Determining Bilateral Trade Patterns Using a Dynamic Gravity Equation

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Abstract

Using a dynamic gravity equation, we show that the *national product differentiation* model explains food and agricultural trade more properly, while the *product differentiation* model is more appropriate to explain large-scale manufacturing trade. In this context, our result is not consistent with the one found by Head and Ries (2001) in the short-run. The intuitive explanation for this result is that inward foreign direct investment can occur through either merger or acquisition in the short-run. Second, the pattern of bilateral trade could quickly adjust to changes in relative income between countries. Furthermore, we illustrate the positive impacts of world income growth on bilateral trade, which is in sharp contrast with the conventional analysis. This reveals yet another way to test the pattern of bilateral trade.

Keywords: dynamic gravity equation, national product differentiation, product differentiation, world income growth

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INTRODUCTION[1]

International trade has accelerated under current multilateral free trade negotiations. Considering the fact that a significant portion of commodity trade among developed countries is intra-industry trade, the impact of trade liberalization on sectoral trade is uncertain because relevant theories suggest that the impact of trade liberalization depends on the properties of products.

There are two prevailing models that explain intra-industry trade: *product differentiation* and *national product differentiation* models. These models, in fact, predict the different effects of trade liberalization on different industry sectors in an economy. The product differentiation model states that countries trade with each other even if the varieties of a good are substitutable because consumers prefer an increasing number of choices, under an assumption that each firm produces a variety of a good (*monopolistic competition*) with an increasing return to scale technology (Krugman 1980; Helpman and Krugman 1985). In this case, the "home market" effect occurs, indicating a larger country has more to gain from trade liberalization because its higher demand attracts foreign firms to locate in the market, and the larger country serves a smaller market through exports. By contrast, the national product differentiation model assumes that products are distinguished by place of production, and the number of varieties supplied by each country is fixed. As a result, countries trade simply because goods are imperfectly substitutable (Armington 1969). In this case, the home market effect is reversed (Head and Ries, 2001; Feenstra *et al*., 2001). Under a more liberalized world system, the higher level of demand in a larger country encourages its imports of the good in question, but there are no new entries to the larger country, so a smaller country gains more from the trade liberalization.[2]

Recently, several studies examined the trade patterns among Organization for Economic Cooperation and Development (OECD) countries and empirically tested the existence of the home market effect. Using the cross sectional data of OECD countries, Davis and Weinstein (1998) found that a country which spent a higher proportion of its income on a good would tend to produce more of that good, which supports the home market effect. Head and Ries (2001) identified the relationship between a country's share of output in an industry and its share of demand in that industry to test the two competing models. They investigated a panel of U.S. and Canadian manufacturing industries for the period 1990-1995. In the long-run, they found a weak home market effect, while the reversed home market effect was found in the short-run.

Feenstra, Markusen, and Rose (1998; 2001) proposed an important theoretical framework to test the (reversed) home market effect using a gravity type equation. They showed that the gravity

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[2] In fact, the monopolistic competition model with restricted or no entry and national product differentiation predict the same effect of trade liberalization (Head and Ries, 2001).

equation is quite general, so it can be used for both *differentiated* and *homogeneous* goods, and estimated the coefficients of the equation to test the two intra-industry trade models. In the case of the product differentiation model, the exports respond more sensitively to exporter's income than to importer's income. Conversely, exports respond more sensitively to importer's income than to exporter's income under the national product differentiation and reciprocal dumping model. The theoretical foundation for the gravity equation is important because it provides a convenient method of testing the home market (or reversed home market) effects for sectoral bilateral trade. By using cross-sectional data of the bilateral export flows among OECD countries, Feenstra *et al.* found that the home market effect occurred for differentiated goods and that the effect was reversed for homogeneous goods.

In the analysis of intra-industry trade patterns using the gravity equation, two important questions remain to be answered. First, although a cross sectional analysis is popularly used to estimate the gravity equation (e.g., Bergstrand, 1985, 1989; McCallum 1995; Baier and Bergstrand, 2001; Feenstra *et al.*, 2001), the analysis cannot answer a policy-related question of the impact of changes in relative market size (or income) of countries on changes in the pattern of bilateral trade *over time*. Temporal effects can be answered by using time series analysis, as Egger (2000), and Glick and Rose (2001) discussed. For instance, the income growth rates in China have been much higher than those in other developing countries in recent years. The impact of the higher income growth rate on changes in the trade pattern of this country is an important policy concern, which cannot be addressed using a cross-sectional approach.

