports and total domestic value added in exports, the ranking of comparative advantage changed substantially. For example, the rankings of the RSCA index in the cases of US pulp, machinery, transport equipment, and food industries dropped in terms of total domestic value added in exports compared with gross exports. On the other hand, those of other manufacturing sectors,

Figure 2 Comparative Advantage in Terms of Gross Exports and Value Added in Exports



Source: Author's calculation using the World Input-Output Table.

electrical equipment, plastics, and metal industries increased in terms of total domestic value added in exports compared with gross exports. Furthermore, if the gross exports data are used to compute RSCA, transport equipment is a comparative advantage sector for the USA. In contrast, if the total domestic value added in exports data are used instead, this sector becomes a comparative disadvantage sector for the USA. These patterns are found also in the other countries. Overall, this analysis shows how an export performance measure using gross exports can be misleading.

3. EMPIRICAL MODEL AND DATA

Building on the model of Eaton and Kortum (2002), CDK (2012) develop a multi-country and multi-industry Ricardian model that is used to quantify the importance of Ricardian comparative advantage with industry-level data. The empirical specification of CDK (2012) is as follows:

$$\ln(x_{ij}^k) = \delta_{ij} + \delta_j^k + \theta \ln(z_i^k) + \varepsilon_{ij}^k, \tag{1}$$

where i, j, and k denote the exporter, importer, and industry, respectively, x_{ij}^k denotes the export performance of exporter i to importer j in industry k, z_i^k is productivity and ε_{ij}^k is an error term.

To examine whether the importance of Ricardian comparative advantage is valid for domestic value added in exports and panel data, we extend the empirical specification of CDK (2012) to use domestic value added in exports as the dependent variable and include time t:

$$\ln(x_{ijt}^k) = \delta_{ijt} + \delta_{jt}^k + \theta \ln(z_{it}^k) + \varepsilon_{ijt}^k, \tag{2}$$

where x_{ijt}^k can be gross exports or domestic value added in exports at the industry level, δ_{ijt} represents the exporter-importer-year fixed effect, and δ_{jt}^k is the importer-industry-year fixed effect. The exporter-importer-year fixed effect removes the time-varying aggregate effects by bilateral country pairs common across industries, thus eliminating omitted variable bias generated from specific characteristics of exporters and importers. The importer-industry-year fixed effect controls for unobserved changes of an industry in the importing country, such as changes in tariffs, industrial growth, and relative price.

Estimating equation (1) may still yield a biased estimate of θ, because our data set has a multidimensional panel data structure. In our panel data set, the dependent variable is observed along the four indices of exporter, importer, industry and time. A key question is how to formalize the heterogeneity of multidimensional indices. Many studies attempt to extend the standard panel data model with fixed effects to a multidimensional structure. For the dependent variable of three indices, y_{ijt}, Matyas (1997) suggests the individual and time fixed effects model such as δ_i, δ_j and δ_t. Baltagi *et al*. (2003) and Baier and Bergstrand (2007) propose a time-varying individual fixed effects model including δ_{it} and δ_{jt}. For our four-dimensional panel data, several combinations of the fixed effects are possible. When we carefully observe the structure of our panel data, however, the productivity levels of exporter-industry are repeated to each trading partner at a point in time. That is, the productivity levels of exporter-industry are common to each importer, while bilateral exports at the industry level are not. To control these common effects to importers, we additionally include the exporter-industry fixed effects in equation (2). Thus our empirical model can be expressed as follows:

$$\ln(x_{ijt}^k) = \delta_{ijt} + \delta_{jt}^k + \delta_i^k + \theta \ln(z_{it}^k) + \varepsilon_{ijt}^k. \qquad (3)$$

Although equation (3) includes exporter-importer-year, importer-industry-year, and exporter-industry fixed effects, OLS may yield biased and inconsistent coefficient estimates if productivity is correlated with the error term. As CDK (2012) indicated, potential sources of endogeneity bias are simultaneity bias and measurement error in productivity. The general method for dealing with this issue is using IV techniques and a first-difference approach (Wooldridge, 2002, Ch. 10).

