Danish Exports and Danish Bilateral Aid

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Publication date:
2014

Document Version
Publisher's PDF, also known as Version of record

Citation for published version (APA):
Hansen, H., & Rand, J. (2014). Danish Exports and Danish Bilateral Aid. (2 ed.) Copenhagen: Ministry of Foreign Affairs of Denmark. Danida. Evaluation Study, No. 2, Vol.. 2014

Applied Economics, 1994, **26**, 107–120

Gravity models: a reformulation and an application to discriminatory trade arrangements

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Gravity models are used to estimate trade flows from 162 countries into 11 major importing countries for 1976, counting the EC as one. The main theories underlying gravity models are reviewed and a new gravity model is derived from a linear expenditure system. A major innovation of this model is that both tariffs and dummy variables for discriminatory arrangements are incorporated. Price variables are also explicitly included in the model. The tariff and the dummy variables are found to be statistically significant and this indicates that previous gravity model studies which used dummies to estimate the trade benefits of preferential tariffs may not have accurately estimated the effects of the preferences. The price variables generally are also found to be statistically significant, which casts doubt on the homogeneous-goods assumption underlying the purchasing power parity hypothesis. Some significant differences in the estimates were found when separate equations were regressed for the EEC and the US.

I. INTRODUCTION

This study reviews the various derivations and empirical results of gravity models over the last 50 years. A new derivation of a gravity model from a linear expenditure system is presented. Regression equations are estimated over a cross-section of imports by 11 major preference-giving countries (counting the European Community as one) from 162 other countries for 1976. Separate regressions are run for the EC and the US. Aside from various preferential trade arrangements, the model also estimates the effect of resistance to imports from countries which were classified as socialist at the time.

The effects of discriminatory trade arrangements are estimated with tariff averages as well as with dummy variables. Supposedly, tariff preferences operate through reductions in the prices of products covered by the arrangement and shipped by the beneficiary countries. This in turn alters the relative price(s) of similar products from non-beneficiaries and import substitutes and leads to an increase in trade flows between the preference-giving countries and the beneficiaries.

The above procedure is different from most previous gravity model studies which used dummy variables alone to estimate the preferential effect. Most importantly, the conventional gravity model does not consider price as a variable that influences trade flows between countries. This is due to the assumption of infinite elasticities of substitution in production and consumption for traded commodities. Bergstrand (1985, 1988) tried to compensate for this shortcoming with a gravity model which explicitly included price variables, and this study follows a similar procedure.

Most previous studies of the effect of preferences on trade with the preference-giving countries, with the exception of Geraci and Prewo (1977) and Sapir and Lundberg (1984), did not explicitly include tariff variables in their models. The model developed in the present study explicitly includes the tariff as a determinant of trade flows. If the tariff and the dummy variables are both statistically significant, it indicates that previous studies using only dummies generated biased estimates of the trade benefits of preferences.

The rest of the paper is arranged as follows: Section II contains a literature survey of gravity models; Section III contains the analytical framework; Section IV contains the quantitative results; finally, Section V presents the conclusions.

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Table 1. *Authors*

List of variables	Tinbergen (1962)	Linneman (1966)	Geraci and Prewo (1977)	Aitken (1973)	Brada and Mendez (1983)	Glejser (1968)	Sapir and Lundberg (1984)
NOB	306	3,532	306	132	17,921	61	15
Data year	1958	1958–60	1970	1967	1954–77	1961	1979 1975–79
R^2	0.84	0.63	N/A	0 87	0 56	0.80	(0.60)[a]
Y_i	0.74 (17.48)	0.86 (43.0)	0.86 (30.71)	0.911 (9.00)	0.357 (39.33)	−0.28 (11.99)	(1.22)
Y_j	0.62 (14 64)	0.98 (49.0)	0.71 (24 48)	1.052 (10.39)	0.131 (17.52)		
N_i		−0.14 (4.67)		−0.369 (3.38)	0.899 (61.45)		
N_j		−0.21 (7.0)		−0.331 (3 03)	0.680 (50 20)		
D	−0 56 (11.78)	−0.77 (25.67)	0.059 (9.34)	−0 349 (2.74)	−0.760 (50.48)		(−0 77)[c]
C	0 05 (4.47)	1.27 (9.07)					
YP_i							
YP_j						−0.13 (2.87)	
AA							
TM							
G							
P							
F		2 57 (9.88)					
FA							
B		6.8 (10.15)					
A	0.02 (2 33)		0.1003 (0.75)	0.892 (4.41)			
EEC				0.887 (3.75)	2.307 (16.51)	0.24 (2.70)	
EFTA				0.572 (3.21)	2.095 (17.55)		
t_j			−0.034 (3 66)				
A_{ij}							
B_{ij}							
U_{ij}							
I_{ij}							
T_{ij}							
VEX							
EXR							
XUV			−0.080 (2.05)				

List of variables	Sattinger (1978)	Abrams (1980)	Bergstrand (1985)	Thursby and Thursby (1987)	Bikker (1987)	Aitken and Obutelewicz (1976)	Sapir (1981)
NOB	380	76	210	144	3,954	167	180
Data year	1972	1973–76	1976	1974–82	1974–84	1971	1078
R_2	0.80	0.80	0.81	0.64	N/A	0 50	0.62
Y_i	0.91 (32.5)	0.76 (47.77)	0 84 (15.79)	2.03 (1.89)	1.06 (24.56)	0.995 (8.20)	1.990 (7 59)
Y_j	0.79 (28 21)	0 65 (41.76)	0.56 (9 34)	0.55 (10.46)	1.06 (33.16)	0.757 (7.73)	1.395 (8.57)
N_i					−0.26 (4.78)		−1.340 (4.06)
N_j					−0.29 (6.93)		−0.173 (1.11)
D	−0.97 (19.84)	−0.25 (24.51)	−0.77 (10 92)	−2.839 (3 97)	−1.07 (31.35)	−0.609 (2.58)	−1.147 (1.17)
C						4.458 (4.56)	
YP_i	0.25 (3.80)						
YP_j	0.08 (1 22)						
AA						2.585 (5 19)	
TM						2 261 (1.42)	
G							0.589 (2.39)
P							2.554
F							
FA						4.421 (5.51)	
B							
A			0 76 (5 62)	1.461 (5.75)			
EEC	0.81 (5.63)	0.313 (10 15)	0.18 (1.35)		−1 54 (3.57)		
EFTA	0 97 (9 97)	0.24 (6.64)	0 73 (3.67)				
t_j							
A_{ij}	0 25 (4.94)						
B_{ij}	−0.59 (3.30)						
U_{ij}	0.42 (2.55)						
I_{ij}	0.78 (9.07)	−0.19 (3.09)					
T_{ij}	0 09 (1.90)						
VEX		−0.05 (3.96)		−0.95 (0.62)			
EXR			0 73 (1 62)	−4.126 (5.64)			
XUV			−0.96 (1.55)	−3.891 (0 99)			

