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GRAVITY CHAINS: ESTIMATING BILATERAL TRADE FLOWS WHEN PARTS AND COMPONENTS TRADE IS IMPORTANT

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ABSTRACT

Trade is measured on a gross sales basis while GDP is measured on a net sales basis, i.e. value added. The rapid internationalisation of production in the last two decades has meant that gross trade flows are increasingly unrepresentative of the value added flows. This fact has important implications for the estimation of the gravity equation. We present empirical evidence that the standard gravity equation model performs poorly by some measures when it is applied to bilateral flows where parts and components trade is important. It also provides a simple theoretical foundation for a modified gravity equation that is suited to explaining trade where international supply chains are important. Future drafts shall explore ways the model can be implemented empirically.

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1. INTRODUCTION

Trade is measured on a gross sales basis while GDP is measured on a value added basis. For the first decades of the postwar period, this distinction was relatively unimportant. Trade in intermediates was always important, but it was quite proportional to trade in final goods. The rapid internationalisation of supply chains in the last two decades has changed this – especially the growth of such trade between developed and developing nations and more recently among developing nations. As a result, gross trade flows are increasing unrepresentative of the value-added flows. This fact has important policy implications (Lamy 2010), but it also has important implications for one of trade economists' standard tools – the gravity equation.

The basic point is simple. The standard gravity equation is derived from a consumer expenditure equation with the relative price eliminated using a general equilibrium constraint. This point, first made by Anderson (1979) and Bergstrand (1985, 1989, 1990) and extended by Anderson and Van Wincoop (2003), suggests that the gravity equation is best adapted to explaining trade in consumer goods. After all, the demand shifter in the consumer expenditure equation is total consumption expenditure and relevant gravity-equation mass variable – GDP of the destination nation – is not a bad proxy for this. For international trade in intermediate goods, however, the use of GDP as the mass variable seems less appropriate.

This paper explores whether the standard gravity equation works for bilateral flows where trade in parts and components is important. This question is motivated by the great changes that international trade has undergone in the past few years. One capital change is the emergence of global and regional value chain production. While intermediates trade has long played a role, in the space of few decades such trade has boomed between advanced nations and emerging economies as well as among emerging nations – especially in Asia, where the phenomenon is known as "Factory Asia". There are, however, similar setups in Europe and between the US and Mexico.

Consider, for instance, a fall in UK spending on cars assembled in Slovakia. It not only lowers Slovakian exports, but also the trade in parts and components that come from many other countries and sectors. According to the Deutsche Bundesbank (2009) a fall in car sales is accompanied by a 2.2 times higher fall in purchases (and therefore both imports and exports) of inputs from many other sectors ranging from casting of metals to electrical engineering, chemicals as well as many services sectors.

The emergence of internationally fragmented production also explains why developments in exports and imports of manufacturing have followed very heterogeneous patterns. In consumer goods trade, emerging countries gained important shares of world export markets but the global distribution of imports is by and large the same nowadays as forty years ago.

Indeed, Table 1 shows that between 1967 and 2007 emerging countries expanded their world export market share of consumer goods by twenty percentage points and developed countries saw their share eroded by the same amount (emerging countries went from 4% to 24%, while developed countries from 89% to 69%). During this period the relative distribution of consumer goods imports barely moved (emerging countries increased their imports by a mere three percentage points, from 7% in 1967 to 11% in 2007 while developed countries accounted then and now for three fourths of global imports); and emerging countries have become more important exporters and importers of intermediate goods, against a background of diminishing shares for developed countries.

Table 1: Exports and imports of consumption and intermediate goods, share in world total for selected regions, value in US dollars.

	Consumption goods		Intermediate goods	
	1967	2007	1967	2007
Imports				
Developed countries	76%	77%	68%	61%
Emerging Countries (incl. BRIC)	7%	11%	12%	24%
Least Developed C.	2%	1%	2%	1%
Exports				
Developed countries	89%	69%	93%	72%
Emerging Countries (incl. BRIC)	4%	24%	3%	21%
Least Developed C.	0%	1%	0%	0%

Sources: Comtrade and Chelem (CEPII); Note: We follow the Chelem (CEPII) classification for the identification of Developed Countries, Emerging Countries and Least Developed Countries.

