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Revisiting Armington and AIDS: How Sensitive Simulated Pattern of Trade is to Functional Form Choices?

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Abstract

Most applied general equilibrium (AGE) and partial equilibrium (PE) models use the Armington approach to represent the trade specification of their models. In the context of analyzing the impact of economic changes in trade policies, it is important what type of specification is used in the trade structure of such models. It may be plausible to use functional forms such as the Constant Elasticity of Substitution (CES) based Armington specification for relatively homogeneous aggregated goods like cereals (or other agricultural goods), but its restrictiveness makes it less satisfactory when examining the trade relationships for more complex and heterogenous aggregated goods such as electronics (or other manufacturing goods). Almost Ideal Demand System (AIDS) is a flexible functional form, and incorporating such a demand system into a trade specification makes more sense for electronic goods where complementary trading relationships could be more prevalent. This paper compares the Armington specification with the AIDS specification for electronic goods using comparatives tatic analysis. The effect of change in price and income over global patterns of trade are examined. The results show that using different specifications of the trade structure in economic models can significantly alter the simulated patterns of trade, both in terms of magnitude and direction of changes in trade flows.

Keywords: Armington; Constant elasticity of substitution; Almost ideal demand system Comparative statics

Introduction

Applied General Equilibrium (AGE) and Partial Equilibrium (PE) models are widely used economic policy modeling and analysis frameworks. The choice of functional forms in the trade specification of such models is important in analyzing trade policy reform scenarios. In the trade structure of those AGE and PE models that use the Armington approach, the goods[1] are first differentiated into domestic and foreign goods, and then foreign goods are differentiated by the country of origin shown in Figure 1. The Armington specification is based on a relatively simple functional form: the Constant Elasticity of Substitution (CES) function. The characteristics of the CES function are that it has a single elasticity of substitution and is homothetic. The main advantage of the Armington specification is that it is parsimonious in parameters that have to be estimated, which is often important in analyses of international trade where data are limited. However, the restrictiveness of the CES function can mean that estimated parameters are biased in certain cases. As a consequence, in some instances CES-based models may not accurately capture the response of import demand to changes in prices and incomes. Despite the restrictiveness of the Armington specification, it is still widely used within the AGE and PE modeling frameworks due to its simplicity, easy use and global regularity properties.

By contrast, parametrically more generous flexible functional forms can reduce the risk of biased parameter estimates. A number of studies have criticized the Armington specification on the basis of its restrictiveness and homothetic nature of the CES-based functional form [1,2]. Other studies have suggested that Deaton and Muellbauer's AIDS specification could be a preferable alternative to the Armington specification [3-6]. The AIDS specification is a locally flexible functional form with a considerably richer parameterization than the CES-based Armington specification. The number of parameters in the AIDS specification, as in other flexible functional forms, depends on the number of trading partners, while the number of parameters in the CES specification does not depend on the number of trading partners. If data is limited, the estimation of the parameters of AIDS specifications of trade models with rich representations of bilateral trade relationships (i.e., including many countries) may not be possible[2]. The use of the AIDS specification allows for the estimation of the parameters without imposing restrictions on the nature of the substitution or complementarity relationships between pairs of goods from different geographic origins. A flexible functional form such as the AIDS when compared with the more restrictive CES-based Armington functional form can be expected to display more realistic responses to price and income changes.

The Armington specification automatically satisfies all of the properties of the demand theory (adding up, homogeneity, symmetry and concavity), that is, no additional parametric restrictions need to be imposed in estimating the functional form. However, in estimating the AIDS specification parametric restrictions are required for it to satisfy microeconomic theory. Adding up, homogeneity and symmetry restrictions can be easily imposed by using equality restrictions on the parameters of the model; however, concavity restrictions are more difficult to impose. Moschini and Ryanand Wales utilize the Cholesky decomposition approach suggested by Lau to impose concavity conditions at one point. To incorporate flexible functional forms like

[1]AGE and PE generally use highly aggregated goods. For instance, cereals are an aggregation of rice, wheat, maize, barley, rye and other grains. Electronics is an aggregation of diodes, semiconductors, radio, television, communication, equipment, computing and machinery etc.

[2] However, the Generalized Maximum Entropy methods allow for the estimation of import demand systems even where the number of parameters to be estimated is larger than the number of observations

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AIDS in AGE or PE models, all the properties of the demand theory have to be satisfied [7-9].

The added value of incorporating parameters based on AIDS estimation into the AGE or PE model is obvious when the goods in question are part of a heterogeneous category such as electronics. In this instance, it makes sense that the pairwise relationship between imports of such goods from different countries could just as easily be complementary as substitutable. A trade model based on Armington specification could yield misleading outcomes in that it would be incapable of capturing such complementaries as may plausibly exist. By contrast, when the goods in question are from a more homogeneous category, such as cereals, the compromises involved in using Armington are less obvious since it is reasonable to expect imports of such goods from different countries to be substitutes. However, we would argue that even in this case, there is still a benefit to be gained from the application of a less restrictive demand system. Rather obviously, it can capture asymmetries that may exist (all countries' goods may not be identically substitutable), which the Armington specification cannot do. However, more fundamentally, the fact that an AIDS-based system can yield unexpected results (such as a complementary relationship between imports of cereals from different countries) is, as we would contend, positive for the research process. Unexpected results that challenge one's prior expectations compel the researcher to engage in more depth with the social material being investigated in order to understand apparent paradoxes. The outcome should be the models that do a better job at explaining the complexity of global trading relationships.