Table 1. (continued)

List of variables	Tinbergen (1962)	Linneman (1966)	Geraci and Prewo (1977)	Aitken (1973)	Brada and Mendez (1983)	Glejser (1968)	Sapir and Lundberg (1984)
MUV							
WPI_i							
WPI_j							
CPI_i							
CPI_j							
PRF			0 64 (6.60)			0.05 (4.23)	(2.29)[c]
L_{ij}			0.478 (3.69)				
TCF			−10 17 (9.17)				
ANP					0.346 (1 54)		
CACM					1.916 (10.15)		
LFTA					−1 476 (17.14)		
PB	0.04 (1.49)						
TS							
KL							(0.59)[c]
HC							(0 16)[c]
ME							(4 49)[c]
IN							(2.08)
PX							(−0.52)[c]

[a]Average R^2 for equations estimated for 1979.
[b]Average T-value for the coefficients of equations estimated for 1975–1979
[c]Average T-value for the coefficients of equations estimated for 1979.

II. LITERATURE REVIEW

Since the early 1940s, the gravity model has been applied to a wide variety of goods and factors of production moving across regional and national boundaries under differing circumstances. The model has been successfully applied to flows of varying types, such as migration, flows of buyers to shopping centres, recreational traffic, commuting, patient flows to hospitals, and interregional as well as international trade. Specifically applied to international trade flows, the gravity model states that the size or the magnitude of trade flows between two countries, e.g. is determined by supply conditions at the origin, by demand conditions at the destination and by stimulating or restraining forces relating to the specific flows between the two countries.

Despite its widespread empirical use, the gravity equation has been a model in search of a theory. Several different theories have been developed in support of the gravity model, and the differences in these theories help explain the many different forms of the gravity equations and differences in their results. See Table 1 for a survey of these results. Table 2 lists the variables used in these gravity model studies. The first justification for the gravity model is rooted in physics. This approach appealed to physical laws of gravitation and electrical forces to arrive at the conclusion that the flow of goods from country i to country j equals the product of the potential trade capacities of the two countries divided by a resistance or distance factor. Using this framework, Isard and Peck (1954) and Beckerman (1956) found that trade flows were greater between geographically closer areas.

The second approach is based on the Walrasian general equilibrium model, with each country having its own supply and demand functions for all goods. Aggregate income

List of variables	Sattinger (1978)	Abrams (1980)	Bergstrand (1985)	Thursby and Thursby (1987)	Bikker (1987)	Aitken and Obutelewicz (1976)	Sapir (1981)
MUV			1.85	0.495			
			(4 14)	(0.97)			
WPI_i			−0.05				
			(0.07)				
WPI_j			−1.12				
			(1.67)				
CPI_i				−1 36			
				(0.34)			
CPI_j				3.54			
				(4.31)			
PRF							
L_{ij}							
TCF							
ANP							
CACM							
LFTA							
PB							
TS				−0 113			
				(1 61)			
KL							
HC							
ME							
IN							
Px							

proxied the level of demand in the importing country and the level of supply in the exporting country. The gravity model is viewed as a reduced-form equation for trade volume (proxied by value) in which prices do not appear because they are endogenous. Distance proxies transport costs which drive a wedge between demand and supply. Early studies based on general equilibrium approach (Tinbergen, 1962; Poyhonen, 1963) concluded that incomes of the trading partners and the distances between them are statistically significant and of the expected positive and negative signs, respectively.

Other studies which found significant effects of income and distance on trade flows include Linneman (1966), Aitken (1973), Aitken and Obutelewicz (1976), Sapir (1981), Geraci and Prewo (1977), Sattinger (1978), Brada and Mendez (1983), Bergstrand (1985, 1988), Bikker (1987) and Thursby and Thursby (1987). Glejser (1968), as an exception, found the income of the exporting countries to have negative impact on trade flows (see Table 1). Furthermore, the majority of the general equilibrium studies found the population sizes of the trading countries to have a negative and statistically significant effect on trade flows (Linneman, 1966; Aitken, 1973; Bikker, 1987; Sapir, 1981). Brada and Mendez (1983), as an exception, found population sizes to have a positive and significant impact on trade flows (see Table 1).

Trade barriers also drive a wedge between supply and demand in the general equilibrium model. Geraci and Prewo (1977) found that the tariff has a statistically significant negative effect on trade flows between countries. Sapir and Lundberg (1984) found that preferential reduction in tariffs had a positive and statistically significant effect on trade flows. The majority of other general equilibrium studies also found preferential arrangements to be trade-enhancing and statistically significant.