Plainly, with the emergence of value chain production, expenditure in the country of destination and supply in the country of origin are no longer the only motives for trade. The old Keynesian world – where my imports depend on my GDP and my exports depend upon your GDP – is likely to be unable to explain manufacturing trade flows generated in the context of value chain production. In this case, imports and exports are more like conveyor belts connecting the various production bays of a global factory. Hence, it is likely that in those countries where imports are mainly intermediate inputs into exports, foreign demand – especially in the largest buyer markets (US and EU) – may determine both exports and imports.

The paper starts with simple theory that generates a number of testable hypotheses. We then confront these hypotheses with the data and find that the estimated coefficients deviate from standard results in the way that the simple theory says they should. The key results is that the standard economic mass variable does not perform well when it comes to bilateral trade flows where intermediates are dominant. The point is easily illustrated by considering how well China's imports from, say, the Philippines, is explained by Chinese consumption expenditure as proxied by GDP. As the Philippines' exports to China comprise mainly parts and components, the imports are more closely linked to the gross output of Chinese manufacturers – relatively little of which is consumed within China.

1.1. Literature

There is nothing new about trade in intermediates. Intermediates have long been important in the trade between the US and Canada; the 1965 US-Canada Auto Pact, for example, explicitly targeted preferential tariff reductions on cars and cars parts. It has also long been important within Western Europe as early studies of the EEC demonstrated (e.g. Dreze 1961, Verdoorn 1960, and Balassa 1965, 1966). The famous book by, Grubel and Lloyd (1975), made clear that much of intra-industry trade was in intermediates, not final goods.

As better data and computing technology became available, the importance of intermediates in trade was rediscovered and documented more thoroughly. In the context of efforts to understand the impact of the EU's Single Market Programme, European scholars focused on the role of intermediates. For example, Greenaway and Milner (1987) list this as one of the 'unresolved issues', writing "it is becoming increasingly obvious that a significant proportion of measured IIT is accounted for by trade in parts and components. [Nevertheless,] most of the models developed so far assume trade in final goods. The modelling of trade in intermediates needs to be explored further." The issue attracted renewed interest following development of the new trade theory in the 1980s (Helpman and Krugman 1985)[1] and again in the 1990s with Jones and Kierzkowski (1990), and Hummels, Rapoport and Yi (1998)[2], and more recently Kimura, Takahashi and Hayakawa (2007), and Grossman and Rossi-Hansberg (2008).

Indeed, the importance of intermediates was reflected in early work by well-known theorists, for example, Vaneck (1963) presents an extension of the Heckscher-Ohlin model that allows for intermediates trade, and Ethier (1981) casts his model of intra-industry trade in a world where all trade was in intermediates.

Studies on the gravity equations applicability to intermediate goods trade are more limited. These include Egger and Egger (2005), and Baldoni et al (2007). The study that is closest to ours is Bergstrand and Egger (2010). These authors develop a computable general equilibrium model that explains the bilateral flows of final goods, intermediate goods and FDI. Calibration and simulation of the model suggests a theoretical rationale for estimating a near-standard gravity model for the three types of bilateral flows. Using a large dataset on bilateral flows of final and intermediate goods trade, and a dataset on bilateral FDI flows, they estimate the three equations and find that the standard gravity variables all have the expected size and magnitude.

The value added of our paper is to derive an analytically solvable theory model that generates a gravity-like equation for trade flows that involve intermediates as well as final goods. We use the model to predict how the use of the standard mass variable (GDP) will result in estimated coefficients outside the expected range for certain sets of bilateral relationships. When we perform the estimates on data pooled across a wide range of nations – as do Bergstrand and Egger (2010) – we find the same results as they do.