When using AGE and PE models to undertake trade policy analysis, it is important that economists and policy analysts understand the implications of using different functional forms to represent the trade structure of the models. This paper applies comparative static analysis to highlight the differences in predictions that arise between Armington and AIDS-based trade models, where trade in electronic goods is concerned. A model of global electronic goods trade is used to examine the sensitivity of the simulated impact of prices and income changes. Comparative static analysis is a simple yet useful tool to understand the important questions regarding how patterns of trade change with changes in prices and income. Readers should note that the analysis in this paper focuses on the demand side of the trade structure and does not examine supply side issues and that consequently prices in our comparative static analysis are treated as exogenous. The comparative static formulation of the Armington and the AIDS specification is derived in the next section. Data and parameters are described in the third section. The results and analysis are shown in the fourth section and conclusions are discussed in the fifth section.

Theoretical Framework

The utility tree shown in Figure 1 has three levels. At first level, utility is attained from the consumption of different goods. In the next two levels of the utility tree, one can find the commonly used structure in the most AGE and PE model for demands of a good p. usually; a CES function is used at these two levels and is well known as the two-level nested Armington approach. The general specification of the utility function of each country k that consumes p goods can be represented as

$$U^{k} = f(X^{1k}, X^{2k}, ... \mathrm{X}^{\mathrm{pk}})$$

$$s.t. \sum_{p} P^{pk} X^{pk} = \mu^{k} \tag{1}$$

At second level, goods are separated into domestically produced X^{pDk} and composite imported versions of the foreign goods X^{pFk}, and at third level, the demand for composite imported goods are further differentiated across different countries of origin. Separability of domestic and composite imported goods is assumed in this paper even though this assumption has been criticized by Winters [3]. This is mainly due to the unavailability of domestic goods data, and analysis takes place only at the third level of the utility tree. This two-level separability structure for demand for a given good p can be represented by the following sub-utility functions:

$$X^{Pk} = f(X^{pFk}, \mathrm{X}^{\mathrm{pDk}})$$

$$s.t. P^{pFk} X^{pFk} + P^{pDk} X^{pDk} = \mu^{pk} \tag{2}$$

$$X^{pFk} = f(\mathrm{X}_{1}^{pFk}, \mathrm{X}_{2}^{pFk}, ...\mathrm{X}_{m}^{pFk})$$

$$s.t. \sum_{i} P^{pFk} X^{pFk} = \mu^{pFk} \tag{3}$$

Armington specification

The Armington specification is based on two papers [10,11]. In the first paper, Armington used the CES function to derive a comparative static formulation of an import demand system[3]. In the second paper, Armington used the CES based import demand system in a quantitative model of how prices affect the geographical pattern of trade. The key innovation of Armington's trade specification is that it allows for bilateral trade flows by differentiating goods on the basis of their country of origin, hence allowing for imperfect substitution between these imported goods. For instance, electronic goods from Japan are considered as different from electronic goods from China. The traditional trade theory, like the Heckshe-Ohlin model, assumes that the product of a given kind supplied by one country is perfectly substitutable by the same kind product supplied by another country; hence trade flows are determined by comparative advantage of products. For instance, if Japan and China produce cars and bicycles, it is only possible for Japan to either export cars to China, import bicycles from China or import cars from China and export bicycles to China. However, in bilateral trade statistics, it is observed that countries both export and import the same product simultaneously. The Armington specification allows one to explain such cross hauling of similar products that occur. Another important feature of the CES function is its analytical tractability and the relatively limited data requirements that are needed to estimate the Armington import demand system. "The CES approach has some restrictive assumptions in its functional form leading to a specification of the product demand functions which, though highly simplified, preserves the relationships between demand, income and prices that are apt to be quantitatively significant"[10,11]. The CES function was proposed by Arrow *et al.* as a production function specification where there are two inputs, labor 'L' and capital 'K', used to produce output 'Q'[12].

The equation 3 can be represented with the Armington specification as

$$X^{pFk} = \left[\sum_{i} \beta_{i}^{pFk} (X_{i}^{pFk})^{-pFk} \right]^{\frac{1}{-pFk}}$$

$$s.t. \sum_{i} P_{i}^{pFk} X_{i}^{pFk} = \mu^{pFK} \tag{4}$$

[3]The CES function was proposed by Arrow *et al.* as a production function specification where there are two inputs, labor 'L' and capital 'K', used to produce output 'Q'. Later, this function was used to represent the demand system. It is plausible to use this function when there are two inputs in the production function or only two goods in the demand system. However, for more than two inputs or goods, the CES function will not be able to capture the realistic price effect.

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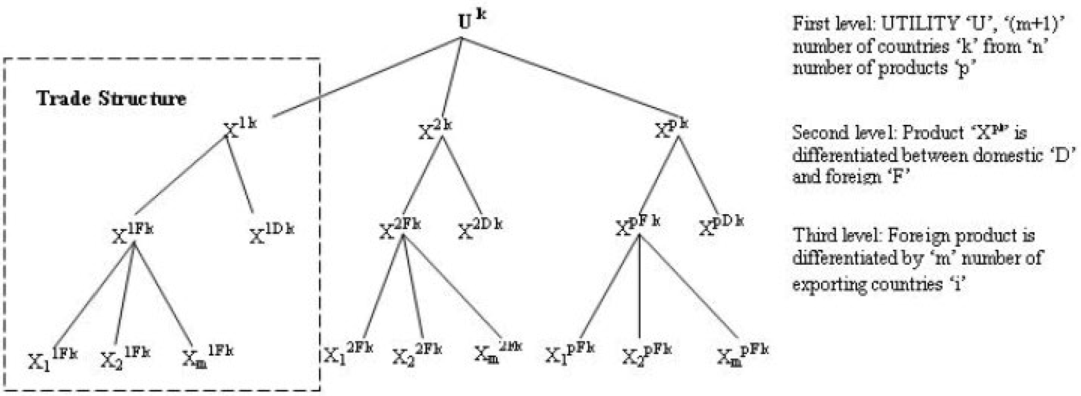

Figure 1: Utility tree.

With $p = (1, 2, ...n)$ products, $k = (1, 2, ...m, m+1)$ importing countries and $i = (1, 2, ...m)$ exporting countries. P^{pFk} is substitution parameter and β^{pFk} distribution parameter.