The third explanation for the gravity equation is based on a probability model. Demanders supposedly are assigned to suppliers in a random fashion. Savage and Duetsch (1960),

Table 2. *List of variables used in previous gravity model studies*

i	= Exporter	
j	= Importer	
Y_i	= Exporter GDP	
Y_j	= Importer GDP	
N_i	= Exporter population	
N_j	= Importer population	
D	= Distance	
C	= 1, 2	2 = Commonwealth preferences
AA	= 1, 2	2 = Assoc. African EC preferences
TM	= 1, 2	2 = Tunisia–Morocco–French preferences
G	= 1, 2	2 = GSP
P	= 1, 2	2 = Portugues preferences
FA	= 1, 2	2 = Other French Africa preferences
F	= 1, 2	2 = French preferences
B	= 1, 2	2 = Belgian preferences
A	= 1, 2	2 = Adjoining country
EC	= 1, 2	2 = EC preferences
$EFTA$	= 1, 2	2 = EFTA preferences
SO	= 1, 2	2 = Socialist exporter
L	= 1, 2	2 = Lomé preferences
NT	= Frequency index of NTB – free products	
FOB	= 2, CIF = 1	
t_j	= 1 + tariff rate average	
A_{ij}	= Absolute difference in agriculture land per capita	
B_{ij}	= Absolute difference in crude birth rate	
U_{ij}	= Absolute difference in urban-rural population	
I_{ij}	= Absolute difference in per capita income	
T_{ij}	= Absolute differences in average mean temperature	
VEX	= Exchange rate uncertainty proxy	
EXR	= Bilateral exchange rate	
XUV	= Export unit value index	
MUV	= Import unit value index	
WPI_i	= Wholesale price index of exporter	
WPI_j	= Wholesale price index of importer	
PRF	= Preferential margin	
L_{ij}	= Common language	
TCF	= Transport cost factor	
ANP	= Andean pact	
$CACM$	= Central American common market	
$LFTA$	= Latin American free trade area	
CPI_i	= Consumer price index of exporter	
CPI_j	= Consumer price index of importer	
NOB	= Number of observations	
$DATA$	= Base year data	
R^2	= Coefficient of determination	
PB	= Benelux preference	
YP_i	= Income per capita of exporter	
YP_j	= Income per capita of importer	
TS	= Difference in taste	
KL	= Physical capital/labour ratio	
HC	= Human capital intensity	
ME	= Total manufactured exports	
IN	= The US direct investment/GNP ratio	
PX	= Composite relative price variable	

Goodman (1963), Leamer and Stern (1970) and Sattinger (1978) basically tried to predict trade flows between countries, where trade flows are regarded as stochastic events, although, Leamer and Stern's study is a hybrid of the probability and the general equilibrium approaches.

The most recent micro-foundations approach to gravity model claims that the other approaches lack strong theoretical foundations. The micro-foundations approach alleges that the crucial assumption of perfect product substitutability of the 'conventional' gravity model is unrealistic, as evidence in recent times has shown that trade flows are differentiated by place of origin. Under the latter condition, exclusion of price variables leads to misspecification of the gravity model. Authors who share this view include Armington (1969), Anderson (1979), Bergstrand (1985, 1988), Thursby and Thursby (1987), Bikker (1987), Abrams (1980), Helpman and Krugman (1985), and Krugman (1979, 1980). The results of their studies show that in addition to the conventional gravity equation variables, price variables are also statistically significant in explaining trade flows among countries (see Table 1). The results also show that the commodity arbitrage necessary for purchasing power parity is imperfect.

III. ANALYTICAL FRAMEWORK

In this section, the gravity equation is derived from a linear expenditure system. This new approach is another attempt to answer the recent criticism that the theoretical foundation of the gravity model is weak. The analysis in this section will assume a weakly separable utility function from which a linear expenditure could be derived.

Assume a two-country world – i = exporter, j = importer – and that the share of traded goods in national expenditure (b_i or b_j), is the same for all countries. There are identical Cobb–Douglas utility functions everywhere, so income elasticities always sum to unity. Finally, assume that each country is completely specialized in the production of its own goods, so that there is one good for each country, and that transport costs and tariffs are zero. With the above assumptions, the imports of goods from country i by country j could be written as

$$M_{ij} = b_j Y_j \tag{1}$$

where b_j is the share of importables in country j's total expenditure, and Y_j is country j's total income.

If it is assumed that income must equal sales, one can write the budget constraint or the trade balance equation for country i as

$$Y_i = b_j \Sigma Y_j \tag{2}$$

It is assumed in Equation 2 that non-traded goods have zero value. From Equation 2,

$$b_j = \frac{Y_i}{\Sigma_j Y_j} \tag{3}$$

If Equation 3 is substituted into Equation 1, the result becomes

$$M_{ij} = \frac{Y_j Y_i}{\Sigma_j Y_j} \tag{4}$$

Equation 4 gives the simplest form of gravity equation. If the error term is appended to Equation 4 and is assumed to be well-behaved, and if the denominator is regarded as a scale factor, the OLS technique can be used to estimate Equation 4.

The economic interpretation of Equation 4 is that the functional form of the gravity equation and a major portion of its explanatory power are encompassed by the expenditure system of the trading partners. Equation 4, however, is too simple for applicability in the real world. This is because it assumes identical preferences, income elasticities of unity, and also prices are assumed to be constant and the same in all countries. Furthermore, in reality, traded goods' shares of total national expenditures vary widely across regions and countries. Previous cross-section studies by Chenery (1960), Kuznets (1966) and Maizels (1968) found that such shares are well explained by income and population sizes: linear or log-linear regression lines of traded goods' share on income and population are stable over time; and traded goods' shares increase with income but decrease with population sizes.

In an attempt to avoid these weaknesses, we modify our gravity model in the following way: First, assume all countries produce traded goods (TG) and non-traded goods (NTG). Second, assume a preference function that is weakly separable with respect to partition between TG and NTG. The utility function can then be written as

$$U = u[g(TG), NTG] \tag{5}$$

From Equation 5, and with a given level of expenditure on traded goods, individual traded-goods shares or demands (Θ_i, Θ_j) are determined as if a homothetic utility function in traded goods alone $g(\cdot)$ were maximized subject to a budget constraint involving the level of expenditure on traded goods. Therefore, the individual traded goods' share of total expenditure on traded goods, with homotheticity, are functions of traded goods' prices only.