To isolate the role of longitudinal changes in productivity over time, Kerr (2013) suggests a first-difference approach in which exporter-importer-year and importer-industry-year fixed effects are included. This first-difference method is surely an unbiased estimator, especially when time periods are small and individual units are large. In fact, Kerr (2013) estimates only three change periods by collapsing the annual data for the period 1980-1999 into each 5-year period. However, when using an unbalanced panel due to missing values like our panel data, the first-difference estimator loses some observations. If they are not “missing at random”, and there is some pattern to those missing, then the sample selection problem arises (Wooldridge, 2006, Ch. 14).

Following Eaton and Kortum (2002), Griffith, Redding, and Van Reenen (2004), and CDK (2012), in which technology is modeled as a function of R&D expenditures, we apply the method of instrument variables with the endogenous variable — labor productivity — and instrument variable — R&D expenditures — at the country-industry level.

The data set features an unbalanced panel structure with missing values that covers 40 countries and 14 manufacturing industries. The panel data on trade flows come from the World Input-Output Table. Following Inkaar and Timmer (2008), labor productivity is defined as an output measure divided by a labor input measure. We use the volume of gross output or the volume of value added as the output measure and the labor input measure is the number of hours worked. These data are taken from World Socio Economic Accounts. While the World Input-Output Table provides data on trade flows for the years 1995-2011, the Socio Economic Accounts cover only the period of 1995-2009. Thus, our analysis period is limited to that of 1995-2009.

Table 4 shows the summary statistics for the 14 industries, aggregating over countries. Electrical and optical equipment has the highest average in terms of gross exports, whereas basic metal and fabricated metal shows the

Table 4 Summary Statistics

Industry	ln(Gross exports)		ln(TDVX)		Labor Productivity Based on Sectoral Value Added	
	mean	St.D.	mean	St.D.	mean	St.D.
Food, Beverages and Tobacco	3.02	2.31	2.58	1.98	0.57	0.53
Textiles and Textile Products	2.84	2.20	2.52	1.93	0.93	1.16
Leather, Leather Products and Footwear	1.53	1.78	1.21	1.47	1.02	1.19
Wood and Products of Wood and Cork	1.76	1.80	1.92	1.63	0.79	0.78
Pulp, Paper, Paper Printing and Publishing	2.46	2.15	2.74	2.01	0.83	0.82
Coke, Refined Petroleum and Nuclear Fuel	2.05	2.30	1.97	1.87	0.85	1.82
Chemicals and Chemical Products	3.55	2.45	3.35	2.21	0.84	0.94
Rubber and Plastics	2.63	2.07	2.61	1.94	0.78	0.71
Other Non-Metallic Mineral	2.11	1.90	2.18	1.77	0.73	0.64
Basic Metals and Fabricated Metal	3.46	2.43	3.63	2.24	0.65	0.57
Machinery	3.38	2.41	2.99	2.17	0.70	0.65
Electrical and Optical Equipment	3.80	2.59	3.42	2.32	1.12	1.92
Transport Equipment	3.21	2.64	2.79	2.24	0.70	0.62
Manufacturing, Nec; Recycling	2.47	2.11	2.16	1.83	0.69	0.64

highest average measured by total domestic value added in exports (TDVX). We observe large discrepancies between gross exports and total value added in exports at the industry level. Moreover, in many industries the standard deviations of gross exports as well as TDVX are only slightly less than the means, indicating that bilateral trade flows are spread out over a wider range of values. The standard deviations of labor productivity in many industries are also larger than the means, again indicating great heterogeneity within industries across countries.

4. EMPIRICAL RESULTS

4.1. Baseline Results

We estimate equation (2) and (3) by OLS before IV estimations and the empirical estimation results are presented in table 5; the dependent variable is the log value of bilateral gross exports or TDVX at the country-industry level. We show the analysis of the other value-added components such as DVX and VAX in the additional analysis.