The n demand functions associated with the utility function in equation 1 can be represented as

$$X^{pk} = f(\mu^k, P^{1k}, P^{2k}......, P^{nk}) \quad (5)$$

The two demand functions associated with equation 3 can be represented as

$$X^{pFk} = f(\mu^{pk}, \mathrm{P}^{pFk}, \mathrm{P}^{pDk}) \quad (6)$$

and

$$X^{pDk} = f(\mu^{pk}, \mathrm{P}^{pFk}, \mathrm{P}^{pDk}) \quad (7)$$

The demand function, when the Armington specification is used to represent consumers' preferences across m different import sources (equation 4) is given by

$$\mathrm{X}^{pDk} = (\beta_i^{pFk})^{\sigma pFk} X^{pF} (\frac{P_i^{pFk}}{P^{pF}})^{-\sigma pFk} \quad (8)$$

and the substitution parameter is given by

$$\rho_i^{pFk} = \frac{1}{\sigma^{pFk}} - 1$$

$$\sigma^{pFk} = \frac{1}{1+\rho^{pFk}}$$

Where σ^{pFk} is the elasticity of substitution.

The elasticities of substitution of import demand in all countries for a given product between any two other countries are all constant and identical. The Armington specification is particularly parsimonious in parameters. For any one product p for $(m + 1)$ importing countries and m exporting countries, there is just one parameter to characterize the $m \times m \times (m + 1)$ price elasticities while due to the CES basis of the Armington import demand system all import demands are homothetic, i.e., the income elasticities are all equal to 1.

$$\sigma^{pF1} = \sigma^{pF2} = ... = \sigma^{pFm} = \sigma^{pFm+1} = \sigma^{pF}$$

Under the Armington specification the impact of price changes on international trade patterns is not just determined by the changes in relative prices but also by how readily importing countries can shift from one exporting country to another in response to changes in relative prices. This ease of substitution is reflected in the elasticities of substitution. "Elasticities of substitution relating to composite trade flows may depend on such factors as the commodity composition of trade, the degree and nature of trade restrictions, the importance of long term contracts, and traditional loyalties to particular products or particular sellers"[10].

For the comparative static formulation, total differentiation of equation 6 and partial derivative of equation 8 gives the following relationship.

$$\frac{d(P_i^{pFk}X_i^{pFk})}{P_i^{pFk}X_i^{pFk}} = \underbrace{\in^{pFk}}_{Income\ Effect}\frac{d\mu^{pK}}{\mu^{pK}} + \underbrace{\left[-(1-S_i^{pFk})(\sigma^{pFk}-1) - S_i^{pFk}(\eta^{pFk}-1)\right]}_{Direct\ Effect}\frac{dP_i^{pFk}}{P_i^{pFk}} + \underbrace{\sum_{j\neq i}\left[S_j^{pFk}(\sigma^{pFk}-1) - S_j^{pFk}(\eta^{pFk}-1)\right]}_{Indirect\ Effect}\frac{dP_j^{pFk}}{P_j^{pFk}} + \eta_D^{pFk}\frac{dP^{pDk}}{P^{pDk}} \quad (9)$$

Where $\in^{pFk} = \frac{\partial X^{pFk}/\partial\mu^{pk}}{X^{pFk}/\mu^{pk}}$ is the income elasticity of the demand for $X^{pFk}, \eta^{pFk} = \frac{\partial X^{pFk}/\partial P^{pFk}}{X^{pFk}/P^{pFk}}$ is the own price elasticity of demand for $X^{pFk}, \eta_D^{pFk} = \frac{\partial X^{pFk}/\partial P^{pDk}}{X^{pFk}/P^{pDk}}$ is the gross price elasticity of demand for X^{pFk} with respect to $P^{pDk}.\mathrm{S}_I^{pFk}$ is the market share of X_i^{pFk} in value terms and is given by $\mathrm{S}_I^{pFk} = \frac{P_i^{pFk}X_i^{pFk}}{P^{pFk}X^{pFk}}$. The first term in the equation 9 is income effect second term is direct price effect, third term is indirect price effect and fourth term is domestic price effect. The domestic price effect can be neglected as it is not considered in the simulation.

Almost ideal demand system (AIDS) specification

A less restrictive specification of the trade structure of import demand models that maintains the assumption of national product differentiation that characterizes the Armington specification is one which uses a flexible functional form such as the AIDS of Deaton and Muellbauer [6]. This functional form does not impose the constancy and pair-wise equality of elasticities of substitution that characterize the Armington specification. The AIDS uses the expenditure function which is the dual of the utility function to derive its associated demand system. The AIDS expenditure function is the following

$$\log C(\mathrm{u,P}) = \alpha_0 + \sum_k \alpha_k \log P_k + \frac{1}{2}\sum_k\sum_j \gamma_{kj}^* \log P_k \log P_j + u\beta_0 \prod_k P_k^{\beta k} \quad (10)$$

Where, P_k are the prices of k goods in the system. From Shephard's lemma the price derivative of the cost function gives quantity demanded X_i; multiplying both side by $\frac{P_i}{C(u,P)}$ and assuming utility maximization the following demand functions in terms of prices (P_i) and expenditure (μ) can be derived:

$$\frac{P_i}{C(u,P)}$$

$$\frac{P_i X_i}{C} = \alpha_i + \sum_j \gamma_{ij} \log P_j + \beta_i \log(\frac{\mu}{P}) \quad (11)$$

Where

$$\gamma_{ij} = -(\gamma^*_{ij} + \gamma^*_{ji})$$

$$\log P = \alpha_0 + \sum_k \alpha_k \log P_k + \frac{1}{2}\sum_j \sum_k \gamma_{kj} \log P_k \log P_j$$

Full details of the AIDS specification can be found in Deaton and Muellbauer [6]. The parameters of the AIDS specification are α_0, α_i, γ_{ij} and β_i. The β_i parameters of the AIDS determine whether goods are luxuries or necessities. With $\beta_i > 0$, S_i increases with μ so that good i can be considered a luxury. Similarly, $\beta_i < 0$ for necessities.