Let Θ_i and Θ_j be the shares of certain traded goods in each country's (i and j) total expenditures on tradables, respectively, and let Φ_i and Φ_j be the share of all traded goods in countries' (i and j) total expenditure. Therefore, the Θ's and Φ's could be expressed as

$$\Phi_j = F_j(Y_j, N_j, P_j) \tag{6}$$

$$\Phi_i = F_i(Y_i, N_i, P_i) \tag{7}$$

$$\Theta_j = f_j(P_i, P_j) \tag{8}$$

$$\Theta_i = f(P_j, P_i) \tag{9}$$

where Y_j is country j's national income, Y_i is country i's national income, N_j is country j's population size, N_i is country i's population size, P_j is country j's (general) price level and P_i is country i's (general) price level.

If Φ_i and Φ_j are assumed to be constant over time, they will satisfy the following approximation:

$$\frac{\Phi_k}{Y_k} \approx F_k\left(\frac{N_k}{Y_k}, \frac{P_k}{Y_k}\right) \quad \text{for } K = i, j \tag{6'}$$

This specification (Equation 6′) is necessary if a linear expenditure function homogeneous of degree zero in income and price is assumed. The emphasis in this situation will be the change in the composition of Φ_j which is caused mainly by the income effect of a change in relative price (since the substitution effect is assumed to be negligible or zero). But if the linear expenditure assumption is relaxed, it is possible to assume that $\Phi_j(\Phi_i)$ varies over time, and the specification of Equation 6 or Equation 7 can be used for estimation purposes. This is especially true because the data used in most empirical estimations are in aggregate form, while specification (Equation 6′) requires disaggregated data. With Equations 5–9, country j's imports of goods from country i could be written as

$$M_{ij} = \Phi_j \Theta_j Y_j \tag{10}$$

The trade balance equation for country i (the exporting country) implies

$$Y_i \Phi_i = \Theta_j \Sigma_j Y_j \Phi_j \tag{11}$$

Equation 11 states that planned expenditure of country i (on tradables) is equal to planned sales. From Equation 11, we can solve for θ_j as follows:

$$\theta_j = \frac{\Phi_i Y_i}{\Sigma_j Y_j \Phi_j} \tag{12}$$

Substituting Equation 12 into Equation 10 gives

$$\begin{aligned} M_{ij} &= \frac{\Phi_i Y_i \Phi_j Y_j}{\Sigma_j Y_j \Phi_j} \\ &= \frac{\Phi_i Y_i \Phi_j Y_j}{\Sigma_i \Sigma_j M_{ij}} \end{aligned} \tag{13}$$

If Equations 6 and 7 are substituted into Equation 13, we have

$$M_{ij} = \frac{F_i(Y_i, N_i, P_i) Y_i F_j(Y_j, N_j, P_j) Y_j}{\Sigma_j [F_j(Y_j, N_j, P_j) Y_j]} \tag{14}$$

If Equation 14 is log-linearized, with the denominator taken as a constant (k) common to both i and j, a gravity equation with the distance term suppressed (to one) is derived.

Equation 14 could be made more estimable by appending the scale factor (or constant term γ) and log-normal disturbance term, U_{ij}, where $E[\log U_{ij}] = 0$. Therefore,

$$M_{ij} = \gamma \frac{F_i(Y_i, N_i, P_i) Y_i F_j(Y_j, N_j, P_j) Y_j}{\Sigma_j [F_j(Y_j, N_j, P_j) Y_j]} U_{ij} \tag{15}$$

Linearization of Equation 15 gives

$$F_i(Y_i, N_i, P_i) = Y_i^{\alpha_1} N_i^{\alpha_2} P_i^{\alpha_3} \tag{16}$$

$$F_j(Y_j, N_j, P_j) = Y_j^{\beta_1} N_j^{\beta_2} P_j^{\beta_3} \tag{17}$$

If the denominator of Equation 15 is treated as a constant (k), it could be written as

$$M_{ij} = \frac{\gamma}{K} Y_i^{\alpha_1} N_i^{\alpha_2} P_i^{\alpha_3} Y_j^{\beta_1} N_j^{\beta_2} P_j^{\beta_3} U_{ij} \tag{15'}$$

The inclusion of P_i and P_j in Equations 15 and 15′ is plausible because of the heterogeneous competition (or product differentiation) which increasingly characterize world trade flows. When products are differentiated by places of origin, prices of similar traded products are not identical (Isard, 1977; Armington, 1969; Krugman, 1977; Bergstrand, 1985, 1988).

Distances among trading partners can be added to Equation 15′ in order to reflect the effect of transport costs. The effect of tariff can also be incorporated.

Let us assume that the delivery (or landed) value of country j's imports from i is given as $M_{ij}T_{ij}$, where M_{ij} is the foreign price value (of imports) and T_{ij} is the transport cost from i to j. This leads to

$$M_{ij}T_{ij} = \boldsymbol{\theta}_j(T_{ij})\boldsymbol{\Phi}_j Y_j$$

implying that

$$M_{ij} = \frac{1}{T_{ij}} \boldsymbol{\theta}_j(T_{ij})\boldsymbol{\Phi}_j Y_j \tag{18}$$

The trade balance equation then becomes

$$\begin{aligned} \boldsymbol{\Phi}_i Y_i &= \left(\sum_j \frac{1}{T_{ij}} \boldsymbol{\Phi}_j Y_j\right)\boldsymbol{\theta}_j(T_{ij}) \\ &= (\Sigma_j TC_{ij}\boldsymbol{\Phi}_j Y_j)\boldsymbol{\theta}_j(T_{ij}) \end{aligned} \tag{19}$$

where

$$TC_{ij} = 1/T_{ij}.$$

Hence,

$$\boldsymbol{\theta}_j(T_{ij}) = \frac{\boldsymbol{\Phi}_i Y_i}{\Sigma_j TC_{ij}\boldsymbol{\Phi}_j Y_j} \tag{20}$$

Substitution of Equation 20 into Equation 18 gives

$$M_{ij} = \frac{\boldsymbol{\Phi}_i Y_i \boldsymbol{\Phi}_j Y_j TC_{ij}}{\Sigma_j Y_j \boldsymbol{\Phi}_j TC_{ij}} \tag{21}$$

TC_{ij} in Equation 21 could be regarded as the total 'trade resistance' variable, i.e.,

$$TC_{ij} = \widehat{TC}_{ij} t_j \tag{22}$$

where $\widehat{TC}_{ij}$ is the distance (or transport costs) from i to j, and t_j is the advalorem tariff imposed by country j on imported goods from country i.