However, when we focus more narrowly on bilateral flows where parts and components trade is systematically important, we find the break-down in the standard estimates predicted by the theory. We believe the difference in the results is due to the fact that for many trade flows, the pattern of trade in intermediates is quite proportional to trade in final goods. This is especially for trade among developed nations. Direct evidence of this can be found in Table 1 and it also emerges from the analysis of the correlation between consumption and intermediate bilateral trade flows. This is equal to 0.76 for our sample of 187 countries worldwide and it reaches a coefficient of above 0.90 for trade between industrialised countries.

In future drafts we shall report the results of experiments with alternative mass variables that could better explain bilateral flows of parts and components. Unfortunately, the mass variable suggested by the model is not available for a wide range of nations.

2. THEORY

The traditional gravity model was developed in the 1960s to explain factory-to-consumer trade (Tinbergen 1962, Poyhonen 1963, Linnemann 1966). This concept is at the heart of the first clear microfoundations of the gravity equation – the seminal 1979 article by James

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[1] As illustrated by the Brookings Institution book “The global factory: Foreign assembly in international trade” (Grunwald and Flam 1985).

[2] Feenstra (1998) for a survey of the 1990s literature.

Anderson (Anderson 1979).[3] Anderson proposed a theoretical explanation of the gravity equation based on a demand function with constant elasticity of substitution (CES) by Armington (1969), where each country produces and sells goods on the international market that are differentiated from those produced in every other country. Subsequent theoretical refinements of the Anderson model have focused on showing that the gravity equation can be derived from many different theoretical frameworks (including Armington preferences, monopolistic competition and trade models for firm heterogeneity) and in correctly accounting for the multilateral dimension of trade.[4] However, none of the existing contributions moved theory towards explaining trade in intermediates. With the aim to fill this gap, this section briefly reviews the standard gravity model microfoundations and then presents a modified version that can account for trade linked to production unbundling.

2.1. Traditional gravity model: Factory to consumer

All mainstream gravity equation derivations are variants Anderson (1979) and thus based on a consumption expenditure function (this includes the widely cited Anderson-Van Wincoop 2001, and Helpman and Krugman 1985 papers; the derivation here follows Baldwin and Taglioni 2007).

Using the well-known CES preference structure, spending on a good that is produced in nation-o and consumed in nation-d is:

$$v_{od} \equiv \left(\frac{p_{od}}{P_d}\right)^{1-\sigma} E_d \; ; \qquad \sigma > 1 \tag{1}$$

where v_{od} is the expenditure in destination country-d on a variety made in origin nation-o, p_{od} is the price of the consumer good, P_d is the nations-d's CES price index, σ is the elasticity of substitution among varieties, and E_d is the nation-d's consumer expenditure. Profit maximization implies that $p_{od} = \mu_{od} p_o \tau_{od}$, where μ_{od} is the optimal price mark-up (unity for perfect competition), and τ_{od} is the bilateral trade cost factor, i.e. 1 plus the ad valorem tariff equivalent of all natural and manmade barriers. Using this and summing over all varieties of the good (assuming symmetry of varieties by origin nation for convenience), we have:

[3] Leamer and Stern (1970) informally discusses three economic mechanism that might generate the gravity equations but these were based on rather exotic economic logics; Anderson (1979) was the first to provide clear microfoundations that rely only on assumptions that would strike present-day readers as absolutely standard.

[4] Theoretical refinements of the Anderson model introduce the Armington structure of consumer preferences in: (i) monopolistic competition frameworks (Krugman, 1980; Bergstrand, 1985, 1989, Helpman and Krugman, 1985), (ii) models by Heckscher-Ohlin (Deardorff, 1998), or (iii) models by Ricardo (Eaton and Kortum, 2001). The catalyst of the more recent wave of theoretical contributions on gravity is the literature on models of international trade with firm heterogeneity, spearheaded by Bernard et al. (2003) and Melitz (2003). In particular, they show that the standard OLS estimation of the gravity model would deliver biased results if firm heterogeneity and the existence of zeroes in the trade matrix is not accurately accounted for (Chaney, 2008 and Helpman, Melitz and Rubinstein, 2008).

$$V_{od} = p_o{}^{1-\sigma} n_d \frac{(\mu_{od}\tau_{od})^{1-\sigma}}{P_d^{1-\sigma}} E_d \qquad (2)$$

where V_{od} is the aggregate value of the bilateral flow (measured in terms of the numeraire) from nation-o (for origin) to nation-d (for destination); n_o is the number of nation-o varieties sold in nation-d.

