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Endogenous Liberalization and Sectoral Trade

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Abstract

This paper incorporates recent advances in gravity modeling, many made by Baier and Bergstrand (2006, 2007), and extends them to multiple sectors and multiple endogenous trade policy instruments. This study examines the effect of tariff reductions and free trade agreement participation on sectoral imports in a panel with about 75 countries, 25 manufacturing sectors, and three time periods. The panel includes sectoral data for bilateral imports, preferential tariff rates, and gross output, as well as national data for GDP and FTA participation.

Preferential tariff reductions increase trade in all sectors, and have a statistically significant effect in all sectors except electronics and certain primary manufacturing sectors. About two-thirds of sectors have a further significant response from engaging in an FTA. Multilateral resistance terms indicate that the trade-diverting effect of tariff reductions with other partners is significant in all sectors except food, beverages, textiles, and apparel, and nontariff trade-diverting effects of free trade agreements are significant in nearly all sectors.

These results are used to estimate changes to U.S. sectoral trade that would result from complete liberalization under a proposed U.S.-Korea free trade agreement. The estimates are based on theoretically-consistent adjustments for country size, sectoral output, and trade barriers, and include both direct effects of policy changes and indirect effects through multilateral resistance terms. The gravity estimates are compared to CGE model results for the same liberalization. The tariff-driven gravity results are very highly correlated with the CGE results across sectors but are on average only one-tenth as large. The CGE results, however, do not match patterns in other FTA-driven changes, and the CGE model considerably underpredicts trade changes in wood, machinery, transport, and electronics sectors relative to gravity-based estimates.

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1 Introduction

Article XXIV of the General Agreement on Tariffs and Trade requires free trade agreements (FTAs) to apply to "substantially all the trade" between member countries, rather than all the trade, and WTO Members commonly notify FTAs that exclude goods or have considerable trade subject to implementation or transition periods. In fact, the majority of the text of these agreements is generally devoted to defining the treatment of individual products. For example, of the 1418 pages in the 2006 U.S.-Peru Trade Promotion Agreement text, at least 1138 pages (80.3 percent) describe the treatment of specific products.[1] Although much of the product-specific details relate to the staging of duty-free access, agreements also distinguish goods with nontariff measures, such as the quantitative limits on sensitive agricultural products including beef, chicken legs, cheese, processed dairy, and sugar in the U.S.-Peru agreement.

In addition, even provisions that apply to all sectors will presumably affect trade in some sectors more than others. For example, trade capacity building in infrastructure and telecommunications would likely benefit sectors with time-sensitive imports more than other sectors. Alternatively, competition policy and investment provisions will affect sectoral imports differently to the extent that they address nontariff barriers that differ by sector.

Although there are very good reasons to suspect that tariff and nontariff provisions in FTAs may affect commodity- or sector-level trade differently, no study has previously estimated these effects except for specific FTAs (particularly, NAFTA). This paper provides the first analysis of these factors across a large number of FTAs (172), years (1990, 1995, and 2000), and manufacturing sectors (25). This paper controls for potential endogeneity of trade

[1] The agreement includes a 530-page U.S. tariff schedule that divides every HTS-8 category into one of six staging categories and a 9-page annex to that schedule for U.S. tariff-rate quotas. For Peru, there is a 406 page tariff schedule with a 14-page annex. There are also chapters devoted to textiles and apparel (45 pages), product-specific rules of origin (90 pages), and several chapters on specific service sectors (43 pages).

flows and trade policy instruments, and estimates multilateral price terms, which provide insight into how FTAs affect trade with nonmember countries in each sector. In the pooled specification, a 1-percentage point reduction in tariffs leads to a 1.3 percent increase in trade, and FTAs increase imports an additional 30.8 percent after accounting for the effect of tariffs. Tariff reductions are estimated to increase imports in all sectors, and effects are significant in all sectors except electronics and primary manufacturing (chemicals, rubber, plastics, and some metals). About two-thirds of sectors have a further significant response from engaging in an FTA.

Another aspect of many FTAs is the attention that trade negotiators and manufacturing associations pay to the trade-reducing effects of FTAs to which their country does not belong. The USTR reports in the 2002 fact sheet on the U.S.-Chile FTA, that

> U.S companies currently operate at a significant competitive disadvantage in Chile, because competitors such as Canada, Mexico, and the European Union all have free trade agreements with Chile. For example, a U.S.-made Caterpillar 140 horsepower Motor Grader sold in Chile pays $13,900 in tariffs. But the same tractor made in Canada pays ZERO tariffs….The National Association of Manufactures estimates that the largest losses of U.S. market share in recent years were in wheat, corn, soybeans, paper, plastics, paints & dyes, fertilizers, heating equipment, and construction equipment.

The results of this paper suggest that trade agreements do divert trade from nonmember countries. The trade-diverting effect of tariff reductions with other partners is significant in all sectors except food, beverages, textiles, and apparel. Nontariff trade-diverting effects of free trade agreements are significant in nearly all sectors. Every manufacturing sector noted by the National Association of Manufactures is significantly affected by FTAs or tariff reductions with other countries, though plastics and transport equipment, which includes the Caterpillar motor grader, are less affected.

1.1 Literature review

Analysis of the effect of an FTA in gravity models has typically been accomplished by including a dummy variable equal to one for countries that engage in the FTA. This approach is potentially biased because it does not account for the endogeneity of FTAs and trade volumes. Burfisher et al. (2004) and Baier and Bergstrand (2007) note that countries with inefficient institutions or burdensome regulations may be more likely to enter into an FTA if they have *low* trade but seek deeper integration with a developed partner. Conversely, Magee (2003, 2004) and Robinson (2006) note that countries may be more likely to enter into an FTA if they are have *high* bilateral trade and hence are "natural trading partners." Estimates of the effect of FTAs on bilateral trade that account for endogeneity are often higher and more significant than earlier estimates. This paper follows Baier and Bergstrand (2007) and controls for this endogeneity with panel data when estimating the effect of FTAs on trade volumes.

Traditional gravity analyses of bilateral trade are also biased because they do not account for trade barriers between other trading partners of the importer and exporter. Anderson and van Wincoop (2003) show that exclusion of these multilateral resistance terms leads to possibly severe omitted variable bias. Feenstra (2004) shows that other coefficients can be consistently estimated if importer and exporter fixed effects are used to capture the effect of the multilateral resistance terms. However, changes in trade policy instruments will alter these multilateral resistance terms, so the current analysis precludes the use of fixed effects. This analysis uses the linear approximation for the multilateral price terms from Baier and Bergstrand (2006). The current paper extends their analysis by including multiple sectors and also incorporates bilateral preferential tariffs.

The derivation of the gravity model for aggregate trade flows in the monopolistic competition framework is now standard, and Anderson and van Wincoop (2004) show that this model generalizes well to sectoral trade. Although true theoretically, there is some concern that, like Newtonian gravity, economic gravity models may apply better to macro variables (i.e. aggregate trade flows) then to micro variables (sectoral flows). This concern has rarely been addressed because the literature on sectoral gravity models is quite limited, particularly in relation to the enormous literature on gravity models for aggregate trade.[2]

A number of papers have examined the effects on commodity- or sectoral-level trade in *specific* FTAs, and often these incorporate data on tariff rates as in the present paper. For example, Yeats (1998) examines Mercosur; Clausing (2001), Fukao, Okubo, and Stern (2003), and Romalis (2005) examine NAFTA or the Canada-U.S. FTA; and Mayda and Steinberg (2006) examine COMESA. Although investigations of disaggregated trade have generally not controlled for either endogeneity or multilateral price terms, Romalis (2005) controls for both in his estimates of elasticities of substitution between member and nonmember imports.[3] Romalis's approach, while elegant, is too parsimonious for the present investigation because successive differencing leaves only the elasticity of substitution and fixed effects to be estimated.