If Equation 22 is substituted into Equation 21, the result is

$$M_{ij} = \gamma \frac{\Phi_i Y_i \Phi_j Y_j \widehat{TC}_{ij} t_j}{\Sigma_j Y_j \Phi_j \widehat{TC}_{ij} t_j} \tag{21'}$$

and

$$M_{ij} = \frac{\gamma}{k} Y_i^{\alpha_1} N_i^{\alpha_2} P_i^{\alpha_3} Y_j^{\beta_1} N_j^{\beta_2} P_j^{\beta_3} \widehat{TC}_{ij}^{\varepsilon_1} t_j^{\varepsilon_2} U_{ij} \tag{23}$$

If the denominator of Equation 21′ is treated as a constant (k), Equation 23 could be regarded as a 'full-blown' gravity equation (model) that includes both the trade-inducing and trade-resisting variables. The main differences between Equation 23 and the conventional gravity equation include the following: First, Equation 23 contains price variables as factors that influence trade flows between trading countries (i and j). Second, a tariff variable (t_j) is explicitly included in Equation 23.

If Equation 23 is written in log-linear form, it becomes

$$\begin{aligned} \log M_{ij} = {} & \log\gamma' + \alpha_1 \log Y_i + \alpha_2 \log N_i + \alpha_3 \log P_i \\ & + \beta_1 \log Y_j + \beta_2 \log N_j + \beta_3 \log P_j \\ & + \varepsilon_1 \log \widehat{TC}_{ij} \\ & + \varepsilon_2 \log t_j + \varepsilon_3 \log \mathrm{d}_{ij} + \log U_{ij} \end{aligned} \tag{24}$$

where preferential dummy variables (d_{ij}) are added to capture any effects of preferential treatment which a tariff coefficient might not pick up, and $\gamma' = \gamma/k$.

Each of the variables in Equation 24 has predictable effects on trade flows between trade partners. The income variables (Y_i, Y_j) are expected to have positive effects on trade flows. On the supply side, an increase in income will indicate greater production available for exports. On the demand side, a rise in income, given a relatively high marginal propensity to import, will lead to an increase in imports, all else remaining constant.

The effect of the population variables (N_i, N_j) on trade flows is indeterminate. Population size can be trade-enhancing as well as trade-inhibiting. On the one hand, a large population may indicate large resource endowment, self-sufficiency, and less reliance on international trade. On the other hand, it is possible that a large domestic market (or population) promotes division of labour and thus creates opportunities for trade in a wide variety of goods. According to the latter argument, the expected sign of coefficient on population is positive.

The two trade-resistance variables, tariff and distance, adversely affect trade flows between countries, so their coefficients are expected to be negative. With regard to the distance variable $\widehat{TC}_{ij}$, for example, long distance between trading countries, all else remaining constant, leads to higher costs and lower profit margin to the importer. Long distance also leads to increased 'Psychic distance' between trading countries. All these characteristics of distance will reduce trade flows between countries.

Similarly, as a tax on imported goods, tariff (t_j) raises the delivery price in the importing country and the price that consumers eventually pay for the imported goods. This in turn leads to a fall in demand for imports, given that the imported good is a 'normal' good.

Following Bergstrand (1985, 1988), the price variables were proxied by unit value indexes, wholesale price indexes, and exchange rates. The coefficients of the price variables (P_i, P_j) cannot be signed *a priori*. The sign of the coefficient on the price level in the exporting country (P_i) depends on the elasticity of substitution among importables (*ESM*), on the elasticity of transformation between exportables (*ETE*), and on the elasticity of transformation between production for domestic market and for foreign markets (*ETDF*).

If $ESM > 1$ and if $ETE > ETDF$, then P_i will be expected to have a negative coefficient. This is because a rising price (or cost) of exportables will make the exporter(s) less competitive in foreign markets. A high elasticity of substitution among importables will enable importers to easily switch from high-cost exporters to low-cost exporters. A high elasticity of transformation among exportable(s) will also enable exporters to easily switch out of the products whose costs or prices are rising. On the other hand, if $ESM < 1$ and $ETE < ETDF$, the reverse argument holds and the P_i may be expected to have a positive coefficient. All these highlight the ambiguous (expected) sign of P_i.

The coefficient of the price level in the importing country (P_j) is positive or negative depending upon whether the elasticity of substitution between domestic and imported products (*ESMD*) is less than or greater than unity. It also depends on the (real) income effect of a change in P_j(relative to P_i). If $ESMD > 1$, a rise in P_j will lead to an increase in imports, while a fall in P_j will lead to a fall in imports. In this case, the coefficient of P_j is expected to be positive. If $ESMD < 1$, a reverse argument may lead the coefficient on P_j to be negative.

The (real) income effect of a change in P_j also has to be considered. With the assumption of separability implicit in Equation 24, the cross price effect (substitution effect) of a change in P_j is negligible or zero but the income effect is not. A rise in P_j will lead to a fall in real purchasing power of the allocated budget or expenditure for imports and *vice versa* for a fall in P_j. With the latter considerations, the sign of the coefficient of P_j depends on the net effects of *ESMD* and real income effect of a change in P_j. This points also to the inability to sign the coefficient of P_j *a priori*.