The AIDS specification for the trade structure for each foreign product p^F of the importing country k from exporting countries i can thus be represented as follows

$$\frac{P_i^{pFk} X_i^{pFk}}{\mu^{pFk}} = \alpha_i^{pFk} + \sum_j \gamma_{ij}^{pFk} \log P_j^{pFk} + \beta_j^{pFk} \log(\frac{\mu^{pFk}}{P^{pFk}}) \quad (12)$$

Where $p = 1, 2, ..., n$ is the number of products, $k = 1, 2, ..., m + 1$ is the number of importing countries and $i, j = 1, 2, ..., m$ is the number of exporting countries. For $(m + 1)$ importing countries and m exporting countries, there are $1/2m \times (m + 5)(m + 1)$ parameters for $m \times m \times (m + 1)$ price elasticities and $m \times (m + 1)$ number of β parameters for $m \times (m + 1)$ income elasticities.

Microeconomic theory requires that consumer demand systems satisfy certain regularity conditions, namely that they add up, are symmetric and that the demand equations are homogeneous of degree 0 in prices and expenditure, as well as that the Slutsky substitution matrix associated with the consumer demand system be negative semi-definite. The adding up restriction requires that for all j

$$\sum_i \alpha_i^{pFk} = 1, \sum_i \beta_i^{pFk} = 0, \sum_i \gamma_{ij}^{pFk} = 0$$

The homogeneity restrictions requires that for all j

$$\sum_j \gamma_{ij}^{pFk} = 0$$

The symmetry restriction requires that δ_{ij}=0

$$\gamma_{ij}^{pFk} = \gamma_{ji}^{pFk}$$

The negative restriction is satisfied if Slutsky matrix l_{ij} is negative semi-definite or eigenvalues are all negative. Slutsky matrix can be written as

$$l_{ij}^{pFk} = \frac{K_{ij}^{pFk} \mu^{pFk}}{P_i^{pFk} P_j^{pFk}}$$

Where

$$K_{ij}^{pFk} = \gamma_{ij}^{pFk} + \beta_i^{pFk} \beta_j^{pFk} \log(\frac{\mu^{pFk}}{P^{pFk}}) - S_i^{pFk}\delta_{ij} + S_i^{pFk}\delta_j$$

Eigenvalues of Slutsky matrix k_{ij}^{pFk} have the same sign as those of matrix k_{ij}^{pFk}. So if matrix k_{ij}^{pFk} is negative semi-definite or all its eigenvalues are negative then the negativity condition is satisfied. Kronecker delta δ_{ij} is unity if $i = j$ and zero if $i \neq j$.

The generalized form of the AIDS specification is

$$X_i^{pFk} = f(\mu^{pFk}, P_1^{pFk}, P_2^{pFk}, ...P_j^{pFk}) \quad (13)$$

To undertake comparative static analysis we totally differentiate equation 13 and partial derivative of equation 12 to get equation 14. The details of the derivation of the equation can be found in Appendix I.

$$\frac{d(P_i^{pFk} X_i^{pFk})}{P_i^{pFk} X_i^{pFk}} = (1 + \frac{\beta_i^{pFk}}{S_i^{pFk}})\frac{d\mu^{pFk}}{\mu^{pFk}} + \sum_j \left[\frac{\gamma_{ij}^{pFk}}{S_i^{pFk}} - \frac{\beta_i^{pFk}}{S_i^{pFk}}(\alpha_j^{pFk} + \sum_l \gamma_{jl}^{pFk} \log P_l^{pFk})\right]\frac{dP_j^{pFk}}{P_j^{pFk}} \quad (14)$$

(Or)

$$\frac{d(P_i^{pFk} X_i^{pFk})}{P_i^{pFk} X_i^{pFk}} = \underbrace{(1 + \frac{\beta_i^{pFk}}{S_i^{pFk}})}_{IncomeEffect}\frac{d\mu^{pFk}}{\mu^{pFk}} + \underbrace{\left[\frac{\gamma_{ii}^{pFk}}{S_i^{pFk}} - \frac{\beta_i^{pFk}}{S_i^{pFk}}(\alpha_i^{pFk} + \sum_l \gamma_{il}^{pFk} \log P_l^{pFk})\right]\frac{dP_i^{pFk}}{P_i^{pFk}}}_{Direct\ Effect} + \underbrace{\sum_{j \neq i}\left[\frac{\gamma_{ij}^{pFk}}{S_i^{pFk}} - \frac{\beta_i^{pFk}}{S_i^{pFk}}(\alpha_j^{pFk} + \sum_l \gamma_{jl}^{pFk} \log P_l^{pFk})\right]\frac{dP_j^{pFk}}{P_j^{pFk}}}_{Indirect\ Effect} \quad (15)$$

The first term in Equation 15 is income effect, second term is direct price effect and third term is indirect price effect. The comparative static formulation for the Armington specification (Equation 5) and for the AIDS specification (Equation 15) is used to examine the effect of changes in price and income on patterns of trade in section 4.

Data and Parameters

The data for electronic goods used in this paper is GTAP Sectoral Classification (GSC2) No. 40 (which is the aggregation of International Standard Industrial Classification (ISIC) Rev.3 code no.30 and 32). It is mapped using the aggregation of Standard International Trade Commodity (SITC) Rev 3 data at 4 digit level from UN Comtrade database. The year 2008 is used as the baseline for the simulation. Electronic goods consists of a diverse range of goods from simple devices such as diodes, transistors, etc. to sophisticated equipment such a as digital automatic data processing machines, photocopying machines, etc. The regions selected are Brazil, China, DEDC (Group of Developed countries), India, Ireland, LDC (Group of Least Developed Countries), REU15 (Rest of EU15), REU27(Rest of EU 27), ROW (Rest of the World), UK and USA [4].