Second, although the time series properties are accounted for in the analysis of intra-industry trade patterns, it is possible to have different results between the short- and long-run, as Head and Ries (2001) argued. They found that the reversed home market effect is more appropriate to explain the pattern of trade for large-scale manufacturing products in the short-run because the number of firms might not adjust within the short time period. However, according to Baldwin (1988) and Baldwin and Krugman (1989), the entry/exit decisions of firms heavily depend on the size of a certain shock, indicating that, if changes in the relative market size between countries are large enough, the new entry/exit of firms can occur even in the short-run. Because the time-series sample used by Head and Ries (2001) was not sufficiently long (six years), if the shock is not substantial enough to influence the entry/exit decision of firms during their sample period, their results might depend on the choice of sample period. For instance, one of the important determinants of relative market size between countries over time is exchange rate movement. Several studies have found that there is a cyclical swinging pattern in real exchange rates among developed countries, and the consensus about the speed of mean reversion of real exchange rates to constant mean is six to eight years (Rogoff, 1996; Papell, 2002). If firms cannot respond to exchange rate shock in the short-run, these exchange rate movements cannot induce an entry/exit decision by the firm. However, if firms respond quickly, these shocks can cause a real impact on trade flows between countries. Therefore, it is worthwhile to investigate the dynamic pattern of intra-industry with longer time-series data.

The main objective of this study is to examine the nature of trade patterns among OECD countries using a gravity equation. To examine the hitherto unsolved questions in a cross-sectional analysis, a dynamic gravity equation is developed to examine the significant impact of changes in relative market size on the pattern of bilateral trade over time in both the short- and long-run. The data we use in this study are bilateral trade flows for 10 developed countries between 1974 and 1999, separated into agricultural trade and large-scale manufacturing

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(machinery and chemical) trade, which depend on constant- and increasing-returns to scale in technology, respectively, in order to compare trade patterns over time between the sectors.

In the framework of a dynamic gravity equation, our finding is consistent with the one found by Feenstra *et al*. (2001) for both the short- and long-run: the *national product differentiation* model explains food and agricultural trade more properly, while the *product differentiation* model is more appropriate to explain large-scale manufacturing trade. However, this result is not consistent with the one found by Head and Ries (2001) in the short-run. This is mainly due to the following reasons. First, inward foreign direct investment can occur through either merger or acquisition in the short-run. Second, the pattern of bilateral trade could quickly adjust to changes in relative income between countries. Moreover, we found a positive impact of world income growth on bilateral trade, which is in contrast to the conventional analysis. This reveals yet another way to test the pattern of bilateral trade.

The paper is organized as follows. In the second section, a brief discussion of the specification for the gravity model is presented, and an intuitive explanation of the key ideas of Feenstra et al. is also discussed. In the next section, a dynamic gravity equation is developed, which accounts for both cross-country specific effects and inter-temporal choice of the traders. The fourth section provides the estimation technique to handle a dynamic model using a panel dataset and the sources of data for the empirical study. The empirical results are presented in the subsequent section, followed by concluding remarks.

GRAVITY EQUATION AND ITS RELATION TO THE PATTERN OF BILATERAL TRADE

Anderson (1979) developed an economic foundation for gravity type equations using a Cobb-Douglas expenditure system. Under the assumption of monopolistic competition, each country is assumed to specialize in different products and to have identical homothetic preferences. *Zero balance of trade* is also assumed to hold *in each period*. Then the equilibrium trade volume from country i to j (X_{ij}^*) at any time period t can be expressed as:

$$X_{ij}^* = \theta_i Y_j \text{ or } \theta_i = X_{ij}^* / Y_j, \tag{1}$$

where θ_i denotes the fraction of income spent on country i's products (the fraction is identical across importers) and Y_j denotes real GDP in importing country j. Since production in country i must be equal to the sum of exports and domestic consumption of goods, country i's GDP is expressed as follows:

$$Y_i = \sum_{j=1}^{N} X_{ij}^* = \sum_{j=1}^{N} \theta_i Y_j = \theta_i \left(\sum_{j=1}^{N} Y_j \right) \text{ or } \theta_i = Y_i / \left(\sum_{j=1}^{N} Y_j \right) = Y_i / Y_W, \tag{2}$$

where $Y_W = \sum_{j=1}^{N} Y_j$ is world real GDP, which is constant across country pairs. Rearranging (2) yields:

$$X_{ij}^* = Y_i Y_j / \left(\sum_{j=1}^{N} Y_j \right) = Y_i Y_j / Y_W . \tag{3}$$

Therefore, this simple gravity equation relies only upon the adding-up constraints of a Cobb-Douglas expenditure system with identical homothetic preferences and the specialization of each country in one good. The basic empirical gravity equation is obtained by taking a natural logarithm of both sides of (3) as follows:

$$\ln X_{ij}^* = \alpha + \beta \ln Y_i + \gamma \ln Y_j + \phi Z_{ij} , \tag{4}$$

where $\alpha = (-\ln Y_w)$, and Z_{ij} is a vector of time-invariant variables such as distance and border effects. Because, *in reality*, countries do not have exactly identical and homothetic taste, the coefficients should not be unity, but are not significantly different from unity in aggregate level trade (Anderson 1979). The pattern of intra-industry trade for a specific industry is well-identified when (4) is utilized (Feenstra et al. 1998; 2001).

Under the monopolistic competition model, countries specialize their products (the product differentiation model). Higher demand in a larger country for varieties of a product attracts more than proportionate entry of foreign firms into the larger country to restore zero long-run profits. The country then serves the small country through exports, assuming the existence of substantial transportation costs. Therefore, in the long-run, the product differentiation model predicts that a country's exports will more sensitively respond to its own income variation than to variations in the importer's income. Thus, the estimated coefficient of β should be greater than that of γ .

However, in the case of the national product differentiation model with constant returns to scale technology, products in each industry are distinguished by *nationality*, indicating that new entry of foreign firms to the larger market does not occur. Because the number of varieties of a good is fixed and products are not substitutable, large demand in a larger country for the varieties of a good causes the small country to be a net exporter. In this case, the exporter is more sensitive to the importer's (larger country) income variation than to the exporter's, indicating the estimated coefficient of β should be smaller than that of γ .[3]

A DYNAMIC GRAVITY EQUATION

The gravity equation (4) is based on assumptions that, at any given time period, traders exchange their specific commodities and that an exact (zero) balance of trade between countries always holds (markets should clear at time period t). However, *in reality*, countries have either a trade deficit or surplus because the equilibrium export volume (X_{ijt}^*) is not always achieved at given time period t. To incorporate this lagging-property of trade, the gravity equation should be modified in a dynamic choice problem. Thus, the assumption of zero trade balance is relaxed by adapting a partial adjustment mechanism suggested by Houthakker and Taylor (1970), so that exports have the following form:

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[3] More detailed theoretical consideration about this issue is presented in Feenstra *et al*. (1998).

$$(\ln X_{ijt} - \ln X_{ijt-1}) = \lambda \cdot (\ln X_{ijt}^* - \ln X_{ijt-1}) + \eta_{ijt}, \tag{5}$$

where η_{ijt} is error terms with mean zero and variance. X_{ijt}^* is the desired equilibrium level of exports which achieves zero balance of trade, at time period t, and X_{ijt} is the actual level of exports. Let's assume that the equilibrium level of exports, X_{ijt}^*, is determined by Equation (4). By inserting (4) into (5) and rearranging Equation (5), we have,

$$\ln X_{ijt} = \alpha\lambda + (1-\lambda)\ln X_{ijt-1} + \beta\lambda \ln Y_{it} + \gamma\lambda \ln Y_{jt} + \phi\lambda Z_{ij} + \eta_{ijt} \tag{6}$$

or $\qquad \ln X_{ijt} = \alpha^* + \lambda^* \ln X_{ijt-1} + \beta^* \cdot \ln Y_{it} + \gamma^* \cdot \ln Y_{jt} + \phi^* \cdot Z_{ij} + \eta_{ijt}.$

This is a typical partial adjustment model. In this model, β^* and γ^* represent the short-run income effects, while β and γ represent the long-run income effects. The coefficient, λ, represents the speed of adjustment parameter, $0 < \lambda < 1$, and should be equal to 1 (or $\lambda^* = 0$) for full adjustment in a one-time period.