The coefficients of the preferential dummy variables (d_{ij}) are expected to have a positive sign. This is because a preferential arrangement entails a reduction in barriers to trade flows, especially artificial ones like tariff and non-tariff barriers. This will in turn have a trade-enhancing influence on trade flows between members of the preferential organization.

In order to give empirical content to this reformulated gravity model, a multivariate, cross-section regression technique will be applied to a unique data set constructed from data bases at the Secretariat of the United Nations Conference on Trade and Development (UNCTAD). A double-log model will be used to estimate the effect of the above variables on trade flows.

Section IV discusses the results obtained by employing the above variables to estimate Equation 24.

IV. EMPIRICAL RESULTS

Eleven major customs areas[1]

In Table 3 are shown the results obtained when Equation 24 is estimated for the trade flows of the 11 major customs areas and their trade partners.[2] The conventional trade flow variables, such as the GDPs, distance, tariffs, and preferential dummies have highly significant coefficients with expected signs.

The array of dummies in Table 3 reflects the number of discriminatory trade arrangements which are becoming ubiquitous with the regionalization of world trade. The significant negative sign of the socialist dummy is explainable in two ways. First, the socialist countries have had a bias against trade. Second, the 11 major importers have had restrictions on trade with socialist countries. The low significance of the EFTA dummy, however, may be explained by the fact that only the European Community had a preferential trade arrangement with EFTA.

The Mediterranean dummy applies to countries with bilateral preferences with the EC, but it as well as the GSP

[1]The 11 are: USA, Japan, Australia, Canada, EC, Norway, Sweden, Austria, Finland, New Zealand and Switzerland

[2]It is pertinent to indicate here our data sources Total imports in Customs Co-operation Council Nomenclature (CCCN) 1–99 are used as the dependent variable in the estimations. The independent variables include GDPs of the trading countries, distance, average tariff rates, population sizes, bilateral exchange rates, wholesale price indexes, and export and import unit value indexes

Information about total imports and tariff rates are obtained from the UNCTAD trade tapes. The UNCTAD data set was constructed in order to examine the pattern of trade between each of 11 developed market economy countries (counting the EC as one) and the rest of the world (162 trade partners). Tariffs are measured by the actual trade-weighted advalorem rates assessed, so that they reflect all lower duties for preferred trade partner Population sizes, GDPs, and export and import unit value indexes are obtained from UNCTAD *Handbook of International Trade and Development Statistics* (1977) Wholesale price indexes and bilateral exchange rates are obtained from IMF, *International Financial Statistics*, (1977) and from the United Nations, *Statistical Yearbook*, (1979/80 edition) all of the same base year. The distance between the trade partners are obtained from the US Naval Oceanographic Office, *Distance Between Ports*, Washington, DC, (1965). To the authors' knowledge, this is the only data set ever assembled in which the actual applied tariff averages have been calculated for such a large sample of trade flows.

Table 3. *Gravity equation coefficient estimates for developed market economy countries' aggregate bilateral trade flows with the world (dependent variable – total value of imports)*

Variables	Coefficient value	T-ratio
Importer GDP (Y_j)	0.453	20 79****
Exporter GDP (Y_i)	1.052	37.57****
Distance ($\widehat{TC}_{ij}$)	−0.757	−8 72****
Tariff (t_j)	−0.776	−4.10****
GSP dummy (d_{ij})	−0.759	−4.64****
Socialist dummy	−3.066	−9 19****
EFTA dummy	−0.254	−0.571
Mediterranean dummy	−1.222	−4.32****
Lome dummy	0.714	2 67***
Bilateral exchange rates	−0.044	−1.22*
Exporters' wholesale price index (P_i)	−0.022	−0.33
Importers' wholesale price index (P_j)	0 170	2.74***
Export unit value	−0.367	−0.58
Import unit value	0 243	1.41*
Constant	0.013	2.203***
$\bar{R}^2=0.53$	F-value = 541.90	$N=1403$

*Significant at 0 90 level.
***Significant at 0.99 level.
****Significant at 0.995 level.
i = Exporter
j = Importer

beneficiary dummy have unexpected negative signs. Apparently, after the preferential tariffs are accounted for by variable t_j, other resistance factors (perhaps non-tariff measures) are limiting imports from less developed countries. This result is not confirmed for the African, Caribbean and Pacific (ACP) countries that are beneficiaries of preferential trade arrangements under the Lomé Convention with the EC. The coefficient of the Lomé variable is positive and highly significant. It should be noted, however, that the Lomé Convention contains many other trade enhancements besides tariff reductions, and that many ACP countries have stronger trading relations with the EC dating back to colonial times.

The price variables in Table 3 are not generally significant, perhaps because of different import demand elasticities in major importing countries. In order to explore this problem further, the gravity equation is estimated for the EC and the US separately because the import propensities of major importers might differ from each other. Therefore, separate regressions were run for the EC and the US. Variables Y_j, N_j and P_j were dropped to avoid perfect multicollinearity.

The United States

Regression estimates for the US in Table 4 showed that when the distance and the other variables discussed in Section III are included in the same equation, the distance variable is insignificant. When this equation is re-estimated but with the exclusion of the distance variable, the level of significance of most other variables improved as shown in Table 5. The F-value of the latter equation also increased.

Table 4. *Gravity equation coefficient estimates for the US Aggregate bilateral trade flows with distance variable (dependent variable – total value of imports)*

Variables	Coefficient value	T-ratio
Exporter GDP (Y_i)	1.262	12.57****
Distance ($\widehat{TC}_{ij}$)	−0.252	−0.72
Tariff (t_j)	−4.270	−1.56*
GSP dummy (d_{ij})	1 157	2.07**
Composite relative price (P_2)	−0 303	−1.70*
Exporter population (N_i)	−0.464	−3.48****
Exporter WPI (P_i)	0 392	1 93*
Exporter unit value	0.733	2.44***
Constant	27 085	1 30*****
$\bar{R}^2=0\ 53$	F-value = 23.87	$N=163$

*Significant at 0.95 level.
**Significant at 0.975 level.
***Significant at 0.99 level.
****Significant at 0.995 level.
*****Significant at 0.90 level
i = Exporter
j = Importer.