The elasticities of substitution parameter for the Armington specification is taken from the GTAP database that is 8.8 in our case, and own price elasticities of aggregated foreign demand are assumed 1 in all the regions. The parameters of AIDS specification are estimated using the Generalized Maximum Entropy (GME) method. This method

[4]Classification of countries in DEDC, LDC and ROW regions is considered as used by Horridge and Labrode (2008) for their TASTE program.

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is used to estimate import demand specifications such as the AIDS which is often not possible using conventional estimation methods due to limited data and multi-collinearity problems that characterize trade data. UNCOMTRADE yearly data from 1988 to 2008 is used to estimate the AIDS parameters. Adding-up, homogeneity, symmetry and local concavity conditions in parameters are imposed in the estimation procedure. Direct, indirect and income effect are calculated using those parameters.

A Comparative Static Analysis of Armington and AIDS Specifications

A comparative static formulation of the Armington and the AIDS specifications with parameters from GTAP and GME estimations is used for the electronic goods to illustrate the impact that the functional form choices have on the trade flows as the result of exogeneously changing the prices and incomes of selected regions. UN Comtrade data 2008 is used as the baseline for the simulation. In the simulation, the price of Chinese and ROW electronic goods has decreased by 20 and 10 percent, respectively. Developed (DEDC, Ireland, REU15, UK and USA), developing (Brazil, China, India, REU27 and ROW) and least developed regions (LDC) increase their expenditure in electronic goods by 10, 20 and 15 percent, respectively

Baseline

In 2008, the value of the world trade in electronic goods was 1.24 trillion US dollars. This trade has doubled in nominal terms between 1998 and 2008. Electronic goods trade now accounts for around 10% of total world exports, making it one of the important traded commodities [13]. Among the selected regions, ROW is the highest importer and exporter with total import and export values of 290 and 411 billion dollars, respectively. China is the second largest exporter and has seen the value of its exports increase by more than a factor of 8 between 1998 and 2008. China imports approximately 70% of its total imports from the ROW and ROW imports about 50% of its total imports from China. The LDC aggregation of countries is the smallest participant in the global electronic goods trade, with total import and export values of 1.96 and 0.098 billion dollars, respectively. Only China, Ireland and Rest of the World had trade surpluses in electronic goods in 2008. Refer to Table 1 for details.

Results and Analysis

The simulation results show that the world trade in electronic goods increases by 14.7% in the Armington specification and 35.8% in the AIDS specification. This increase in percentage in the Armington specification is due to the income effect, i.e., due to the increase in expenditure in electronic goods by regions. Only with the price effect, the percentage of world trade does not change. The decrease in the price of Chinese and ROW products increases the import demand for these products, i.e., due to direct effect, but the increase in import values have to be decreased from the other regions by the same amount, i.e., due to indirect effect. The change in global net import demand will be zero if only a change in prices is considered. The reason for this is that the elasticity of substitution is the same among regions in the Armington specification. However, the increase in world trade of electronic goods in the AIDS specification comes from both price and income effects. In the AIDS specification, both substitution and complementary effects to price changes can occur and, moreover, import demands are non-homothetic. It is seen that complementary and substitution relationships between different sources of imports in one country market can differ in another country market. For instance, Indian and Chinese electronic goods are substitutes in Brazil but complements in the UK's market. The AIDS specification, as a flexible functional form, has enough parameters to capture the own price, cross price and income effects.

China and ROW increase their total exports while exports for other regions decrease under the Armington specification. In the AIDS specification, China and ROW, as well as all the other regions increase their total exports shown in Figure 2. In the Armington specification, the Marshallian own price elasticities are negative and the cross price elasticities are positive. The positive cross price elasticities only allow for substitution relationships between imports of goods from different countries.

In the estimated AIDS specification, own price Marshallian elasticities are all negative and cross price elasticities are both positive and negative. The positive and negative cross price elasticities allow for both substitution and complementary relationships between import demands for goods from different countries.

In the AIDS specification, increase in export from countries other than China and ROW could arise for two reasons. Firstly, electronic

Exporting Countries	Importing Countries												
	Brazil	China	DEDC	India	Ireland	LDC	REU15	REU27	ROW	UK	USA	Total Export	Export %
Brazil	-	0.040	0.015	0.006	0.011	0.001	0.232	0.025	1.170	0.002	0.252	1.755	0.141
China	5.653	-	51.283	6.125	3.177	0.528	64.398	19.173	144.411	8.193	95.975	398.917	32.118
DEDC	0.720	32.066	-	0.759	0.474	0.230	19.568	4.634	45.823	3.196	21.852	129.322	10.412
India	0.040	0.093	0.360	-	0.003	0.067	0.662	0.381	1.975	0.071	0.500	4.152	0.334
Ireland	0.041	1.608	1.506	0.062	-	0.013	7.248	1.271	4.088	3.004	1.374	20.216	1.628
LDC	0.000	0.012	0.017	0.002	0.001	-	0.018	0.005	0.036	0.002	0.004	0.098	0.008
REU15	0.853	5.894	12.436	1.023	2.571	0.446	-	20.610	33.008	19.059	6.412	102.310	8.237
REU27	0.192	0.928	3.025	0.080	0.684	0.032	29.688	-	9.794	6.099	1.967	52.490	4.226
ROW	6.543	140.328	51.844	4.359	3.348	0.509	64.079	22.883	-	12.095	105.001	410.988	33.090
UK	0.060	0.582	1.402	0.117	2.161	0.051	11.252	2.013	3.451	-	1.698	22.786	1.835
USA	1.142	10.985	16.264	0.710	1.595	0.081	16.401	1.540	46.926	3.351	-	98.995	7.970
Total Import	15.246	192.536	138.151	13.243	14.026	1.957	213.547	72.536	290.681	55.071	235.036	1242.030	
Import %	1.227	15.502	11.123	1.066	1.129	0.158	17.193	5.840	23.404	4.434	18.924		

Note: '-'indicates that domestic consumption is not considered in this analysis.