All empirical models include exporter-importer-year and importer-industry-year fixed effects to account for their unobserved time-varying factors. Equation (2) does not include exporter-industry fixed effects, but equation (3) does. The estimates of θ in all empirical specifications are positive and statistically significant. Comparing the estimation results of equation (2) and equation (3), one sees that the estimates of θ including exporter-industry fixed effects — estimating equation (3) — are consistently smaller to some degree than those estimating equation (2). This implies that estimations without exporter-industry fixed effects in our panel data set may be biased upwards. In addition, the adjusted R-squared increases when the estimation includes exporter-industry fixed effects.[2)]

As discussed above, OLS estimation may suffer from an endogeneity problem due to simultaneity bias and measurement error in productivity. Thus we estimate equation (2) and equation (3) by applying IV techniques and the results are reported in table 6. The labor productivity is instrumented with the log value of R&D expenditures.[3)]

IV estimation reveals remarkable results for the estimates of θ. Compared to the estimation results in table 5, the magnitude of θ is

2) We do not use exporter-industry-year fixed effects, because the time-varying exporter-industry fixed effects have the same structure with the labor productivity.

3) The source of data on R&D is the Analytical Business Enterprise Research and Development (ANBERD) database provided by OECD. These data are not available for some countries, including Brazil, Bulgaria, Cyprus, Greece, India, Indonesia, Latvia, Lithuania, Malta and Russia.

Table 5 Impacts of Labor Productivity on Gross Exports and Total Domestic Value Added (TDVX) in Exports

Dep. Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	ln(gross export)	ln(gross export)	ln(TDVX)	ln(TDVX)	ln(VAX)	ln(VAX)	1n(DVX)	1n(DVX)
ln(labor productivity based on sectoral value added)	0.399 (0.004)[a]	0.162 (0.006)[a]	0.388 (0.003)[a]	0.170 (0.005)[a]	0.387 (0.003)[a]	0.186 (0.005)[a]	0.652 (0.006)[a]	0.315 (0.008)[a]
Exporter-importer-year fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Importer-industry-year fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Exporter-industry fixed effect	No	Yes	No	Yes	No	Yes	No	Yes
No. obs.	325,645	325,645	325,645	325,645	325,645	325,645	325,645	325,645
Adj. R^2	0.50	0.71	0.57	0.73	0.57	0.78	0.54	0.76

Notes: Heteroskedasticity-robust standard errors are reported in parentheses. [a] denotes significance at the 1% level.

Table 6 Results of IV Estimations

Dep. Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	ln(gross export)	ln(gross export)	ln(TDVX)	ln(TDVX)	ln(VAX)	ln(VAX)	1n(DVX)	1n(DVX)
ln(labor productivity based on sectoral value added)	24.35 (0.984) [a]	4.534 (0.301) [a]	21.97 (0.883) [a]	4.174 (0.252) [a]	21.947 (0.882)[a]	3.765 (0.251)[a]	26.505 (1.067)a	4.168 (0.251)[a]
Exporter-importer-year fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Importer-industry-year fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Exporter-industry fixed effect	No	Yes	No	Yes	No	Yes	No	Yes
Observations	174,284	174,284	174,284	174,284	174,284	174,284	174,284	174,284
F statistic	603.7	406.3	603.7	406.3	603.7	406.3	603.7	406.3

Note: Heteroskedasticity-robust standard errors are reported in parentheses. [a] denotes significance at the 1% level.

considerably larger. For example, the coefficients of θ in column (2) and (4) are about 4.534 and 4.174, respectively, whereas those in table 5 is 0.162 and 0.170, respectively. According to column (4) of table 6, our preferred specification, a 1% change in labor productivity is associated with about 4.17% changes in TDVX. Furthermore, we also find that the estimates of θ are significantly higher when IV estimation does not include exporter-industry fixed effects. These coefficients in column (3), (5) and (7) are 21.97, 21.94 and 26.05, respectively. This again implies that an IV regression of equation (2), excluding exporter-industry fixed effects, would lead to overestimation of the impacts of labor productivity on export performance. In addition, high values of the F-statistic mean that the instrument variable is not weak. This means that OLS estimates are not free from endogeneity problems. In addition, the coefficient of the R&D is positive and statistically significant as shown in table A1. On the whole, the results in table 6 indicate that Ricardian comparative advantage does matter for total domestic value added in exports.