The income of the exporting countries (Y_i) has the expected positive sign, and it is significant at a 0.995 confidence level. This confirms the idea that the higher the income of the exporting countries, the greater will be their production capacity and the amount they can export. It also indicates a greater ability of the exporters to produce and export at a lower cost, all else remaining constant.

The tariff variable (t_j) has the expected negative sign, and it is significant at 0.95 confidence level. This confirms that the tariff is a trade resistance variable. Since the GSP reduces tariffs for LDC beneficiaries, this estimate suggests that the GSP has a large significant positive impact on LDC exports to the US.

The preferential dummy variable (d_{ij}) has an expected positive sign, and it is significant at 0.975 confidence level. This shows that the US GSP scheme enhanced trade flows between it and the beneficiaries of its scheme. The significance of the dummy variable also indicates that the tariff variable does not fully reflect the impact of the GSP on imports from beneficiaries. Since the tariff variable applies to imports from all countries, it could be thought of as indicating the trade creation effect of lower tariffs. The dummy may be reflective of the trade diversion effect of the GSP.

In an attempt to empirically estimate the effect of relative price changes on trade flows among trade partners, a composite relative price variable (P_2) is constructed. The composite relative price variable is the ratio of the exporters'

Table 5. *Gravity equation coefficient estimates for the US Aggregate bilateral trade flows without distance variable (dependent variable – total value of imports)*

Variables	Coefficient value	T-ratio
Exporter GDP (Y_i)	1.270	12.65****
Tariff (t_j)	−4.046	−1.52*
GSP dummy (d_{ij})	1.138	2 00**
Composite relative price (P_2)	−0.332	−1 89*
Exporter population (N_i)	−0 489	−3 92****
Exporter WPI (P_i)	0.406	2.02**
Exporter unit value	0.719	2 33***
Constant	23.373	1.22*****
$\bar{R}^2=0.53$	F-value = 27.25	$N=163$

*Significant at 0.95 level.
**Significant at 0.975 level
***Significant at 0 99 level.
****Significant at 0.995 level
*****Significant at 0.90 level
i = Exporter.
j = Importer

wholesale price index to US (importer's) wholesale price index multiplied by bilateral exchange rates. When the bilateral exchange rate was introduced independently in the estimated equation(s), it was insignificant Because of the possibility that its effects can operate through relative prices, we decided to construct the composite relative price variable. The construction and use of this composite variable is appropriate because if the 'Law of one price' holds, according to the conventional general equilibrium notion, the value of this variable will be insignificant. This is because exchange rate adjustment will ensure that the price level in the trading countries is the same. There is no deviation from purchasing power parity (PPP). But the significance of the composite relative price variable will show that PPP doctrine is invalid in this case.

The results show that the composite relative price (P_2) has a negative sign, and it is significant at 0.95 confidence level This suggests that the PPP doctrine is wrong as far as trade flows between the US and its trade partners are concerned The significance and the sign of the composite price variable suggests that the elasticity of substitution among importables (*ESM*) is less than one and that the elasticity of transformation between exportables (*ETE*) is less than the elasticity of transformation between production for domestic markets and for foreign markets (*ETDF*). This means that with a rising price (or cost) of the exportables, the importers will not easily curtail imports Exporters are not able also to switch easily from products whose cost of production or price is rising.

The negative sign of the composite price coefficient also suggests that the elasticity of substitution between domestic and imported goods (*ESMD*) in the importing country is less than one. A rise in general price level in the importing country (P_j) will lead to fall in imports. The sign of the composite price variable also shows that the *ESMD* effect reinforces the negative income effect of a price rise (reduction in purchasing power) in the importing country. The latter negative effect is further reinforced by the rising price of foreign currency (or depreciation of domestic currency). This also tends to support the second reason for constructing the composite price variable; that the exchange rate effects operate through the relative price. The rising price of foreign currency and the rising domestic price reduce the purchasing power of consumers in the importing country, hence the negative sign of the composite price variable.

The exporters' wholesale price index (P_i) coefficient has a positive sign, and it is significant at 0.95 confidence level. This confirms the negative sign of the composite price variable. It suggests that *ESM* is less than one and that *ETE* is less than *ETDF* The low *ESM* may indicate that most of the US imports are complementary goods. This is especially true of US imports from the LDCs. A rising price of the exportable will make more of it available for export to the US. With a growing US economy, the demand for these complementary products also rises. The rising P_i makes the exportable available for export while the rising demand abroad (US) leads to increases in export despite a rising price in the exporting country, hence the positive sign of the P_i coefficient. The complementarity argument can further be supported by reference to the sign of the P_i coefficient when the trade flows among the 11 major customs areas and their trade partners are estimated. The effect of the complementary goods, mainly from the LDCs, was overwhelmed by the effect of substitute or similar goods trade among the major industrial countries This implies a high *ESM*, and this tends to support the negative coefficient of P_i (see Table 3), even though it is not statistically significant. The positive effect of P_i in Tables 4 and 5 also shows that the P_j effect on trade flows must be negative for the composite price variable to be negative, since the exchange rates are non-negative.

As a further effort to estimate the effect of price variables in Equation 24, the export unit value index is also included in the regressions shown in Tables 4 and 5. If *ETE* is greater than *ETDF*, the export unit value index coefficient will be negative, while if *ETE* is less than *ETDF*, the coefficient of the export unit value index will be positive. The results reported in Tables 4 and 5 show the export unit value index to be significant at 0.99 confidence level, and it has a positive sign. This means that *ETE* is less than *ETDF*. It also means that if a rise in export unit value index is caused by an increase in foreign demand, producers will easily shift from production of goods consumed domestically to exportables whose unit values are rising in foreign markets. It also shows that the rate of this switch is greater than that among exportables.