Komorovska, Kuiper, and van Tongeren (2007) is the study most similar to this paper. They use a sectoral gravity model to provide counter-factual trade shares to overcome the

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[2] A separate literature has estimated the gravity model for broad aggregates of commodities, such as the differentiated, reference priced, and homogenous product groups identified in Rauch (1999). These studies generally find that performance varies by commodity group, and monopolistically competitive sectors often perform more in line with theoretical predictions homogenous sectors. Other studies, such as Eichengreen, Rhee, and Tong (2004), have divided commodities using the U.N. Broad Economic Categories of capital, intermediate, and consumer goods. Performance differs by category, but these categories are not divided along theoretical lines, so it is less clear how to interpret these performance differences.

[3] Romalis reports elasticities of substitution of 6.3–10.9 for the United States, 2.8–8.1 for Canada, and 0.6–2.5 for Mexico. Mayda and Steinberg (2006), following Romalis, find results for Ugandan elasticity of substitution between COMESA and non-COMESA imports that are similar to Romalis's Mexican estimates.

"small shares stay small" problem inherent in many CGE models (i.e., to improve the ability of these models to simulate trade policy responses for exporters with low initial trade shares.) They use a theoretically-consistent gravity specification for disaggregated food and agricultural sectors, and they employ Pseudo Poisson Maximum Likelihood (PPML) to control for zero-trade flows and heteroskedasticity in their estimation.[4] Their results are promising and their approach generates larger trade responses for small exporters than the standard GTAP model. However, their gravity estimates of the effect of trade barriers are less consistent with theory than this in paper, which may reflect a limitation of their cross-section data or a lack of applicability of gravity in general to fine sectors.

2 The sectoral gravity equation

Anderson and van Wincoop (2004) show the gravity model for aggregate trade generalizes well to sectoral trade.[5] Because the current model is similar to their model, we relegate the derivation of the sectoral model to the appendix and here focus on comparing the sectoral model to the more familiar model for aggregate trade.[6] The sectoral gravity specification is given by

[4] See Santos Silva and Tenreyo (2006) and Tenreyo (2007) for a discussion of the advantages of PPML over OLS in gravity specifications.
[5] See Anderson and van Wincoop (2003) and Feenstra (2004) for derivation with aggregate trade flows. Although these models are commonly denoted monopolistic competition models, results in this paper apply to a broader class of models with CES demand for varieties distinguished by country of origin.
[6] This specification differs from Anderson and van Wincoop (2003, 2004) in the inclusion of additional elements of demand for foreign products incorporated in the demand shifter and in the assumption that sectoral expenditure shares are identical across countries.

$$M_{ij}^{k} = \alpha Y_i Y_j^k D_{ij}^k \left(\frac{T_{ij}^k}{P_i^k P_j^k} \right)^{1-\sigma}, \quad (1)$$

where M_{ij}^{k} denotes imports of goods in sector *k* into country *i* from country *j*, Y_i is importer GDP, Y_j^k is exporter sectoral gross output, T_{ij}^k is the ad-valorem-equivalent trade cost of exporting a good in sector *k* from *j* to *i*, P_i^k and P_j^k are price indexes for sector *k* in the importer and exporter, respectively, and α is a constant. D_{ij}^k, which is not a standard element in gravity equations, is a country *i* demand shifter for products from *j*. It includes all elements that affect demand for foreign goods without affecting costs.[7] The demand shifter, transport costs, and price indexes are not directly observed, but will be related to observable variables below.

The sectoral gravity equation shares key features with gravity models of aggregate trade. First, imports in equation (1) are a function of importer expenditure and exporter supply. The distinction between expenditure and supply may be unfamiliar, because both are measured by GDP in gravity models of aggregate trade. Because this model of sectoral trade assumes identical sectoral expenditure shares across countries, importer expenditure continues to be measured by GDP. In contrast, exporter supply (i.e., sectoral gross output) is included directly. The different treatment of expenditure and supply is dictated by data availability; international sectoral production data are more readily available than sectoral expenditure data.

Second, imports are a function of trade costs and price indexes. Because of the CES demand structure, price indexes depend on the price of all imported foreign varieties, and so are nonlinear functions of trade costs with, and prices in, all foreign trade partners.[8] In an aggregate

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[7] Although nonstandard, we include the demand shifter because it reduces the number of multilateral resistance terms. See the appendix for derivation.

[8] Recent specifications differ from earlier, atheoretical gravity equations chiefly in the inclusion of these price terms. Higher prices in either the importer or exporter will raise bilateral imports. For the importer *i*, for a given distance, imports from *j* will be higher as *i* is farther away from, or has higher trade costs with, other exporting

model, these price levels are closely related to the remoteness of the importer and exporter. Baier and Bergstrand (2006) show that these terms also depend on FTA participation throughout the world. In a sectoral model, however, the relevant price level is the price of imported varieties in a particular sector rather than a national price level. Thus prices in a sectoral model are also determined by sectoral trade barriers (such as tariff rates) and likely vary considerably across sectors within a country.

2.1 Estimation

Estimating the gravity equation requires minimizing the residuals of equation (1) subject to a system of nonlinear price equations.[9] There have been a number of approaches to estimating this system. Anderson and van Wincoop (2003) use nonlinear least squares. Feenstra (2004) shows that consistent estimation is also possible if price terms, also called multilateral resistance terms, are replaced by importer and exporter fixed effects, though this is not as efficient. However, the multilateral resistance terms change when trade barriers are reduced. Because this paper focuses on reductions in these barriers, fixed effects are not appropriate here.

Baier and Bergstrand (2006) considerably simplify this estimation using a first-order Taylor-series expansion of the multilateral resistance terms. They center their expansion around the equilibrium values of the these terms given the simplifying assumption of zero trade costs.[10] With this approximation, the price terms are shown to be the sum of terms for the importer's trade resistance, the exporter's trade resistance, and overall world trade resistance. They show

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countries. For the exporter j, exports to i will be higher as j faces higher trade costs in its other export markets. See Anderson and van Wincoop (2003), Feenstra (2004), and Harrigan (2002) for further discussion of the nature and importance of including these resistance terms in gravity equations.

[9] Because importer and exporter price levels are a function of prices in all other countries, each country introduces a separate price equation into the system.

[10] The derivation requires an assumption about the properties of the equilibrium. Baier and Bergstrand examine both the symmetric equilibrium, in which all countries have equal size, and an asymmetric equilibrium, in which they do not. This paper reports both specifications. The symmetric specification has better econometric properties, and the asymmetric one better matches our ex-ante analysis of the U.S.-Korea FTA.

that OLS estimation of their specification produces virtually identical results to nonlinear least squares.

Applying Baier and Bergstrand's approach, equation (1), in logs, is approximated by

$$\text{(2)} \qquad \ln M_{ij}^{k} = \alpha + \ln Y_{i} + \ln Y_{j}^{k} + \ln D_{ij}^{k} + (1-\sigma)\ln T_{ij}^{k} - (1-\sigma)\ln MR_{ij}^{k}.$$

MR denotes multilateral resistance, and is given by

$$\text{(3)} \qquad \ln MR_{ij}^{k} = \sum_{i} s_{i} T_{ij}^{k} + \sum_{j} s_{j}^{k} T_{ij}^{k} + \sum_{i}\sum_{j} s_{i} s_{j}^{k} T_{ij}^{k},$$

where s_i is the share of country *i* in world GDP, and s_j^k is the share of world output of good *k* produced by country *j*.[11]

This specification highlights the importance of trade costs to imports. Trade costs appear twice: directly, and indirectly in the multilateral resistance term. To implement this specification, trade costs must be associated with observable variables. I assume that tariff rates, FTAs, and geographic variables, such as distance or indicators for island or landlocked status, all affect costs.[12] Although nontariff measures and transport costs also raise import prices, data limitations preclude their use because of the large number of countries and the panel nature of this data set.[13] Following the literature, we assume that

[11] The specification contains several theoretical coefficient restrictions. The coefficients on GDP and gross output should both be equal to one, and the coefficients on trade costs and multilateral resistance should have the same magnitude and opposite signs. Although we will examine whether these restrictions hold in the estimation below, we will follow most of the literature and not restrict the coefficients to their theoretical values.