Table 1: Electronic Goods Trade Matrix (billion US dollars), 2008

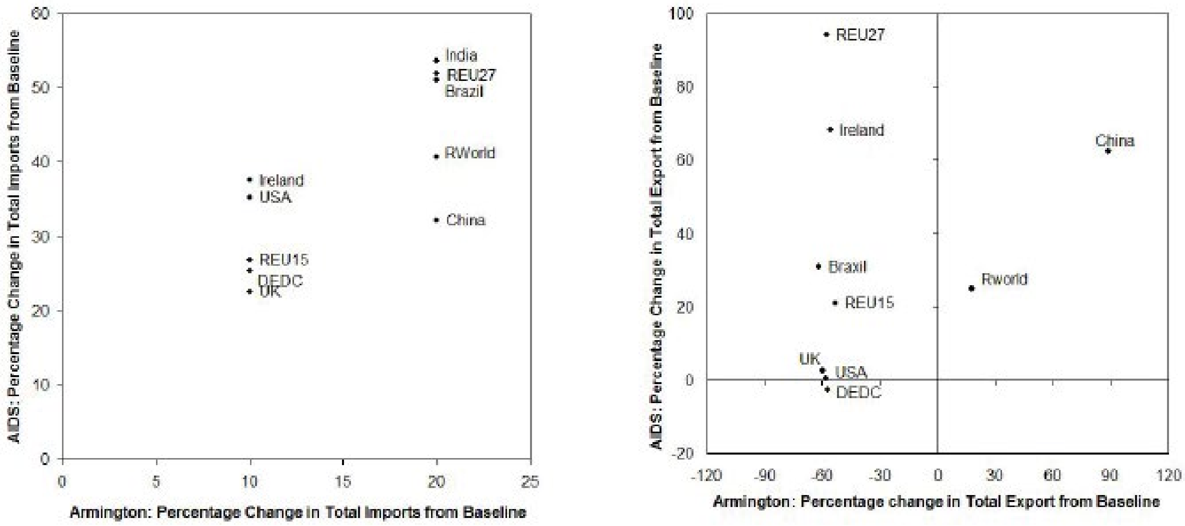

Figure 2: Percentage change in total imports and total exports from Baseline in Armington and AIDS specification.

goods from these countries are complementary to Chinese and ROW goods so that when prices of Chinese and ROW goods decrease, then imports from those countries increase. Secondly, when the regions increase their expenditure on electronic goods, they are likely to increase their import demand from these countries. China and ROW increase the percentage of export in all the countries. Ireland, DEDC, UK and USA are able to increase the percentage in some of their export markets and decrease in some other regions in the AIDS specification shown in Table 2. Brazil, India and LDC exit from some of their export markets in the AIDS specification. This may be due to a substituting away to Chinese and ROW goods and electronic goods from these countries (Brazil, India and LDC) are considered to be inferior goods in those markets. However, Brazil, India and LDC are able to increase the total export percentage as these countries are able to grow in some other export marketd and compensate for the losses they have to bear as a result of their exit from some of the other export markets. The results show that there are significant differences in the magnitude and the direction of trade flow changes under the two alternative trade structure specifications shown in Table 2 and Figure 3.

In the Armington specification, China increases and Brazil, DEDC, India, Ireland, LDC, REU15, REU27, UK and USA all decrease their exports to all regions. ROW increases its exports to all regions except the USA. This is because the decrease in the price of Chinese products has more of an effect than the decrease in price of ROW product on the import demand for ROW electronic goods in USA.

The results show that the percentage change in import demand of all the regions except China and ROW is the same, i.e., the percentage change in import trade values from DEDC, India, Ireland, LDC, REU15, REU27, UK and US to ROW is everywhere -57.5; to China it is everywhere -36.8, and so on Table 2. Again, this follows from the elasticity of substitution constancy characteristic of the Armington specification. By contrast the results show that under the AIDS specification effects are different for all regions as shown in Table 2.

All regions increase their total imports of electronic goods under both the Armington and AIDS trade structure specifications. The percentage increase in total imports in the Armington specification is the same as the increase in the percentage of expenditure on the electronic equipment, i.e., developed region imports increase by 10%, developing region imports increase by 20% and imports in least developed countries increase by 15%. Under the AIDS specification, total imports by Brazil, China, DEDC, India, Ireland, REU15, REU27, UK and USA increase by a higher percentage than their percentage of expenditure as shown in Figure 2. China's total share of the global electronic goods trade increases from 32% in the baseline to 52% in the simulation in the Armington specification. This large increase in China's share in the total electronic goods trade under the Armington specification is reflected in decreases in the shares of other regions in electronic goods trade. Under the Armington specification the share of DEDC in the global electronic goods trade decreases from 10.41 % under the baseline to 3.89%, while the share of REU15 decreases from 8.23% in the baseline to 3.35%. However, this is not the case in the AIDS specification; there are only slight changes in the total export shares.

In the baseline, China, ROW and Ireland have a trade surplus and all the other regions have trade deficits in electronic goods. The results shows that the trade surplus increases in China and ROW from the baseline but decreases in all the other regions for the Armington specification. In the AIDS specification, the simulation results show that the trade surplus from the baseline increases in China, ROW and Ireland, while it decreases in all the other regions except REU27. Increases or decreases in trade surplus (or deficit) from the baseline are moderate in the AIDS specification compared to the Armington specification as shown in Table 3. In DEDC, trade deficits have decreased by more than 9 times from the baseline in the Armington specification compared to mere 1.25 times in the AIDS specification. In China, trade surplus increases by 2.5 times from the baseline in the Armington specification and just by merely 1.09 times in the AIDS specification.