4.2. Robustness Check

In this section, we check the robustness of our empirical results. We consider alternative methodology and samples. In the previous section, we used 2SLS that has the computational edge. 2SLS is more efficient when the cross-equation covariation is small, but 3SLS becomes more worthwhile as this covariation becomes larger (Belsley, 1988). The second robustness check is to use alternative samples which are divided into EU members, developed and developing countries.

4.2.1. Stage least squares

To check the endogeneity problem again, we use three-stage least squares. 3SLS produces asymptotically more efficient estimates than 2SLS, as 3SLS is the combination of 2SLS and SUR and uses the information that the

Table 7 Estimation Results of 3SLS

Dep. Variable	ln(gross export)	ln(TDVX)	ln(VAX)	ln(DVX)
ln(labor productivity based on sectoral value added)	5.210 (0.291)[a]	4.791 (0.243)[a]	4.783 (0.242)[a]	7.342 (0.374)[a]
Exporter-importer-year fixed effect	Yes	Yes	Yes	Yes
Importer-industry-year fixed effect	Yes	Yes	Yes	Yes
Exporter-industry fixed effect	Yes	Yes	Yes	Yes
Observations	174,284	174,284	174,284	174,284

Notes: Heteroskedasticity-robust standard errors are reported in parentheses. [a] denotes significance at the 1% level.

disturbance terms in the two structural equations are contemporarily correlated (Zellner and Theil, 1962). As shown in table 7, the estimation results of 3SLS and 2SLS are quite similar. Again, we identify that Ricardian comparative advantage does matter for gross exports and value added in exports.

4.2.2. Alternative samples

Applying IV estimation, we estimate equation (3) on alternative samples that include only EU members, developed and developing countries. The choice of alternative samples has two reasons. First as CDK (2012) suggest, IV regression may not remove potential bias due to endogenous trade protection. Thus, we examine the importance of Ricardian comparative advantage using a sample that includes only EU exporters and importers. Second, according to the theory of CDK (2012) and Eaton and Kortum (2002), assuming the Fréchet distribution of productivity across countries and industries, the magnitude of θ reflects the extent of intra-industry heterogeneity that is related to patterns of comparative advantage. A bigger θ means less intra-industry variation, while a lower value of θ indicates more intra-industry heterogeneity. To examine this, we estimate equation (3) again by building two subsamples in which exporters and

Table 8 IV Estimations on Alternative Samples and Alternative Measures of Value Added in Exports

Dep. Variable	ln(TDVX)			ln(VAX)	ln(DVX)
	EU Countries	Developed Countries	Developing Countries	All Countries	All Countries
ln(labor productivity based on sectoral value added)	0.719 (0.155)[a]	1.527 (0.327)[a]	4.429 (0.512)[a]	3.765 (0.251)[a]	4.168 (0.251)[a]
Exporter-importer-year fixed effect	Yes	Yes	Yes	Yes	Yes
Importer-industry-year fixed effect	Yes	Yes	Yes	Yes	Yes
Exporter-industry fixed effect	Yes	Yes	Yes	Yes	Yes
Observations	47,202	48,525	35,496	174,284	174,284
F-statistic	961.6	230.0	92.6	406.3	406.3

Notes: Heteroskedasticity-robust standard errors are reported in parentheses. [a] denotes significance at the 1% level. Developed countries include Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Ireland, Luxembourg, Netherlands, Portugal, Spain, Sweden, UK and USA.

importers are composed of only developed and developing countries, respectively. Because most trade among developed countries is intra-industry, we expect a higher value of estimate θ for developing countries and a lower value for developed countries.

The results are presented in table 8. Columns (1), (2) and (3) show the estimation results for EU exporters and importers, developed and developing country pairs, respectively. All empirical models include exporter-importer-year and importer-industry-year and exporter-industry fixed effects to account for unobserved time-varying factors and the repeated common technology level to each partner. Columns (1) shows the estimation results from restricting our sample to only EU members and the estimates of θ is positive and statistically significant at the 1% level. This implies that our estimates are not severely biased due to endogenous trade protection, confirming the result of CDK (2012).