[12] In contrast, we assume that other common gravity variables such as proxies for common language, religion, or colonial history affect foreign demand but not trade costs and so are part of the demand shifter. Although these terms may have some effect on prices, practically, their exclusion from multilateral resistance does not affect the empirical results because these variables are constant over time and the specification is in first differences. See also footnote 16.

[13] These variables have been used only in investigations that employ fewer countries. For example, Hummels (2001) includes freight costs, but includes only six countries, and Harrigan (1993) includes freight rates and nontariff measures for 13 countries.

(4) $$\ln T_{ij}^{k} = \alpha_1^k TARIFF_{ij}^{k} + \alpha_2^k FTA_{ij} + \sum_g \alpha_g^k GEOGRAPHY_{g,ij} + \varepsilon_{ij}^{k}.$$

Each of these trade-cost terms has an associated multilateral resistance term. For example,

(5) $$\ln MRTAR_{ij}^{k} = \sum_i s_i TAR_{ij}^{k} + \sum_j s_j^k TAR_{ij}^{k} + \sum_i \sum_j s_i s_j^k TAR_{ij}^{k}.$$

This contains tariffs applied by importer *i* to all its trade partners, tariffs applied by importer *j* to all its trade partners, and a term for tariffs applied to imports throughout the world.

2.1.1 Endogeneity

As noted in the introduction, FTA participation may be endogenously determined with trade volumes. Although this endogeneity will bias the estimate of the effect of FTAs on trade flows, the direction of bias is not known, because countries may engage in FTAs with low-trade partners to achieve deep integration, or conversely they may engage in FTAs with high-trade "natural" trading partners. Baier and Bergstrand (2007) argue that panel data control for endogeneity better than instrumental variables because of the scarcity of instruments that are correlated with trade barriers but not correlated with trade volumes. With a panel, first differencing is more efficient than fixed effects if error terms are serially correlated. Lai and Trefler (2002) find very high serial correlation in error terms, so first differencing is our preferred specification.[14] Differencing also controls for time-invariant unobserved variables that might be simultaneously affecting trade flows and other right hand side variables such as income, output, and prices.[15]

[14] Lai and Trefler (2002) find that a 1 percent rise in trading imports continues to impart a 0.36 percent increase in imports after a decade.

[15] Importer GDP is also an endogenous variable: imports partially determine national income through the accounting identity, and national income partially determines expenditure on imports. This is occasionally controlled for in gravity models of aggregate imports, for example by constraining the coefficient on importer GDP to one. These simultaneous determination is much weaker with *sectoral* imports, however, and we do not control for it here.

2.1.2 Zero-trade flows

The problem of zero-trade flows in gravity estimation has recently attracted much attention, and the use of sectoral trade data exacerbates the econometric issue of zero-trade flows. Examining aggregate trade, Helpman et al. (2006) report that about 50 percent of country pairs do not trade with one another in their sample of 161 countries. Examining sectoral trade, Haveman and Hummels (2004) report that importing countries buy from a median of only 7.4 percent of exporters in their sample of 173 countries and 438 manufacturing industries.

Santos Silva and Tenreyro (2006) argue convincingly that PPML estimation best controls for zero-trade flows, and Tenreyro (2007) has extended this approach to panel data. This paper does not yet employ PPML. However, the first differencing used to control endogeneity may also help control for the zero-trade flows. In levels, the zero-trade flows create a probability mass at zero; first differencing moves the probability mass to the center of the distribution. Because the error variance is likely not constant across the distribution, we will compare the OLS results to quantile regression results to examine whether effects differ across the conditional distribution of the independent variables.

2.1.3 First differenced specification

Because the estimation strategy involves first differencing the data, all variables that are constant over time are eliminated from the regression.[16] The remaining cost variables are the ad valorem equivalent of bilateral tariff rates, which varies by sector, and an indicator variable set to one in the presence of an FTA, which is the same across sectors.

[16] Although bilateral distance and other geographic variables are constant over time, GDP shares are not, so the multilateral resistance terms for these variables vary over time. Practically, however, the GDP-share-weighted resistance terms are roughly constant, and have been excluded from the regression to avoid problems with near multicollinearity.

With differencing, the gravity equation becomes

$$\Delta \ln M_{ij}^{k} = \beta_1^k + \beta_2^k \Delta \ln Y_i + \beta_3^k \Delta \ln Y_j^k + \beta_4^k \Delta TAR_{ij}^k + \beta_5^k \Delta FTA_{ij} + \beta_6^k \Delta MRTAR_{ij}^k + \beta_7^k \Delta MRFTA_{ij} + \varepsilon_{ij}^k, \quad (6)$$

2.1.4 Partial effects

This paper also examines changes to trade flows resulting from complete liberalization of trade in an FTA between two specific countries, the United States and Korea. In equation (6), an FTA affects tariffs and FTA indicators directly for the signatories, and also affects the multilateral resistance terms. A theoretically-consistent ex-ante estimate of the changes resulting from this FTA can be made using coefficients on direct and multilateral terms for tariffs and FTAs in combination with U.S. and Korean GDPs and gross output shares.[17] Assuming that GDP and output shares do not vary over time, the change in imports in signatory *s* from its FTA partner *t* is given by

$$\Delta \ln M_{st}^{k} = \beta_4^k \Delta TAR_{st}^k + (s_s + s_t^k - \tfrac{1}{2} s_s s_t^k)\beta_6^k \Delta TAR_{st}^k - \tfrac{1}{2} s_t s_s^k \beta_6^k \Delta TAR_{ts}^k + \beta_5^k + (s_s + s_t^k - \tfrac{1}{2} s_s s_t^k - \tfrac{1}{2} s_t s_s^k)\beta_7^k. \quad (7)$$

The first three terms on the RHS result from the bilateral tariff reduction, and the final two terms capture the effect of other reduced trade costs that result from the FTA.[18] It is straightforward to calculate the standard error of this linear combination of coefficients.

3 Data

This gravity specification requires both national and sectoral data. The sectoral data include gross output, bilateral imports, and preferential tariff rates; the national data include GDP and FTA participation. All values are in real dollars, converted using exchange rates and

[17] Baier and Bergstrand (2006) derive a similar term for a specification of aggregate trade flows without tariffs.
[18] The change in tariffs from an FTA liberalization is defined to be nonpositive.

U.S. price deflators. The 1990–2000 period was selected to maximize data availability, because relatively few countries report tariff schedules before 1990 or gross output after 2002.

GDP data for importers are from the World Bank World Development Indicators, which offered the most extensive country coverage. Gross output for exporters was taken from the UNIDO INDSTAT3 database, which contains 3-digit ISIC Rev. 2 data.[19] The number of observations differs by sector because only about 70 percent of countries report output for all 26 sectors; the remainder report between 5 and 25 sectors, and overall 22 percent of gross output observations are missing for these countries.

Bilateral sectoral imports are from World Integrated Trade Solutions (WITS), which contains import data from COMTRADE concorded to ISIC Rev. 2 to match the gross output data. When available, import data are always complete for all 25 sectors, though in most cases bilateral imports are zero.

FTA coverage is taken from a number of sources, including the Baier and Bergstrand FTA dataset, WTO country directories, and the websites of FTA directorates. Because the effectiveness of FTAs varies considerably, the dataset includes only agreements in which most members actually granted tariff concessions (generally demonstrated either by the existence of a tariff schedule in WITS or by corroboration by agencies other than the agreements' own directorates). Agreements in which few members applied tariffs, or that included relatively few tariff lines, were excluded. These selection criteria include only 172 of the 240 FTAs that were technically in force by July 2000.