The world income $(\ln Y_t^w)$ in Equation (1) is treated as a constant term in a cross-sectional analysis because world income is fixed at any given year t. However, in a time-series or panel analysis, world income varies over time, which affects the share of income of a country, as well as bilateral trade flows. For instance, although an importing country's income increases compared to the prior period, the share of income can decrease if world income increases faster than that of an importing country, resulting in fewer imports. Thus, variation in world income over time should be incorporated in (6).

Another concern about Equation (6) is how to manage an unobservable, cross-country specific effect. It is convenient to use the time-invariant variable, Z_{ij} (i.e., distance, border, and customs union effect), if Z_{ij} is observable and the complete set of variables, explaining the unobservable, cross-country specific effect. However, as Egger (2000) argued, Z_{ij} is probably incomplete, and hence, it is appropriate to assume a specific effect, which uses a full set of cross-country specific dummies. Therefore, the model (6) becomes:[4]

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[4] In fact, the partial adjustment mechanism has been popularly used to examine dynamic models. For instance, Baltagi and Levin (1986) used the model analyzing a dynamic demand for an addictive good; Islam (1995) applied it to a dynamic model for growth convergence; Ziliack (1997) used it for a dynamic life-cycle labor supply model.

$$\ln X_{ijt} = \alpha_{ij}^* + \lambda \ln X_{ijt-1} + \beta^* \ln Y_{it} + \gamma^* \ln Y_{jt} + \phi^* \ln Y_{wt} + \eta_{ijt}. \tag{7}$$

Equation (7) is estimated using a dynamic panel data analysis.[5]

ESTIMATION

In the presence of a lagged dependent variable among regressors with a cross-country specific error component, usual econometric methods (e.g., one-way fixed and random effect models) are not appropriate because they yield biased and inconsistent estimates (Nickell, 1981). To account for this, it is convenient to rewrite Equation (7) as a general matrix form.

$$y = D\delta + u \text{ and } u = D_\mu \mu + v \tag{8}$$

where $y = \left[\ln X_{ijt} \right]$; $D = [\ln X_{ijt-1}, \ln Y_{it}, \ln Y_{jt}, \ln Y_{wt}]$; $\delta' = \left[\lambda, \beta^*, \gamma^*, \phi^* \right]$. $D_\mu = I_N \otimes i_T$; I_N is an identity matrix with dimension N; i_T is a vector of ones of dimension T; and $\otimes$ denotes Kronecker product. μ represents a cross-country specific effect; v is a conventional error term. The dynamic panel data regression described in (8) is characterized by two sources of statistical problems: first, serial correlation due to the presence of a lagged dependent variable among regressors, and second, country specific effects characterizing the heterogeneity among the cross-country relationships. It is well known that the ordinary least squares (OLS) estimator is biased and inconsistent because the lagged dependent variable y_{it-1} is correlated with the error term ($E(y_{it-1} | u_{ijt}) \neq 0$). Even with usual fixed or random effects (or within) estimators popularly used for a panel data analysis, the lagged dependent variable is still correlated with the error term, which gives us biased estimates (Nikell, 1981; Baltagi, 2001).