The estimation results for developed country pairs are reported in columns (2) and (3). The coefficients of θ are also positive and remain statistically significant despite the reduction of observations. Compared to the estimates θ for developing countries in columns (3), the magnitude of θ for developed country pairs is smaller (1.57) than 4.43. This is consistent with the theoretical implication that a small value of θ among developed countries implies more intra-industry heterogeneity. Thus, these results suggest that developed countries have greater scope for intra-industry comparative advantage and developing countries have a restricted range for intra-industry comparative advantage.

4.3. The Case of Korean Manufacturing

Korea over the past four decades has demonstrated incredible economic growth and Korea's industrial structure reached an advanced phase through changes in growth-leading industries (Pai, 2017). It will be interesting to investigate the importance of comparative advantage for Korean industries. In this subsection, we estimate the impacts of labor productivity on export performances for Korean manufacturing by employing IV estimation. The results are reported in table 9. Columns (2), (4), (6) and (8) show the estimation results when the exporter-industry fixed effects are included. We again find that the coefficients of the labor productivity without exporter-industry fixed effects are consistently larger to some degree than those estimating equation (3), implying overestimations of the impacts of labor productivity on export performance when exporter-industry fixed effects are not included. The coefficients of the labor productivity are significant in all specifications. This means that comparative advantage determines the patterns of trade in Korean manufacturing.

Table 9 Results of IV Estimations for Korean Manufacturing

Dep. Variable	(1) ln(gross export)	(2) ln(gross export)	(3) ln(TDVX)	(4) ln(TDVX)	(5) ln(VAX)	(6) ln(VAX)	(7) ln(DVX)	(8) ln(DVX)
ln(labor productivity based on sectoral value added)	11.214 (0.458)[a]	0.607 (0.218)[a]	9.622 (0.380)[a]	1.278 (0.160)[a]	9.618 (0.380)[a]	1.277 (0.160)[a]	11.427 (0.462)[a]	1.209 (0.222)[a]
Exporter-importer-year fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Importer-industry-year fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Exporter-industry fixed effect	No	Yes	No	Yes	No	Yes	No	Yes
Observations	8,187	8,187	8,187	8,187	8,187	8,187	8,187	8,187
F-statistic	596.3	488.9	596.3	488.9	596.3	488.9	596.3	488.9

Notes: Heteroskedasticity-robust standard errors are reported in parentheses. [a] denotes significance at the 1% level.

5. CONCLUSIONS

Following the methodology of Koopman *et al*. (2004) and using the World Input-Output Table, we decomposed gross exports at the industry level into various value-added components such as direct, indirect domestic value added and value added that returns home for 40 countries and 14 manufacturing industries for the period 1995-2011. We showed that TDVX, VAX and DVX ratios for the world declined between 1995 and 2011. Furthermore, there are significant heterogeneities across countries and among industries in the initial levels of TDVX, VAX, and DVX ratios, in the magnitude of their changes and the change directions.

In this study, we investigated whether the importance of Ricardian comparative advantage is valid for value added in exports that does not include intermediate inputs imported from various industries in a number of countries. Using a panel data model with exporter-importer-year, importer-industry-year and exporter-industry fixed effects, we found strong support for the importance of Ricardian comparative advantage for domestic value added in exports. Furthermore, the results were robust to the alternative samples in which countries are divided into EU members, and developed and developing country pairs. In particular, we examined the theoretical implications of Eaton and Kortum (2002) and CDK (2012) that the magnitude of θ reflects the extent of intra-industry heterogeneity. We found that the estimate of θ for developed country pairs is smaller than that for developing country pairs, indicating that developed countries have greater scope for intra-industry comparative advantage. We also examined the robustness of our empirical results using the same cross-sectional data set as CDK (2012) and, thus, the same measures of productivity, but measured the dependent variable in terms of domestic value added in exports. The empirical results showed that all measures of Ricardian comparative advantage have profound effects on the patterns of trade. In particular, the importance of comparative advantage remained still significant when export performance is measured by other value added components, including indirect domestic value added and domestic value added that returns home. Finally, we also find that Ricardian comparative advantage is important for determining the patterns of trade in Korean manufacturing.