[19] To increase country coverage, particularly in more recent years, some data were concorded from the INDSTAT4 database, which contains 4-digit ISIC Rev.3 data. No concordance was possible for Sectors 356 and 390, but the remaining sectors concorded well.

Bilateral sectoral tariff rates are taken from the TRAINS and IDB databases, available through WITS. For each country pair and sector, the importer's average tariff rate, weighted by import values, of all HTS 6-digit sectors within the sector was used.[20] The creation of a panel of bilateral tariff rates is complicated because tariff schedules are not available for all reporters in all years, and preferential rates are less frequently reported than MFN rates. In many cases new schedules are not issued when tariff rates do not change, so generally it is better to select an earlier schedule than a later one when data are missing. To account for missing schedules for 1990, 1995, and 2000, alternative schedules were chosen in the following order: in the reference year, then one year prior, then two years prior, and then one or two years following the reference year.[21] Considerable effort was taken to include all possible tariff schedules for the 172 agreements included in the list of effective FTAs.[22] A further complication is that although WITS reports tariffs beginning in 1988, it includes relatively few countries prior to 1992. To increase coverage for 1990, historical sectoral tariff rates from UNCTAD for about 40 developing countries were incorporated into the dataset.[23] Although these rates were not bilateral, none of these countries were FTA members at that time, so there should be relatively few missing preferential tariff rates.

Finally, the prevalence of specific tariffs and nontariff measures can make reported tariff rates poor indicators of trade barriers in certain sectors, particularly food and tobacco,

[20] It is well known that weighted average tariff rates may understate average protection levels because sectors with high tariffs are generally given low weights. However, the unweighted average tariff rates are not ideal because they give equal weight to sectors regardless of sector size; further, the unweighted rates reported by WITS exclude all 6-digit sectors with zero imports from the average, so they may also understate protection as do the weighted average rates. Alternative measures are not widely available. Collected duties are available for only certain importers, such as the United States, and other measures of trade restrictiveness, such as by Kee, Nicita, and Olarreaga (2006) are available for many countries but generally only for a single year.

[21] This selection process was revised when data selected for two successive periods were less than four years apart.

[22] In some cases this required using preferential schedules that differed from the MFN schedule by one or two years, though only preferential tariff rates lower than or equal to MFN rates were included.

[23] These rates are from UNCTAD (1994). I thank Samuel Munyaneza for providing the data.

because generally only the ad valorem portion of any tariff is included in WITS.[24] Although sources exist which estimate ad-valorem equivalent (AVE) rates of these measures, these sources were not suitable in the present context. The Bouët, et al. (2004) Market Access Map (MAcMap) tariff database, for example, contains bilateral AVE rates but only for 2001 and 2004, and the method of AVE construction differed across years. Recent features of WITS allow computation of AVE rates over time, but not bilaterally. Although food was retained in the panel, the tobacco sector was dropped because estimates were highly dependent on the type of averaging employed and reported tariff rates differed widely across data sources.

These resulting dataset consists of an unbalanced panel of 25 industries, 82 importing countries, and 72 exporters countries.[25] The years covered are 1990, 1995, and 2000. Other than gross output, which is reported with long lags, the availability of data improves over time.

4 Results

To recap section 2.1, the estimating equation is a theoretically-based gravity equation that includes approximations of multilateral resistance terms that can be estimated without imposing constrained optimization. It is estimated in first differences to control for endogeneity between trade flows and trade policy instruments. For convenience, the estimating equation (6) is repeated here:

$$\begin{aligned}\Delta \ln M_{ij}^{k} &= \beta_1^k + \beta_2^k \Delta \ln Y_i + \beta_3^k \Delta \ln Y_j^k + \beta_4^k \Delta TAR_{ij}^k + \beta_5^k \Delta FTA_{ij} \\ &+ \beta_6^k \Delta MRTAR_{ij}^k + \beta_7^k \Delta MRFTA_{ij} + \varepsilon_{ij}^k ,\end{aligned} \qquad \textbf{(6)}$$

[24] Though U.S. tariff rates for food in table 6 are quite close to the rates in the GTAP database, which includes ad-valorem equivalents of specific tariffs.
[25] A number of countries merged or split during or just prior to this period, including Russia, Germany, Yemen, Czechoslovakia, Ethiopia, and Yugoslavia. Where possible, data were made consistent over successive periods to produce meaningful differences, but in several cases this was impossible and observations were dropped. Because the panel is not balanced, countries were included if they were consistent over any two successive periods.

Results are reported in several specifications. First, the paper uses OLS to examine the sectoral gravity specification when all 25 manufacturing sectors are pooled, including the effect on bilateral imports of each part of the specification: (a) economic size, (b) reductions in importer tariffs and participation in an FTA with the exporter, and (c) tariff changes and FTA participation with other trade partners. Second, pooled quantile regressions are presented to assess how results are affected by zero-trade flows. Third, sectoral results compare effects across sectors. Fourth, results of the asymmetric specification are briefly presented to provide coefficients for the analysis of the U.S.-Korea FTA. The fifth section contrasts gravity results to CGE results for this FTA.

4.1 Pooled OLS results

In the pooled OLS regression, coefficients of all variables have expected signs, and are very precisely estimated. The coefficient on importer GDP is almost exactly equal to the theoretical value of unity, but the coefficient on exporter sectoral gross output is much lower than unity. It is difficult to compare this result to the literature, because almost no studies use a theoretically-consistent gravity equation at the sectoral level.[26] It is possible that using PPML regression would improve the gross output results, and Santos Silva Tenreyro (2006) note that PPML eliminates "puzzling asymmetries in elasticities with respect to importer and exporter characteristics" in their specification with aggregate flows. PPML is thus a promising estimation technique for this study, and is in fact rapidly becoming a standard.

Bilateral tariff changes and FTAs affect imports in the expected ways. A 1-percentage point decrease in preferential tariffs increases bilateral imports by 1.32 percent, and tariff rates are high enough that their elimination could substantially raise trade flows. For example, the

[26] The closest paper is Komorovska, Kuiper, and van Tongeren (2007), but their cross-section regression with country fixed effects necessarily excludes GDP and gross output.

average preferential tariff rate across all sectors and countries in 2000 was 9.1 percent, and sample average tariff rates ranged from about 5 percent in electric equipment and industrial chemicals to over 14 percent in apparel and beverages. Signing an FTA increases bilateral imports in manufacturing sectors by 30.8 percent beyond the gains from tariff reductions.[27]

Changes in tariffs and FTAs between other trade partners also affect bilateral imports through multilateral resistance terms in theoretically-consistent ways.[28] For example, a one-percentage point increase in tariff rates between all other pairs of countries *increases* bilateral imports by 0.82 percent.[29] Because multilateral resistance is analogous to remoteness, this tariff increase has an effect similar to increasing the distance between all pairs of countries. As the importer and exporter become more remote from their trading partners, bilateral trade increases. A one-percent increase in *all* tariff rates, however, including the rate applied by the importer to the exporter, would result in a net 0.50 percent decrease in bilateral trade.

Conversely, increased FTA participation with other trade partners *reduces* bilateral imports. If all countries engaged in one additional FTA, trade diversion would decrease average bilateral-pair imports by 16.7 percent.[30] More generally, the magnitude of the bilateral import

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[27] $e^{0.269} = 1.308$, or a 30.8 percent increase.

[28] Although the coefficients have the correct sign, the magnitude of each multilateral term is greater than the corresponding direct bilateral coefficient. This discrepancy has been observed in aggregate trade flows in Baier and Bergstrand (2004 and 2006). As in those papers, we do not impose the theoretical coefficient restriction of equal magnitudes and opposite signs.