Conclusion

The simulation results show that the overall percentage increase in the world trade of electronic goods is higher under the AIDS specification than under the Armington specification for the simulated price and income shock. In addition, the Armington specification may

	Brazil	China	DEDC	India	Ireland	LDC	REU15	REU27	ROW	UK	USA	Total Export
Armington Specification												
Brazil	-	-36.850	-77.179	-77.826	-43.955	-57.333	-60.449	-45.842	-57.501	-30.338	-88.548	-61.836
China	84.670	-	78.821	78.174	112.045	98.667	95.551	110.158	98.499	125.662	67.452	88.755
DEDC	-71.330	-36.850	-	-77.826	-43.955	-57.333	-60.449	-45.842	-57.501	-30.338	-88.548	-57.112
India	-71.330	-36.850	-77.179	-	-43.955	-57.333	-60.449	-45.842	-57.501	-30.338	-88.548	-61.378
Ireland	-71.330	-36.850	-77.179	-77.826	-	-57.333	-60.449	-45.842	-57.501	-30.338	-88.548	-55.806
LDC	-71.330	-36.850	-77.179	-77.826	-43.955	-	-60.449	-45.842	-57.501	-30.338	-88.548	-59.411
REU15	-71.330	-36.850	-77.179	-77.826	-43.955	-57.333	-	-45.842	-57.501	-30.338	-88.548	-53.174
REU27	-71.330	-36.850	-77.179	-77.826	-43.955	-57.333	-60.449	-	-57.501	-30.338	-88.548	-57.844
ROW	6.670	41.150	0.821	0.174	34.045	20.667	17.551	32.158	-	47.662	-10.548	17.812
UK	-71.330	-36.850	-77.179	-77.826	-43.955	-57.333	-60.449	-45.842	-57.501	-	-88.548	-59.757
USA	-71.330	-36.850	-77.179	-77.826	-43.955	-57.333	-60.449	-45.842	-57.501	-30.338	-	-57.909
Total Import	20.000	20.000	10.000	20.000	10.000	15.000	10.000	20.000	20.000	10.000	10.000	14.712
AIDS Specification												
Brazil	-	-100.000	-100.000	-100.000	-100.000	-100.000	194.736	550.421	-100.000	1030.997	468.239	31.024
China	66.951	-	40.538	95.813	105.621	147.322	45.075	85.274	59.109	55.225	82.076	62.321
DEDC	-12.920	-3.978	-	-9.012	-45.284	-48.118	-0.131	10.585	6.695	-9.013	-21.902	-2.555
India	-100.000	-100.000	-100.000	-	98.344	1692.019	-100.000	2735.822	-100.000	608.135	-100.000	201.602
Ireland	18.464	414.490	-35.986	302.630	-	13.321	10.452	125.070	136.346	0.118	-32.303	68.267
LDC	-100.000	2450.954	10457.202	520.941	-100.000	-	24.638	9179.995	511.470	-100.000	-100.000	2835.990
REU15	23.579	-9.634	16.334	21.765	18.384	3644.235	-	2.731	8.785	16.224	-59.062	20.890
REU27	149.412	-100.000	139.921	294.099	104.079	25.372	73.910	-	195.374	71.068	-27.189	94.159
ROW	56.286	41.293	14.348	16.201	33.705	213.809	12.965	38.270	-	5.580	11.951	24.886
UK	282.172	-2.582	8.528	-15.708	4.514	-28.645	-2.071	-33.094	23.455	-	20.265	2.602
USA	-18.292	-1.125	-2.535	-5.515	-17.311	-24.035	-13.782	-30.484	9.752	-11.290	-	0.392
Total Import	51.104	32.126	25.406	53.618	37.544	976.69	26.838	51.909	40.753	22.535	35.225	35.817

Note: Some of the percentage changes are made -100% if they are greater than -100% to avoid negative trade values in post-simulation results.

Table 2: Percentage change in trade values from baseline.

Regions	Baseline	Armington Specification	AIDS Specification
Brazil	-13.491	-17.625	-20.737
China	206.381	521.881	393.137
DEDC	-8.829	-96.526	-47.231
India	-9.091	-14.294	-7.821
Ireland	6.189	-6.496	14.723
LDC	-1.859	-2.015	-18.201
REU15	-111.237	-187.038	-147.175
REU27	-20.045	-64.918	-8.274
ROW	120.307	135.325	104.124
UK	-32.285	-51.414	-44.103
USA	-136.041	-216.880	-218.443

Table 3: Effect on trade balance (in billion dollars).

overestimate the gains accrued to the region that is reducing its price and either overestimate or underestimate the loss to the other regions. This is due to the constant and identical elasticity of substitution and homotheticity assumptions inherent in its functional form. Under the AIDS specification, some of the gains in trade share are Tables 2 and 3 captured by regions whose goods do not change in price. This result reflects the AIDS specification's ability to capture complementary relationships between the import demands for electronic goods from different countries as well as the non-homothetic nature of the import demand under the AIDS specification.

The results of our simulation exercise show starkly the differences between the effects on import demand that each specification predicts. This analysis illustrates that functional form choices in AGE models are important in determining the patterns of change in simulated trade flows and that functional form choices have important implications for the results of trade policy analyses and ultimately for our understanding of the impact of international trade reform.

Under the Armington specification, the elasticity of substitution plays the major role in deter- mining the magnitude of change in the import demand. The higher the elasticity of substitution the higher the magnitude of change in import demand. Moreover, such a specification always has positive cross price elasticities. It is important to emphasize that, with the Armington specification, regional cross price effects are always the same. In other words, when prices change in the US, an Armington specification predicts that this will have an identical impact on Ireland's demand for that good from China, DEDC, India, LDC, REU15 etc. This is undoubtedly the limitation of the Armington specification. By contrast, such an outcome would not occur in an AIDS type model, since it has sufficient parameters to capture diverse cross price elasticity effects.