The first difference (FD) transformation is, in general, used to eliminate the cross-country specific effect in dynamic panel data. Thus, from (8), we obtain:

$$\Delta y_{it} = \Delta D_{it} \delta + \Delta u_{it}, \tag{9}$$

where Δ is a usual first differencing operator such as $\Delta q_{it} = (q_{it} - q_{it-1})$ for any variable q. By transforming into the first difference, it is easier to manage a correlation between the predetermined explanatory variables and the remainder error. In addition, the potential non-stationarity problem of the variables can be conveniently removed. However, a correlation problem still remains between Δy_{it-1} and Δv_{it}. To resolve the problem, the predetermined variables Δy_{it-2} or y_{it-2} are used as instrument variables for Δy_{it-1}, as suggested in Anderson and Hsiao (1982). They show that these instruments are not correlated with Δv_{it} if Δv_{it} is not serially correlated. Although this instrumental variable (IV) estimation method with first difference transformation leads to consistent estimates, it does not yield efficient estimates of the

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[5] Another potential problem is that most of the variables in equation (7) are treated as non-stationary variables in the macroeconomic literature. Therefore, the estimation results could be biased due to the well-known spurious regression problem. This problem will be mitigated by our choice of the estimator.

parameters because it neither makes use of all the available moment conditions[6] nor takes into account the differenced structure on the residual disturbance (Δv_{it}).

To obtain more efficient estimates, Keane and Runkle (1992) suggested the forward-filtering 2SLS method (KR estimate), which treats unknown serial correlation in residual disturbance (Δv_{it}). The first-differenced errors in Equation (9), Δv_{it}, are either serially correlated of an MA (1) type with unit root if the original v_{it} is not serially correlated or have unknown serial correlation if the v_{it} is serially correlated itself. In these cases, there will be a large gain in efficiency in performing the KR procedure. The suggested method to solve the serial correlation problem is that, using the first difference transformation with 2SLS method, residuals should be obtained first. With these residuals, we can calculate $\hat{\Omega}_{FD} = E(\Delta v \Delta v') = I_N \otimes \hat{\Sigma}_{FD}$. We use the Cholesky decomposition of $\hat{\Sigma}_{FD}^{-1}$ and get upper triangular matrix $\hat{P}_{FD}$, which gives us $\hat{Q}_{FD} = I_N \otimes \hat{P}_{FD}$. One pre-multiplies the model by $\hat{Q}_{FD}$ and estimates the model by 2SLS using the original instruments. This procedure gives us a KR-estimator such as,[7]

$$\hat{\delta}_{FD-KR} = \left[\Delta D' \hat{Q}_{TS}' P_W \hat{Q}_{TS} \Delta D \right]^{-1} \Delta D' \hat{Q}_{TS}' P_W \hat{Q}_{TS} \Delta y \qquad (10)$$

with variance-covariance matrix $\text{cov}(\hat{\delta}_{FD-KR}) = \hat{\sigma}_v^2 \left[\Delta Z' \hat{Q}_{FD}' P_W \hat{Q}_{FD} \Delta Z \right]^{-1}$. In fact, KR estimator requires $N > T$, which applies in our case.

The data are collected annually from 1974 to 1999. The real value of exports from country i to country j in year t for a sector k, X_{ijt}^k, is obtained in terms of the U.S. dollar and deflated by the U.S. consumer price index. The variable is constructed as follows. Using the OECD bilateral trade data set, taken from *Trade in Commodities*, classified by the one-digit standard international trade code (SITC), we get nominal export values in U.S. dollars from i to j for each sector k. These values are deflated by the consumer price index in the United States (1982-84=100), from the *Bureau of Labor Statistics* (BLS). The sectors considered in this study are food and live animals (SITC 0: agriculture), chemical and related products (SITC 5: chemical), and machinery and transport equipment (SITC 7: machinery).

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[6] In fact, the generalized method of moment (GMM) approach (e.g., Ahn and Schmitt 1995; Arellano and Bond 1991) is popularly used to estimate the dynamic panel data. However, Ziliak (1997) performed Monte Carlo experiments for different types of dynamic panel data models, including two stage least squares (2SLS) estimator, GMM estimator, and KR estimator using bias/efficient criterion. He found substantial downward bias in GMM estimator as the number of moment conditions expands, which out-weigh gains in efficiency. In addition, the results suggest the KR estimator has lower bias and is more efficient than the 2SLS estimator, so that the estimator is recommended.