[29] As given in equation (3), the multilateral tariff term is approximated by the sum of importer, exporter, and world average tariffs. Each of these three elements rises by one percent when world tariffs rise, so the estimated increase in bilateral imports is one third of the multilateral tariff coefficient.

[30] This assumes that there are N countries, each country with at least one existing FTA partner. If each country adds one more FTA partner, then the multilateral FTA term increases by 3/N for all country pairs. Although there are 82 importers and 72 exporters in the sample, on average only about 20 countries import and 20 export each product. If N=20, then the implied decrease in bilateral pair imports from one additional FTA for all countries is 1.032/(20/3)=0.15, which corresponds to a 16.7 percent increase. This does not imply that an increase in FTA participation would lower world trade overall, because these decreases would be offset by trade increases between new FTA partners.

change depends on the country composition of new FTAs. Section 4.5 estimates trade changes that would result from an FTA between the United States and Korea.

4.2 Pooled quantile results

Results differ considerably by quantile, and a portion of these differences can be attributed to zero-trade flows. Magnitudes for all coefficients are larger (and statistically significantly so) at the 0.75 quantile than at the median or 0.25 quantile. Because the observations are differenced and in logs, the observations with the largest increase in imports will be those that go from zero to positive trade. The larger coefficients at the 0.75 quantile imply that tariff reductions and FTAs have the greatest effect on observations without initial trade. Sectors in which trade declines to zero are less affected by trade and tariff rates than those with new trade. And the median results, which are most affected by observations with unchanged trade flows (including observations that maintain zero trade), are generally least affected by trade and tariffs. Together, the quantile results tend support the OLS results, which lie between the 0.25 and 0.75 quantile results for all coefficients.[31]

4.3 Sectoral Results

Sectoral results generally exhibit key characteristics of the pooled regression. All sectoral coefficients on importer GDP are larger and closer to their theoretical value than coefficients on exporter output. Though not all coefficients are significant, all but three of the 150 sectoral coefficients have the correct sign. Multilateral effects tend to have higher coefficients than bilateral effects, and always do so when coefficients are significant.

Examining the coefficients for bilateral and multilateral tariffs and FTAs, almost all of the sectoral coefficients have the correct sign, and most sectoral effects are also precisely

[31] Of course, quantile regressions may not have better econometric properties than OLS, so consistency of results may be misleading if all regressions are similarly biased. This is another reason supporting the use of PPML estimation for comparison.

estimated. The direct trade-creating effect of a bilateral tariff reduction is greatest in leather, footwear, and paper, and it is generally lowest and least precisely estimated in primary manufacturing sectors, like chemicals, rubber, plastic, and most metals. The indirect trade-diverting effect of non-pair tariff reductions are low and imprecisely estimated in some of the primary manufacturing sectors as well as food, beverage, textiles, and apparel. The trade-generating effect of bilateral FTA formation is least significant in food, beverages, and leather, while the trade diverting effects of non-pair FTAs are significant in all but a few sectors.

Overall, trade in downstream manufacturing sectors like machinery, transport, and equipment is generally strongly affected by tariffs and FTAs. Reductions in barriers have large trade-creating and trade-diverting effects in these sectors. Some sectors, such as food, beverages, textiles, apparel, leather, and footwear, are significantly affected by direct tariff cuts but less affected by FTAs or multilateral tariff effects. Trade in primary manufacturing industries is less affected by either tariffs or FTAs. The sector least affected is iron and steel, which likely reflects high transportation costs.[32]

4.4 Asymmetric specification results

The asymmetric specification weights multilateral effects by the economic size (GDP or gross output) of trade partners. As discussed in section 2.1, the asymmetric specification has less desirable econometric properties than the symmetric one. However, coefficients from the asymmetric specification can be directly incorporated into ex-ante examinations of specific FTAs, which we examine in section 4.5.

The chief difference between the pooled symmetric and asymmetric results is that FTAs have much smaller effects in the asymmetric specification (table 3). The contrast between the

[32] Hummels (2001) reports that the iron and steel sector has the highest U.S. freight rate among any two-digit manufacturing SITC category except fertilizers and coal; in contrast, the freight rate of nonferrous metals is 75 percent lower, and nonferrous metal imports are affected by most tariff and nontariff effects in this study.

two specifications is particularly large in the 0.75 quantile. The estimated trade-generating effect of a bilateral FTA is lower, and the trade-diverting effect of non-pair FTAs is close to zero and not significant. There are two potential reasons for this discrepancy. First country size could be negatively correlated with the trade-generating and trade-diverting effects of FTAs (e.g., big countries may increase imports relatively little or small countries may increase exports greatly). However, the lower significance of the FTA terms suggests that a more likely cause is near multicollinearity between the size-weighted multilateral terms with the measures of economic direct FTA effects and economic size.

In the sectoral results in table 4, all tariff coefficients have the correct sign. As in the symmetric specification, tariffs are least significant in primary manufacturing sectors and electronics, but are significant in nearly all other sectors. Bilateral FTAs are estimated to increase imports in almost all sectors, although the result is rarely significant. Effects of non-pair FTAs are generally not significant and have the theoretically correct sign in only about half of the sectors.

4.5 Analysis of the U.S.-Korea FTA

We estimated bilateral trade changes from complete liberalization in an FTA between the U.S. and Korea using equation (7).[33] These estimates incorporate coefficients from the sectoral regressions in table 4 and data on U.S. and Korean GDP, sectoral gross output, and bilateral sectoral tariff rates.

Table 5 shows that the biggest import changes occur in electric machinery and transport equipment. Apparel, beverages, furniture, chemicals, and plastics also have significant, but smaller, increases in both countries. There is no significant change in most primary

[33] The results in this section assume complete liberalization of all sectors, and do not incorporate negotiated tariff and nontariff reductions contained in the U.S.-Korea FTA text.

manufactured goods (rubber, plastic, glass, minerals, and metals). Tariff-based changes are always positive and generally significant, but these are offset by nontariff-based changes, which are much less significant and occasionally negative. Overall, FTAs are estimated to increase imports in all sectors except industrial chemicals and minerals, but the change is significant in only about half of the sectors.

Table 6 compares the gravity estimates of changes in U.S. imports from Korea resulting from the FTA to similar estimates from the GTAP CGE model.[34] There are some unavoidable differences between the two models but the liberalization scenarios have been made as comparable as possible. The GTAP version 6 base year is 2001, which is one year after the sample period. Sectors have been aggregated to be comparable across databases, and GTAP tariff wedges are similar to tariffs in the gravity database for the year 2000, though GTAP rates are often slightly higher because they include ad-valorem equivalents of specific tariffs. The GTAP liberalization included only tariff reductions, and did not include reductions in export taxes or subsidies.

Although GTAP changes are much higher, the tariff-based gravity estimates are highly correlated across sectors with the CGE results, with a correlation coefficient of 0.64. This correlation is even higher when overly high estimates of upstream agricultural protection in the GTAP database are corrected.[35] Korean agricultural wedges in GTAP are based on published Korean MFN rates, which are considerably higher than rates actually applied to U.S. exports in some sectors (e.g., oil seeds and corn) under Korean tariff-rate quotas.[36] Applying the correct

[34] I thank Alan Fox for providing the GTAP simulation results.
[35] In the GTAP model, upstream agricultural protection increases downstream food exports because the prices of agricultural products decline considerably after liberalization of large agricultural price wedges. This makes Korean food much more competitive on world markets, leading to large export increases.
[36] See USITC (2007, forthcoming) for details.

agricultural price wedges, liberalization increases U.S. food imports only 25.4 percent, and the correlation between the GTAP and tariff-based gravity results rises to 95.6 percent.