Population size (N_i) has a negative coefficient, and it is significant at the 0.99 confidence level. This confirms the Leamer and Stern (1970) and Linneman (1966) views that population size has a negative effect on trade flows between countries, while it does not tend to support the Brada and Mendez (1983) view. The result shows that an increase in population size leads to less reliance on foreign trade. Self-sufficiency is achieved with an increasing population size, thereby reducing trade flows between the US and its trade partners.

The distance variable ($\widehat{TC}_{ij}$) has the expected negative sign but is insignificant. This may mean that distance (or transportation cost) is not an important factor which influences trade flows between the US and its major trade partners. The largest US trade partner is Canada, a contiguous country, and the other major partners (Japan and Europe) are at similar and relatively small distances from the US in comparison to most LDCs. Recall that when the model is estimated over trade flows between 11 major customs areas and all of their trade partners, the distance variable became significant with the expected negative sign (see Table 3). This supports the idea that the insignificance of distance when only US aggregate bilateral trade flows were estimated may be due to lack of variation.

Table 6. *Gravity equation coefficient estimates for the EC aggregate bilateral trade flows (dependent variable – total value of imports)*

Variables	Coefficient value	T-ratio
Exporter GDP (Y_i)	1 108	17.99****
Distance ($\widehat{TC}_{ij}$)	−0 513	−2.68***
Tariff (t_j)	−1.511	−1 51*
GSP dummy	1.368	2 33***
EFTA dummy	0.916	0.85
Lome dummy	3 022	4.55***
Socialist dummy	−1.515	−2 05**
Mediterranean dummy	1 552	1.98*
Exporter WPI (P_i)	−0 124	−0.76
Exporter unit value	−0.084	−0.04
Composite relative price (P_2)	0.011	0.18
Exporter population (N_i)	0.053	0.86
Constant	3.472	0 37
$\bar{R}^2 = 0\ 73$	F-value = 34 97	$N = 152$

*Significant at 0 95 level.
**Significant at 0 975 level
***Significant at 0.99 level.
****Significant at 0.995 level
i = Exporter
j = Importer

The European Community

The results of estimation of the EC's trade flows with its trade partners are shown in Table 6. The conventional trade flow variables, with the exception of population size, are highly significant with the expected signs. For example, the income of the exporting countries has a positive sign and it is significant at 0.995 confidence level; the distance variable has a negative sign and it is significant at 0.99 confidence level; and the tariff variable has a negative sign and it is significant at 0.95 confidence level.

The significance of the tariff variable indicates that lower tariffs do increase EC imports, while the significance of the preferential dummies indicates additional positive effects from the EC's preferential schemes. The insignificance of the population variable may suggest that political and colonial ties are more important than population sizes in EC's trade with the major beneficiaries of its preferential schemes.

The dummies in the EC regression equation are highly significant, with the exception of that for the EFTA (see Table 6). This may indicate the importance and prevalence of preferential or discriminatory arrangements in the EC trade. The insignificance of the EFTA dummy may suggest that other factors such as, proximity and cultural similarity, may be a more important determinant of trade flows between the EC and the EFTA countries than the preferential trade arrangement.

The price variables are insignificant in the EC regression equation. This may highlight the importance of quota and ceilings in the EC trade with its trade partners. It may further suggest that international price differentials are not important in EC trade with its trade partners. This is because, the price differential (or advantage) can be counteracted by subsidies and other domestic price distorting policies which are relatively numerous in the EC. It is also possible that the insignificance of the price variables is due to low price elasticities for the EC traded goods. This result is in contrast to US estimates with some significant price variables.

Another difference between the US and the EC regression results is that the EC has more preferential arrangements, as shown by relatively more dummies, than the US (see Tables 4–6). This suggest that the EC already has liberalized trade with many partner countries and it may explain EC intransigence in the current Uruguay Round of GATT negotiations. The F-value and the coefficient of joint determination ($\bar{R}^2$) also are higher in the EC than in the US regression equation. This means that the EC regression equation has a relatively higher explanatory power than that of the US (see Tables 4–6).

The conventional trade flow variables, with the exception of the population size, are also more significant in the EC than in the US regression. This is especially true of the distance variable which is highly significant in the EC regression but insignificant in that of the US.

However, the fact that the effect (or significance) of the price variables is generally low in the regression equations for the US, the EC, and the 11 major customs areas, may indicate the importance of non-tariff (or non-price) barriers in world trade in contemporary times. Despite the general improvement in world technology and productivity, with the consequent decrease in cost and price, world trade may not increase if the latter effects are counteracted by non-tariff barriers to trade. Therefore, reform of the GATT to liberalize non-tariff barriers appears to be crucial in the determination of the future shape, direction, and benefits of international trade. For relative price differentials to play their conventional role in world trade, non-tariff barriers have to be drastically reduced.

V. CONCLUSION

The aim of this paper has been to estimate a reformulated gravity model on trade flows of the more developed countries. The composite relative price variable is found to be statistically significant in determining trade flows between the US and its trade partners, but price variables are generally not very significant when estimated across 11 major importers and for trade between the EC and its trade partners.

The effects of preferential trade arrangements are estimated with both dummy variables and by preferential tariff rates. Both variables are found to have statistically significant effects on trade flows. This shows that previous studies which estimated preferential effects with dummy variables only, may inaccurately estimate their effects. It also shows that the tariff rate does not fully reflect all the factors which influence the flow of trade between preference-giving and preference-receiving countries. Other factors which influence such trade flows may include the beneficiaries' competitiveness, non-tariff measures and institutional ties.

Given the significant relative price effect of tariffs and the significance of the tariff effect on trade flows, the results of the present study confirms that other factors commonly used in gravity models, such as GDP, population and distance (with some exceptions) are significant influences on trade flows.

ACKNOWLEDGEMENTS

The authors wish to acknowledge helpful comments and suggestions on an earlier draft from an anonymous referee and from Dr Colin M. Ramsay and Dr Chukwuma P. Ijoma. All errors and omissions remain our own.

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