[7] In fact, Keane and Runkle proposed a forward-filtering model with a standard cross-country specific error component model (FE-KR estimator). We choose the first-difference model for two reasons. First, the FE-KR estimator is consistent only when the instruments are strictly exogenous, while the FD-KR estimator is consistent whether the instruments are strictly exogenous or predetermined. Second, we believe some of the variables in our model are non-stationary so that regressors are correlated with each other due to the stochastic trends, resulting in a multicollinearity problem with level data. By using the growth form equation, this possibility can also be mitigated.

The gross domestic products for each exporting and importing country and world income are given in their nominal value in U.S. dollars from the *World Economic Outlook Database* (IMF 2001), and are deflated by the U.S. consumer price index (1982-84=100). Given the sample of 10 countries (Belgium-Luxembourg, Canada, France, Germany, Italy, Japan, Netherlands, Switzerland, the United Kingdom, and the United States), there is a cross-section of 90 bilateral trade flows (10×9), with annual data covering 25 years (1975-1999) for each trade flow, generating a complete panel of 2250 initial observations (90×25).

RESULTS

Table 1 presents the results of the KR estimates in the short-run with three different choices of instrumental variables, $\Delta \ln X_{ijt-2}$, $\ln X_{ijt-2}$, and both, as suggested by Anderson and Hsiao (1982). The coefficients of exporter's and importer's income growth rates are central. For food and agricultural trade, the estimated coefficients of the exporter's income growth rates (0.121, -0.043, and 0.122 for respective instrumental variables used) are consistently less than those of the importer's income growth rates (0.530, 0.620, and 0.524). All are statistically significant at the one percent level except food and agricultural trade with $\ln X_{ijt-2}$ (-0.043). Since food and agricultural products are relatively homogeneous, these results are in accordance with the cross-sectional results of Feenstra *et al.*, indicating that the national product differentiation model can explain the pattern of bilateral trade for agricultural products among OECD countries. Two reasons might explain these results. First, agricultural production is characterized by both constant returns to scale and by intensive use of immobile land (Krugman 1981). Second, consumer preference and production practices stemming from weather conditions and/or soil types are different across countries.

For trade in the machinery and chemical sectors, the product differentiation model is found to explain the pattern of intra-industry trade. The rates of exporter's income growth ($\Delta \ln Y_{it}$) are greater than those of the importer ($\Delta \ln Y_{jt}$): 0.510, 0.521, and 0.524 versus 0.394, 0.396, and 0.387 for the respective instrument variables in the case of the machinery sector; and 0.298, 0.307, and 0.295 versus 0.237, 0.188, and 0.236 for the respective instrument variables in the case of the chemical sector. The results indicate that industrial goods are differentiated based on production technology and consumer preference in targeted markets, but not national resource endowment.

The results for both the machinery and chemical sectors are consistent with the long-run results of Feenstra *et al*, but are *not* consistent with the results of Head and Ries, who found that the national product differentiation model was more appropriate to explain the pattern of trade in these large-scale manufacturing industries in the short-run. However, it can be explained that a large demand for large-scale manufacturing products attracts foreign firms to locate in a larger country even in the *short-run* for the following reasons. First, inward foreign direct investment can be achieved through either merger or acquisition in the market in the short-run under a freer trade environment. Second, the pattern of bilateral trade could quickly adjust to changes in relative income between countries.

Table 1. Estimation Results of KR Estimator with Different Instrumental Variables (Short-run)

	IV: $\Delta \ln X_{ijt-2}$			IV: $\ln X_{ijt-2}$			IV: Both		
	Food	Machinery	Chemical	Food	Machinery	Chemical	Food	Machinery	Chemical
$\Delta \ln X_{ijt-1}$	-0.508	0.303^a	0.322^a	4.659	0.319^a	0.446^a	-0.518	0.338^a	0.322^a
	(-1.52)	(11.10)	(9.48)	(0.92)	(11.91)	(16.86)	(-1.63)	(12.66)	(9.96)
$\Delta \ln Y_{it}$	0.121^a	0.510^a	0.298^a	-0.043	0.521^a	0.307^a	0.122^a	0.524^a	0.295^a
	(3.20)	(16.08)	(10.09)	(-0.27)	(16.47)	(11.37)	(3.24)	(16.72)	(10.01)
$\Delta \ln Y_{jt}$	0.530^a	0.394^a	0.237^a	0.620^a	0.396^a	0.188^a	0.528^a	0.387^a	0.236^a
	(14.06)	(12.44)	(8.05)	(3.95)	(12.56)	(6.97)	(14.08)	(12.39)	(8.02)
$\Delta \ln Y_{wt}$	0.414^a	0.745^a	0.678^a	0.519	0.720^a	0.763^a	0.417^a	0.706^a	0.678^a
	(3.95)	(10.56)	(10.21)	(1.17)	(10.24)	(12.30)	(4.00)	(10.07)	(10.29)