This comparison highlights several strengths of the CGE approach. First, it captures upstream and downstream effects that may differ from the average effect in the panel. These effects may be particularly prominent when examining trade flows with partners that that highly protect food and agricultural products. Second, the CGE approach captures terms of trade effects in sectors that may be important in FTAs with large partners. The GTAP results show that sectors with the lowest initial tariffs and hence least policy-induced foreign demand increases will be most adversely affected by terms-of-trade changes. The current adjustment for country size in the gravity estimates can not capture movements in the terms of trade, but changes could be made to the theory to allow interaction between country size and FTAs, or to the estimation to impose a constraint on economy-wide trade changes.

The gravity estimates provide a useful benchmark against which the CGE results can be compared. The gravity results, both tariff-based and overall, show that countries generally have had much more moderate import changes in food, textiles, apparel, leather products, and footwear than is predicted by the GTAP model. Gravity results are useful both to inform future models and to improve current ones, as in Komorovska, Kuiper, and van Tongeren (2007). Second, the gravity approach can provide useful estimates about FTA effects even in the absence of detailed NTM data. The overall gravity results show that the nontariff effects are large and significant in wood, machinery, transport, and electronic sectors. Gravity results are thus particularly informative in these sectors, which have low or even negative CGE estimates because of their low initial tariff rates.

5 Conclusion

This paper incorporates recent gravity advances by Baier and Bergstrand (2006, 2007), and extends them to multiple sectors and multiple endogenous trade policy instruments. It provides the first analysis of the sectoral effect of tariff and nontariff provisions in FTAs on sectoral manufacturing trade. The results suggest that a theoretically consistent gravity model is a valid tool for the interpretation of bilateral trade at the sectoral level, with some caveats. Unlike Newtonian gravity, most forces observed the aggregate macro level remain strong at the sectoral micro level. However, the differences between the predicted and actual values for exporter size and multilateral resistance indicate that new variables or estimation techniques could be beneficial at the sectoral level.

In all sectors except iron and steel, either preferential tariff reductions or FTA participation significantly increase trade. Tariffs significantly affect all sectors except electronics and primary manufacturing sectors (chemicals, rubber, plastics, and some metals). About two-thirds of sectors have a further significant response from engaging in an FTA. The paper also estimates the trade-*reducing* effects of tariff reductions for other exporters and FTAs to which a country does *not* belong. The trade-diverting effect of tariff reductions with other partners is significant in all sectors except food, beverages, textiles, and apparel. Nontariff trade-diverting effects of free trade agreements are significant in nearly all sectors.

This paper also estimates the effects of complete liberalization in an FTA between two specific countries, the United States and Korea, and compares the estimates to results from the GTAP CGE model. The gravity estimates are theoretically consistent and incorporate U.S. and Korean GDP, sectoral output, and tariff barriers. Tariff-based gravity changes are considerably smaller than, but highly correlated with, the GTAP results. However, the GTAP results do not match patterns in nontariff-based gravity results. The comparison highlights strengths of each approach and suggests areas for improvement. Gravity models would benefit from specification changes and coefficient restrictions to reflect the effects of upstream-downstream linkages and changes in terms of trade. CGE models may benefit from incorporation of large nontariff-driven effects, particularly in wood, machinery, transport, and electronic sectors.

Appendix: Derivation of the sectoral gravity equation

In this framework, monopolistically competitive firms produce varieties of goods in *K* industries. These varieties are distinguished by their country of origin, and there are *C* countries. The quantity demanded of a single variety of good *k* consumed in country *i* and produced in country *j* is given by c_{ij}^{k}.[37] As in standard monopolistic competition models, demand for each variety in country *i* is determined by the following: the c.i.f. price of this variety shipped from country *j*, denoted p_{ij}^{k}; the CES aggregate price index for industry *k*, denoted P_{i}^{k}; and the total expenditure on good *k*. Thus,

$$\textbf{(8)} \qquad c_{ij}^{k} = \frac{(p_{ij}^{k})^{-\sigma} D_{ij}^{k} \mu^{k} Y_{i}}{(P_{i}^{k})^{1-\sigma}},$$

where μ^{k} is the fraction of income spent on industry *k*, which is the same for all countries, and Y_{i} is country *i*'s GDP. A less common feature of this demand equation is the presence of the demand shifter D_{ij}^{k}, which incorporates non-price elements that alter demand for foreign goods. With the incorporation of the demand shifter, the CES price index is defined as

$$\textbf{(9)} \qquad (P_{i}^{k})^{1-\sigma} = \sum_{j} D_{ij}^{k} n_{j}^{k} (p_{ij}^{k})^{1-\sigma}.$$

[37] Throughout, lowercase denotes variables for each variety, and uppercase denotes national or industry variables.

The f.o.b. price of a variety in industry k produced in exporter j is given by p_j^k. The c.i.f. and f.o.b. prices are related by

$$\textbf{(10)} \qquad p_{ij}^k = p_j^k T_{ij}^k ,$$

where T_{ij}^k is the ad valorem equivalent of trade costs from j to i in industry k.[38]

For each variety, output is the sum of the amounts shipped to each country, which must take into account the quantities "lost" in shipping, so that $y_j^k = \sum_i c_{ij}^k T_{ij}^k$. Multiplying by prices generates C market clearing conditions for each industry such that the value of firm production is equal to the value of world consumption, or

$$\textbf{(11)} \qquad p_j^k y_j^k = \sum_i c_{ij}^k p_j^k T_{ij}^k .$$

If trade costs and demand shifters are symmetric, so that $T_{ij}^k = T_{ji}^k$ and $D_{ij}^k = D_{ji}^k$, the solution to the C market clearing conditions for each industry in (11) is given by

$$\textbf{(12)} \qquad p_j^k = \left(\frac{s_j^k}{D_{ij}^k n_j^k} \right)^{\frac{1}{1-\sigma}} / P_j^k , \text{ and}$$

$$\textbf{(13)} \qquad (P_i^k)^{1-\sigma} = \sum_j s_j^k \left(\frac{T_{ij}^k}{P_j^k} \right)^{1-\sigma} ,$$

where $s_j^k = \dfrac{Y_j^k}{\mu^k Y_w} = \dfrac{Y_j^k}{Y_w^k}$,

which is the share of world output of good k produced in country j, and n_j^k is the number of varieties produced in industry k in country j.[39]

[38] T is referred to as an iceberg transportation cost, because the fraction T-1 of the good "melts" during shipping.
[39] The proof follows Feenstra (2004).

To generate the gravity equation, we need the equation for bilateral sectoral imports by country *i* from country *j*, M_{ij}^{k}. Assuming that all firms in the same industry within a country produce at the same price and quantity, $M_{ij}^{k} = n_j^k p_{ij}^k c_{ij}^k$. Substituting (8), (10), and (12) into this equation for M_{ij}^{k} produces the gravity equation:

$$\textbf{(14)} \qquad M_{ij}^{k} = \alpha\, Y_i Y_j^k D_{ij}^k \left(\frac{T_{ij}^k}{P_i^k P_j^k} \right)^{1-\sigma},$$

where $\alpha = 1/Y_w$.

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Table 1 Symmetric specification: Pooled results

Regression	Δ Importer GDP		Δ Exporter Output		Bilateral pair				Multilateral Resistance				Obs.
					Δ Tariffs		Δ FTA		Δ Tariffs		Δ FTA		
	β_2	t	β_3	t	β_4	t	β_5	t	β_6	t	β_7	t	
OLS	0.996	46.66	0.260	28.70	-1.318	-16.72	0.269	11.52	2.481	11.80	-1.032	-20.05	87,177
0.25 quantile	0.846	38.56	0.259	26.77	-1.001	-11.72	0.215	8.91	1.817	8.30	-0.152	-2.91	87,177
0.50 quantile	0.883	54.32	0.268	38.82	-0.929	-15.53	0.187	10.50	1.457	9.11	-0.568	-14.49	87,177
0.75 quantile	1.077	37.74	0.267	20.63	-1.324	-12.25	0.300	9.82	2.702	9.44	-1.602	-22.54	87,177

Notes: Dependent variable is the change in the log of bilateral sectoral imports. Importer GDP and exporter sectoral gross output are in logs. The constant is not reported. The symmetric specification uses an unweighted average of tariffs and FTAs in the multilateral terms, without weighting by importer GDP or exporter gross output.