APPENDIX

Table A1 The First-stage Estimation of Table 6

Dep. Variable ln(labor productivity based on sectoral value added)	(1)	(2)
Ln(R&D)	0.016 (0.001) [a]	0.026 (0.001) [a]
Exporter-importer-year fixed effect	Yes	Yes
Importer-industry-year fixed effect	Yes	Yes
Exporter-industry fixed effect	No	Yes
Observations	174,284	174,284

Table A2 Country and Industry Classification

Country	Industry
Australia, Austria, Belgium, Brazil, Bulgaria, Canada, China, Cyprus, Denmark, Czech Republic, Estonia, Finland, France, Germany, Greece, Hungary, India, Indonesia, Ireland, Italy, Japan, South Korea, Latvia, Lithuania, Luxembourg, Malta, Mexico, Netherlands, Poland, Portugal, Romania, Russia, Slovak Republic, Slovenia, Spain, Sweden, Taiwan, Turkey, UK, USA	Food, beverages and tobacco, Textiles and textile products, Leather, leather products and footwear, Wood and products of wood and cork, Pulp, paper, printing and publishing, Coke, refined petroleum and nuclear fuel, Chemicals and chemical products, Rubber and plastics, Other non-metallic mineral, Basic metals and fabricated metal, Machinery, not elsewhere classified, Electrical and optical equipment, Transport equipment, Manufacturing, not elsewhere classified; recycling

Source: Timmer *et al*. (2015).

RERERENCES

Baier, S. L. and J. H. Bergstrand, “Do Free Trade Agreements Actually Increase Members International Trade?,” *Journal of International Economics*, 71, 2007, pp. 72-95.

Balassa, B., “Trade Liberalization and ‘Revealed’ Comparative Advantage,” *Manchester School of Economic and Social Studies*, 33, 1965, pp. 99-123.

Baldwin, R., “Global Supply Chains: Why They Emerged, Why They Matter, and Where They are Going,” in D. K. Elms and P. Low, eds., *Global Value Chains in a Changing World*, Geneva: World Trade Organization, Chapter 1, 2013, pp. 13-59.

Baltagi, B. P. Egger and M. Pfaffermayr, “A generalized Design for Bilateral Trade Flow Models,” *Economic Letters*, 80, 2003, pp. 391-397.

Belsley, D., “Two- or Three-Stage Least Squares?,” *Computer Science in Economics and Management*, 1, 1988, pp. 21-30.

Bombardini, M., C. Kurz, and P. Morrow, “Ricardian Trade and the Impact of Domestic Competition on Export Performance,” *Canadian Journal of Economics*, 45, 2012, pp. 585-612.

Brasili, A., P. Epifani, and R. Helg, “On the Dynamics of Trade Patterns,” Liuc Papers No. 61, 1999.

Burstein A, and J. Vogel, “Globalization, Technology, and the Skill Premium: A Quantitative Analysis,” NBER Working Paper, No. 16459, 2010.

Choi, N. and S. Park, “Comparative Advantage of Value Added in Exports: the Role of Offshoring and Transaction Costs,” KIEP Working Paper 16-09, Korea Institute for International Economic Policy, 2016.

Costinot, A., D. Donaldson, and I. Komunjer, “What Goods Do Countries Trade? A Quantitative Exploration of Ricardo’s Ideas,” *Review of Economic Studies*, 79, 2012, pp. 581-608.

Dalum, B., K. Laursen, and G. Villumsen, “The Long Term Development of OECD Export Specialisation Patterns: De-specialisation and Stickiness,” DRUID Working Papers 96-14, DRUID, Copenhagen

Business School, Department of Industrial Economics and Strategy/Aalborg University, Department of Business Studies, 1996.

Daudin, G., C. Rifflart, and D. Schweisguth, "Who Produces for Whom in the World Economy?," *Canadian Journal of Economics*, 44, 2011, pp. 1409-1538.