Notes: *t*-ratios are in parenthesis; **a**, and **c** denote significant at the 1 and 10 percent level. IV denotes instrument variable.

The most seemingly unexpected results are from the estimated coefficients of the world income growth rate ($\Delta \ln Y_w$). All estimated coefficients have a *positive* sign, and most of them are statistically significant at the one percent level.[8] Conventionally, an increase in world income has negatively affected the bilateral trade between countries i and j when cross-sectional data are used in a gravity equation. Note that the primary idea of the gravity equation is to explain the level of trade flows with the assumption of *limited world income at any given time period*. In fact, there is no particular reason to believe that this assumption remains the same for the growth form of the equation. For example, a family consumes a bundle of goods with a limited income at any given time. In this case, the level of consumption for a particular good should be negatively related to the consumption of other goods because the total income is fixed. However, as the total income increases over time, consumption of the particular good and the other goods increase. In this case, the relationship between the changes in consumption of a particular good and the change in total income is expected to be generally positive, and the size of the total income impact depends on the types of goods. Therefore, the positive sign of the estimated coefficients of the world income growth rate is *not inconsistent* with the idea of the gravity equation. In general, less than the *proportionate* growth of trade between countries i and j is expected in response to the world income growth.

In fact, the estimated coefficients of world income for each industry sector allow us to test the two models of the intra-industry trade in another way. According to the monopolistic competition model proposed by Krugman (1981), countries, having similar- and high-income levels, produce product-differentiated goods under increasing returns to scale technology, and they trade with each other more than with lower income countries. Considering the fact that our sample consists of high- and similar-income countries, it is expected that the growth rate of bilateral trade for the product differentiated goods between our sample countries has been much higher than that of goods under the national product differentiation model. If this proposition is correct, the estimated coefficient of world income must be larger in the case of the product differentiated goods than in the case of the national product differentiation goods. As shown in Table 1, the estimated coefficients ($\Delta \ln Y_{wt}$) are 0.745, 0.720, and 0.706 in the case of machinery trade and 0.678, 0.763, and 0.678 for chemical trade, which are greater than those in the case of the food sector (0.414, 0.519, and 0.417). This result confirms that bilateral trade for a large-scale manufacturing industry among OECD countries grows faster than for the agricultural sector.

Table 2 summarizes the estimated long-run coefficients. Overall, the economic implications of the long-run results are similar to those of the short-run results. The estimated coefficient of the lagged dependent variable (λ) is an important variable in the long-run. If an exact balance of trade occurs, λ must equal one (or $\lambda^* = 0$), meaning that full adjustment of trade occurs in one time period. In the case of the food sector, the null hypothesis that λ equals one cannot be rejected for all cases. Therefore, we can conclude that trade in the food and agricultural sector adjusts quickly to the equilibrium level. In contrast, the estimated λs are 0.697, 0.681, and 0.662 for the respective instrument variables used in the case of the machinery sector, and 0.678, 0.554, and 0.678 for the chemical sector. These results indicate that, in the case of the large-scale manufacturing sector, there is a sluggish adjustment of trade in response to variation in relative income between countries, compared to the trade for agricultural products. However,

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[8] We investigate the original gravity model (4) using a cross-sectional approach followed by Feenstra *et al*. The estimated coefficients of world income are all negative and statistically significant in most cases. The results are available from the authors on request.

adjustments are completed within two years. As mentioned above, this is one of the potential reasons why our short-run results differ from the findings of Head and Ries and are more consistent with the long-run results of Feenstra *et al*.