Table 2 Symmetric specification: Sectoral results

Sector	Δ Importer GDP		Δ Exporter Output		Bilateral				Multilateral				Obs.
					Δ Tariffs		Δ FTA		Δ Tariffs		Δ FTA		
	β_2	t	β_3	t	β_4	t	β_5	t	β_6	t	β_7	t	
Food products	1.14	12.47	0.27	4.99	-0.68	-2.89	0.15	1.48	0.67	0.86	-1.12	-4.87	4,482
Beverages	1.22	9.11	0.13	1.42	-0.79	-3.49	0.24	1.85	1.47	1.84	0.32	0.88	2,414
Textiles	1.00	10.99	0.33	8.01	-1.43	-4.45	0.28	2.66	1.19	1.32	-1.97	-8.16	4,623
Wearing apparel	1.39	13.23	0.31	8.57	-1.28	-4.00	0.31	2.81	1.03	1.44	-1.22	-4.97	3,666
Leather products	1.35	11.02	0.11	3.05	-3.53	-7.61	0.04	0.31	4.82	4.52	-0.96	-3.14	3,037
Footwear	1.25	8.60	0.31	5.97	-2.67	-5.54	0.21	1.51	4.13	2.86	-2.21	-5.89	2,274
Wood products	1.20	10.79	-0.02	-0.33	-2.28	-4.86	0.28	2.48	3.65	2.42	-1.19	-3.85	3,431
Furniture	1.18	9.95	0.19	4.16	-1.52	-3.33	0.37	3.08	5.74	4.83	-0.24	-0.75	3,069
Paper products	0.88	7.84	0.42	6.32	-3.17	-6.44	0.40	3.37	8.16	6.49	-1.20	-4.33	3,382
Printing, publishing	0.88	8.71	0.29	5.07	-1.62	-3.97	0.16	1.52	5.95	4.35	-1.18	-4.77	3,713
Industrial chemicals	0.79	8.39	0.35	7.04	-0.58	-1.22	0.10	0.93	2.25	2.36	-1.81	-8.17	3,943
Other chemicals	0.76	8.42	0.12	3.14	-0.83	-2.21	0.22	2.04	2.42	2.24	-0.64	-3.09	3,736
Rubber products	0.88	8.79	0.24	4.28	-0.55	-1.25	0.22	2.09	-0.30	-0.24	-1.01	-4.01	3,462
Plastic products	0.88	8.74	0.23	4.49	-0.72	-1.73	0.38	3.59	1.20	1.14	-1.16	-5.07	3,509
Pottery and china	0.97	7.16	0.27	4.80	-1.08	-1.89	0.37	2.69	6.70	3.94	-1.21	-3.81	2,098
Glass products	1.24	11.31	0.24	4.05	-1.25	-2.70	0.28	2.36	3.33	2.44	-0.96	-3.61	3,062
Mineral products	1.05	8.87	0.14	3.00	-1.92	-3.72	0.06	0.42	7.77	4.57	-0.79	-2.67	2,721
Iron and steel	0.86	6.42	0.27	3.35	-0.38	-0.62	0.17	1.12	0.58	0.36	-1.14	-3.79	2,870
Non-ferrous metals	0.92	7.16	0.06	1.16	-1.56	-2.27	0.19	1.46	2.65	1.98	-0.67	-2.27	2,605
Fabricated metal	0.96	10.75	0.18	4.37	-0.53	-1.26	0.31	3.02	2.27	2.30	-0.51	-2.42	4,237
Non-electric machinery	0.93	10.70	0.40	13.22	-2.13	-5.31	0.36	3.44	4.88	5.10	-1.30	-6.27	4,740
Electric machinery	0.76	7.91	0.39	8.03	-1.77	-4.27	0.44	3.89	4.07	3.92	-0.71	-3.01	4,665
Transport equipment	1.05	8.02	0.36	5.27	-1.45	-3.51	0.52	3.57	5.18	3.79	-0.12	-0.39	3,851
Electronic equipment	0.60	6.69	0.13	3.95	-0.43	-0.93	0.32	3.23	4.20	2.97	-0.79	-3.77	3,732
Other manufacturing	1.15	12.16	0.11	3.42	-1.22	-3.44	0.29	2.76	0.41	0.42	-1.86	-8.07	3,855

Table 3 Asymmetric specification: Pooled results

Regression	Δ Importer GDP		Δ Exporter Output		Bilateral Δ Tariffs		Bilateral Δ FTA		Multilateral Δ Tariffs		Multilateral Δ FTA		Obs.
	β_2	t	β_3	t	β_4	t	β_5	t	β_6	t	β_7	t	
OLS	1.104	52.81	0.274	30.18	-1.793	-20.29	0.132	5.50	1.978	14.34	0.007	0.17	87,177
0.25 quantile	0.885	44.90	0.264	29.71	-1.040	-11.80	0.174	7.59	0.838	6.24	0.069	1.70	87,177
0.50 quantile	0.952	61.16	0.283	41.98	-1.492	-22.67	0.083	4.62	1.591	15.50	0.112	3.64	87,177
0.75 quantile	1.249	47.29	0.284	23.11	-2.125	-17.56	0.069	2.28	2.680	14.39	0.006	0.12	87,177

Notes: Dependent variable is the change in the log of bilateral sectoral imports. Importer GDP and exporter sectoral gross output are in logs. The constant is not reported. The asymmetric specification weights the multilateral terms by the world GDP share of each importer and world gross output share of each producer.