Eaton, J. and S. Kortum, "Technology, Geography, and Trade," *Econometrica*, 70, 2002, pp. 1741-1779.

Griffith, R., S. Redding, and J. Van Reenen, "Mapping the Two Faces of R&D: Productivity Growth in a Panel of OECD Industries," *Review of Economics and Statistics*, 86, 2004, pp. 883-895.

Grossman, G. and E. Rossi-Hansberg, "The Rise of Offshoring: It's Not Wine for Cloth Anymore," in *The New Economic Geography: Effects and Policy Implications*, Federal Reserve Bank of Kansas City, 2007, pp. 59-102.

Hillman, A. L., "Observations on the relation between 'revealed comparative advantage' and comparative advantage as indicated by pre-trade relative prices," *Weltwirtschaftliches Archiv*, 116, 1980, pp. 315-321.

Hummels, D., J. Ishii, and K. Yi, "The Nature and Growth of Vertical Specialization in World Trade," *Journal of International Economics*, 54, 2001, pp. 75-96.

Inklaar, R. and M. P. Timmer, "GGDC Productivity Level Database: International Comparisons of Output, Inputs and Productivity at the Industry Level," *GGDC Research Memorandum*, 104, 2008.

Johnson, R. C. and G. Noguera, "Accounting for Intermediates: Production Sharing and Trade in Value Added," *Journal of International Economics*, 86, 2012a, pp. 224-236.

___________, "Fragmentation and Trade in Value Added over Four Decades," NBER Working Paper No. 18186, 2012b.

Kerr, W. R., "Heterogeneous Technology Diffusion and Ricardian Trade Patterns," Harvard Business School Working Paper, No. 14-039, 2013.

Koopman, R., Z. Wang, and Shang-Jin Wei, "Give Credit Where Credit is

Due: Tracing Value Added in Global Production Chains," Working Paper, USITC, 2010.

__________, "Tracing Value-Added and Double Counting in Gross Exports," *American Economic Review*, 104, 2014, pp. 459-494.

Kowalski, P., *Developing Countries' Participation in Global Value Chains-Implications for Trade and Trade-Related Policies*, Paris: OECD, 2014.

Kummritz, V., "Global Value Chains: Benefiting the Domestic Economy?," CTEI Working Papers 2014-05, Centre for Trade and Economic Integratio, 2014.

Lausen, K., "Revealed Comparative Advantage and the Alternatives as Measures of International Specialisation," DRUID Working Paper No. 98-30, 1998.

Levchenko, A. A. and J. Zhang, "The evolution of comparative advantage: Measurement and welfare implications," *Journal of Monetary Economics*, 78, 2016, pp. 96-111.

Matyas, L., "Proper Econometric Specification of the Gravity Model," *The World Economy*, 20, 1997, pp. 363-369.

Morrow, P., "Ricardian-Heckscher-Ohlin Comparative Advantage: Theory and Evidence," *Journal of International Economics*, 82, 2010, pp. 137-151.

Pai, M. K., "Size Impact and Productivity Growth in Korea's Export-leading Industries," *Korea and the World Economy*, 18, 2017, pp. 329-366.

Stehrer, R., "Accounting Relations in Bilateral Value Added Trade," Working Paper 101, Vienna Institute for International Economic Studies, 2013.

Stehrer, R., N. Foster, and G. de Vries, "Value Added and Factors in Trade: A Comprehensive Approach," *wiiw* Working paper 80, 2012.

Timmer, M. P., E. Dietzenbacher, B. Los, R. Stehrer, and G. J. de Vries, "An Illustrated User Guide to the World Input-Output Database: the Case of Global Automotive Production," *Review of International Economics*, 23, 2015, pp. 575-605.

Wooldridge, J. M., *Econometric Analysis of Cross Section and Panel Data*, MIT Press, 2002.

__________, *Introductory Econometrics: A Modern Approach*, 3rd ed., Cengage Learning, 2006.

Zellner, A. and H. Theil, “Three-Stage Least Squares: Simultaneous Estimation of Simultaneous Equations,” *Econometrica*, 30, 1962, pp. 54-78.