Compared to the results of cross-sectional approaches (e.g., Bergstrand 1989; Feenstra *et al.* 2001), the long-run estimated coefficients of our approach produce slightly smaller estimated coefficients. However, considering the fact that we relax the assumption of fixed world income and deal with a growth form equation, a direct comparison with results from the cross-sectional approaches may not be meaningful.

Table 2. Estimated Long-run Coefficients

	IV: $\Delta \ln X_{ijt-2}$			IV: $\ln X_{ijt-2}$			IV: Both		
	Food	Machinery	Chemical	Food	Machinery	Chemical	Food	Machinery	Chemical
λ	---	0.697	0.678	---	0.681	0.554	---	0.662	0.678
$\Delta \ln Y_{it}$	0.121	0.732	0.429	-0.043	0.765	0.554	0.122	0.792	0.435
$\Delta \ln Y_{jt}$	0.530	0.565	0.350	0.620	0.581	0.339	0.528	0.585	0.348
$\Delta \ln Y_{wt}$	0.414	1.069	1.000	0.519	1.057	1.377	0.417	1.066	1.000

IV denotes instrument variable.

CONCLUDING REMARKS

It is a general opinion that trade liberalization is beneficial to the world economy. However, whether liberalization is beneficial to a specific industry sector within a country is a complicated matter. In fact, the two models explaining intra-industry trade predict different effects of trade liberalization on different industry sectors in an economy. Feenstra, Markusen, and Rose (2001) developed a theoretical foundation for a gravity equation to test the two models, and found supporting evidence for their theoretical framework using a cross-sectional analysis. Because of the property of cross-sectional analysis, it is not possible to use this approach to analyze the impact of changes in relative size (or income) of countries on changes in trade patterns; therefore, time-series analysis is required. In addition, whether their long-run results using a gravity equation approach hold in the short-run is still questionable. In this paper, a dynamic gravity equation is developed to confront these questions.

It is found that the national product differentiation model is appropriate to explain the pattern of food and agricultural trade between developed countries in a dynamic gravity framework. However, for the large-scale manufacturing products such as machinery and chemical goods, the product differentiation model is found to explain the pattern of intra-industry trade among sample countries for the both short- and long-run. In fact, these results are consistent with the cross-sectional evidence provided by Bergstrand, and Feenstra *et al*, but inconsistent with short-run results suggested by Head and Ries.

Another important finding in the dynamic gravity framework is a *positive* impact of world income growth on bilateral trade. The different magnitudes of the impacts of world income supports our finding: the impacts on bilateral trade for machinery and chemical products are greater than for food and agricultural products, which confirms that the product differentiation model better explains large-scale manufacturing trade, while the national product differentiation model is more appropriate to explain agricultural trade.

Our dynamic approach also provides different policy implications than a cross-sectional approach. A relatively higher income growth rate of a country causes its import to increase more than its export in the case of food and agricultural trade. In the case of the large scale manufacturing industries, by contrast, a relatively high income growth rate of a country is expected to induce new entries, resulting in more export growth than import growth. Two inferences can be drawn from our findings. First, countries that have experienced a relatively higher income growth rate, such as China, will experience high inward foreign direct investment in large-scale manufacturing industries, resulting in higher export growth rates than import growth rates in these industry sectors. Meanwhile, this relatively higher income growth rate might cause greater import than export growth in the case of the food and agricultural sector.

Second, one of the important determinants of a relative income growth rate over time is exchange rate movement under the floating exchange rate system. A real appreciation of a country's currency relative to other currencies causes more purchasing power for consumers in the country experiencing the appreciation, leading to a greater level of import than export. For a large-scale manufacturing sector, the appreciation of its own currency partially offsets the increase in export growth. However, for the food and agricultural sector, the appreciation may accelerate the increase in import growth. The U.S. real agricultural trade-weighted exchange rate appreciated by 25 percent between 1995 and 2000. Moreover, the U.S. dollar appreciated by 42

percent relative to the currencies of its trade competitors during the same period. Thus, this real appreciation in the U.S. dollar negatively affects the U.S. trade balance for food and agricultural products more than for large-scale manufacturing products.

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