Table 4 Asymmetric specification: Sectoral results

Sector	Δ Importer GDP		Δ Exporter Output		Bilateral Δ Tariffs		Bilateral Δ FTA		Multilateral Δ Tariffs		Multilateral Δ FTA		Obs.
	β_2	t	β_3	t	β_4	t	β_5	t	β_6	t	β_7	t	
Food products	1.22	13.75	0.29	5.49	-0.85	-3.51	0.04	0.41	1.13	2.43	-0.07	-0.41	4,482
Beverages	1.20	9.07	0.09	1.02	-0.94	-3.82	0.22	1.72	0.98	2.34	0.27	1.31	2,414
Textiles	1.08	12.15	0.35	8.42	-2.26	-6.74	0.13	1.24	2.80	4.60	-0.49	-2.76	4,623
Wearing apparel	1.52	14.84	0.34	9.65	-1.69	-4.62	0.14	1.18	1.23	2.23	0.03	0.16	3,666
Leather products	1.48	12.32	0.08	2.33	-3.79	-7.80	-0.09	-0.73	3.55	4.37	-0.05	-0.23	3,037
Footwear	1.50	10.52	0.37	7.09	-2.30	-4.39	0.20	1.28	1.57	1.87	-0.77	-3.26	2,274
Wood products	1.34	12.28	-0.06	-1.07	-3.75	-7.47	0.13	1.09	5.04	6.06	-0.06	-0.24	3,431
Furniture	1.29	11.09	0.20	4.55	-2.54	-4.10	0.42	3.36	3.61	4.03	-0.55	-2.60	3,069
Paper products	1.02	9.17	0.44	6.61	-4.21	-7.49	0.31	2.62	4.90	6.81	-0.38	-1.85	3,382
Printing and publishing	1.10	11.30	0.30	5.32	-1.25	-2.80	0.01	0.13	1.22	1.57	0.14	0.75	3,713
Industrial chemicals	0.98	10.61	0.40	7.97	-2.17	-3.87	-0.08	-0.73	3.19	4.18	-0.37	-2.03	3,943
Other chemicals	0.83	9.49	0.12	3.38	-0.68	-1.69	0.07	0.65	0.35	0.54	0.38	2.29	3,736
Rubber products	0.95	9.59	0.31	5.78	-0.98	-1.76	0.01	0.08	0.31	0.36	0.43	2.03	3,462
Plastic products	1.03	10.56	0.26	5.15	-2.49	-4.98	0.15	1.40	3.39	4.78	0.19	0.89	3,509
Pottery and china	1.18	8.90	0.31	5.44	-0.49	-0.76	0.30	2.10	1.15	1.09	-0.24	-0.98	2,098
Glass products	1.35	12.59	0.26	4.37	-2.16	-3.94	0.24	1.94	3.07	3.39	-0.48	-2.16	3,062
Mineral products	1.16	9.82	0.19	4.13	-1.97	-3.33	-0.01	-0.10	2.97	3.03	-0.14	-0.56	2,721
Iron and steel	0.91	6.93	0.30	3.75	-2.04	-2.79	-0.05	-0.30	3.24	2.77	0.19	0.66	2,870
Non-ferrous metals	0.98	7.75	0.06	1.15	-3.53	-4.39	0.17	1.26	5.50	4.27	-0.51	-1.93	2,605
Metal products	0.99	11.34	0.19	4.48	-1.87	-3.55	0.05	0.47	3.14	4.16	0.78	4.32	4,237
Non-electric machinery	1.05	12.14	0.42	14.00	-2.79	-5.69	0.17	1.54	3.19	4.53	0.13	0.72	4,740
Electric machinery	0.85	9.06	0.39	8.04	-1.81	-3.70	0.22	1.93	1.92	2.78	0.70	3.51	4,665
Transport equipment	1.11	8.67	0.34	4.96	-1.41	-3.27	0.38	2.55	1.74	2.41	0.62	2.29	3,851
Electronic equipment	0.70	8.08	0.13	3.94	-0.45	-0.81	0.13	1.34	1.14	1.55	0.42	2.39	3,732
Other manufacturing	1.32	14.30	0.11	3.58	-1.94	-4.77	0.02	0.20	1.17	1.93	0.16	0.78	3,855

Table 5 U.S.-Korea FTA: Estimated change in U.S. and Korean bilateral imports, percent and significance

Sector	Change in U.S. imports from Korea due to:						Change in Korean imports from U.S. due to:					
	Tariffs		Nontariff FTA		Total		Tariffs		Nontariff FTA		Total	
	%	t	%	t	%	t	%	t	%	t	%	t
Food products	2.23	2.22	2.01	0.20	4.24	0.41	11.43	2.28	2.16	0.21	13.59	1.21
Beverages	6.18	3.15	31.38	2.49	37.57	2.96	13.90	3.48	29.02	2.36	42.93	3.36
Textiles	13.02	5.31	-4.30	-0.41	8.72	0.81	13.15	6.38	2.35	0.23	15.50	1.52
Wearing apparel	15.18	4.86	15.00	1.36	30.18	2.69	14.81	4.93	14.78	1.37	29.59	2.71
Leather products	23.20	7.23	-11.02	-0.89	12.18	0.97	17.88	7.95	-9.84	-0.81	8.05	0.66
Footwear	20.09	4.25	-7.30	-0.54	12.79	0.94	26.41	4.49	12.88	0.89	39.29	2.73
Wood products	5.28	5.43	10.96	0.96	16.23	1.42	11.69	5.33	10.93	0.95	22.62	1.95
Furniture	1.35	3.11	23.81	2.07	25.17	2.19	6.32	2.76	21.45	1.83	27.77	2.37
Paper products	4.32	6.54	18.47	1.53	22.79	1.89	7.92	6.40	17.80	1.46	25.72	2.11
Printing and publishing	0.36	2.41	5.97	0.57	6.33	0.61	0.85	2.65	4.61	0.45	5.46	0.53
Industrial chemicals	1.81	2.78	-21.42	-1.95	-19.61	-1.78	7.52	2.94	-19.83	-1.83	-12.30	-1.12
Other chemicals	1.14	1.81	19.58	1.87	20.72	1.98	3.88	1.79	20.41	1.94	24.29	2.28
Rubber products	1.34	2.36	15.42	1.44	16.75	1.57	6.75	2.22	11.57	1.12	18.32	1.75
Plastic products	5.06	3.81	21.52	2.02	26.58	2.50	10.42	3.81	21.42	2.01	31.84	2.96
Pottery and china	0.84	0.23	22.58	1.65	23.43	1.71	2.47	0.57	26.82	1.98	29.29	2.16
Glass products	0.16	3.52	7.92	0.68	8.09	0.69	10.05	3.45	12.89	1.13	22.95	2.00
Mineral products	0.48	2.44	-5.98	-0.45	-5.50	-0.41	8.93	2.71	-4.76	-0.37	4.18	0.32
Iron and steel	0.68	1.80	2.33	0.15	3.01	0.20	10.39	2.45	-1.15	-0.08	9.24	0.63
Non-ferrous metals	1.27	3.28	-0.25	-0.02	1.01	0.08	7.35	3.68	3.69	0.29	11.03	0.85
Metal products	0.62	2.42	30.88	3.06	31.50	3.12	6.13	2.38	29.33	2.92	35.46	3.48
Non-electric machinery	0.19	5.49	21.29	2.02	21.47	2.04	8.90	5.29	20.51	1.99	29.41	2.83
Electric machinery	0.79	3.36	47.15	4.11	47.94	4.18	2.01	3.56	40.55	3.68	42.55	3.87
Transport equipment	0.42	2.24	58.45	4.10	58.88	4.13	3.08	2.29	56.57	4.02	59.65	4.24
Electronic equipment	0.03	0.56	26.65	2.72	26.68	2.72	-0.37	-0.21	32.31	3.04	31.94	2.97
Other manufacturing	4.91	5.35	7.55	0.72	12.46	1.18	3.85	5.34	8.09	0.75	11.94	1.11

Table 6 Change in U.S. imports from Korea: Comparison of GTAP and gravity results, percent and significance

Sector	GTAP		Gravity				
	U.S. Tariff rate	Import change, percent	U.S. Tariff rate	Tariff-driven import change		Total import change	
				Percent	t	Percent	t
Food products	4.71	234.69	4.59	2.23	2.22	4.24	0.41
Beverages and tobacco[a]	3.32	14.16	10.09	6.18	3.15	37.57	2.96
Textiles	11.00	101.28	10.32	13.02	5.31	8.72	0.81
Wearing apparel	15.07	157.44	12.04	15.18	4.86	30.18	2.69
Leather products and footwear	11.14	169.33	10.16	21.91	5.99	12.43	0.95
Wood products and furniture	0.46	-1.21	1.07	1.66	3.29	24.47	2.13
Paper, printing, and publishing	0.33	-2.91	1.41	3.52	5.70	19.45	1.63
Chemical, rubber, plastic products	3.04	20.09	1.86	1.96	2.72	-3.89	-0.33
Mineral products	2.10	7.15	0.75	0.45	2.48	-2.10	-0.15
Iron and steel	1.25	2.17	0.75	0.68	1.80	3.01	0.20
Non-ferrous metals	2.38	17.85	0.75	1.27	3.28	1.01	0.08
Metal products	2.42	10.90	0.69	0.62	2.42	31.50	3.12
Machinery and equipment	1.50	6.02	0.45	0.55	4.22	37.26	3.32
Transport equipment and parts	2.31	8.32	0.50	0.42	2.24	58.88	4.13
Electronic equipment	0.21	-1.86	0.11	0.03	0.56	26.68	2.72
Other manufacturing	4.09	27.14	3.16	4.91	5.35	12.46	1.18

Notes:
[a] Gravity results do not include tobacco