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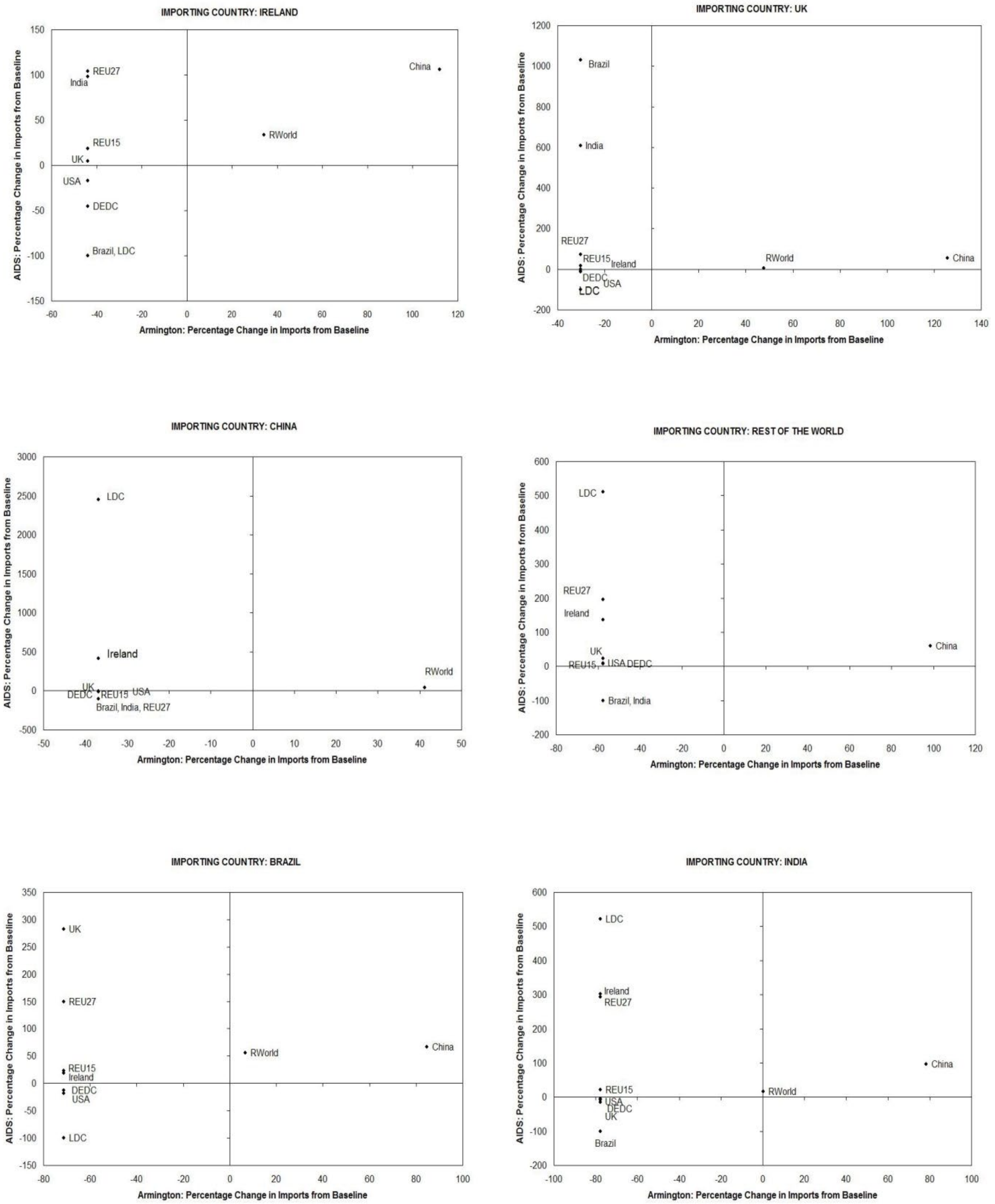

Figure 3: Percentage change in imports from Baseline for Armington and AIDS specification in different countries.

When dealing with an aggregate and complex commodity category such as electronic goods (or indeed any manufacturing goods), it is likely that price and income changes induce very different responses in different countries. For instance, Indian and Chinese electronic goods may be highly substitutable in Brazil but complementary in the UK. This reflects the reality of the nature of the electronic goods that Brazil and the UK import from India and China. If goods that India and China export to Brazil are similar, then such goods are substitutable. This could be the case for simple electronic devices such as transistors and semiconductors etc. On the other hand, the UK may import computer processing units from China and monitor screen from India. Such imports are complementary, and so a price fall in China could lead to increased UK imports from India. The fundamental issue is that the category that we call electronic goods defines a wide range of goods, and some of the goods in this broad category are complementary whereas others are substitutes. Furthermore, given the increasingly fragmented nature of global production, such complementaries between a country's imports are ever more likely. This underlines the ever increasing importance of using trade models that are based on reasonable and flexible functional forms.

This paper highlights the importance of non-homotheticity and complementarity in the case of electronic goods. The production of manufactured goods today is driven by global supply chains. Jara and Lamy argue that since the production of final goods is increasingly fragmented, many of its component are outsourced to many countries, thus the concept of 'country of origin' has lost its meaning today [14,15]. The study conducted by Sturgeon and Kawakami shows that global value chains in the electronics industry are more geographically extensive and dynamic than in other sectors [16]. In such industries, fragmentation of production processes means that parts and components are imported from different countries before finished goods are exported to the final market. Such complexity is also observed in other manufacturing industries as diverse as automobiles, aircrafts, clothing, etc. The recent global forum on trade statistics emphasized the need for trade statistics that represent global manufacturing processes in more comprehensive ways [17]. The availability of such inclusive data that reflect the complex nature of the trading system that we observe today will also require much more complex models with flexible functional forms to do *ex-ante* trade policy analysis.

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