To turn the expenditure function into a gravity equation, Anderson (1979) and Anderson and Van Wincoop (2001) assume nations make only one product (i.e. $n_{od} = 1$ for all o and d), so the nation's GDP is its supply of the good. Supply and demand match when expressions like (2) – summed across all destinations (including nation-o's sales to itself) – equals nation-o's output of the good, i.e. its GDP, which here we denote with the term Y_o. Namely:

$$Y_o = p_o^{1-\sigma} \sum_d n_o \frac{(\mu_{od}\tau_{od})^{1-\sigma}}{P_d^{1-\sigma}} E_d$$

Solving this we obtain that $p_o^{1-\sigma} = Y_o / \Omega_o$ where $\Omega_o = \sum_d n_d \frac{(\mu_{od}\tau_{od})^{1-\sigma}}{P_d^{1-\sigma}} E_d$, and plugging this into (2) yields the traditional, consumer-based, gravity equation:

$$V_{od} = \tau_{od}{}^{1-\sigma} E_d Y_o \frac{1}{P_d^{1-\sigma}} \frac{1}{\Omega_o} \qquad (3)$$

Note that P_d is the nation-d CES price index, while Ω_o is the nation-o market potential index. In the special case highlighted by Anderson and Van Wincoop (2001), the two are identical and the product is labelled 'multilateral trade resistance'.

In the typical gravity model estimation, E_d is proxied with nation-d's GDP, Y_d is proxied with nation-o's GDP, and $\tau^{1-\sigma}$ is proxied with bilateral distance. As trade costs are not bilaterally symmetric, the two must be kept distinct and they are controlled for with various econometric techniques.

Another well-known derivation is from Helpman and Krugman (1985); they start from (1) and make supply-side assumptions that turns p_o into a constant, but makes n_{od} proportional to nation-o's GDP so the resulting gravity equation is similar – at least in the case of frictionless trade (the case they worked with in 1985).

2.2. Gravity equation derivation with vertical linkages

To expand the gravity equation to allow for parts and components trade among firms, we need a trade model where intermediate goods trade is explicitly addressed. It proves convenient to work with the Krugman and Venables (1996) "vertical linkages" model which focuses squarely on the role of intermediate goods. Here we present the basic assumptions and the manipulations that produce the modified gravity equation.

2.2.1. Basic assumptions

Krugman and Venables (1996) works with the standard new economic geography model with two sectors (a Walrasian sector, A, and a monopolistic competition sector M) and a single primary factor, labour L. Production of A requires only L, but production of each variety of M requires L and a CES composite of all varieties as intermediate inputs (i.e. goods are purchased both for final consumption and as intermediate inputs). For simplicity, the CES aggregate on the supply side is isomorphic to the standard CES consumption aggregate.

Specifically, the indirect utility function for the typical consumer is:

$$V = I / P^c; \qquad P^c \equiv p_A^{1-\mu}(P)^{\mu}; \quad P \equiv \left(\int_{i=0}^{n^w} p_i^{1-\sigma} di \right)^{1/(1-\sigma)} \qquad (4)$$

where I is consumer income, P^c is the perfect consumer price index, p_A is the price of A, the parameter "μ" is the Cobb-Douglas expenditure share for M-sector goods, σ is the elasticity of substitution among varieties, P is the CES price index for M varieties, p_i is the consumer price of variety i, and, n^w is the world number of varieties. In a two-country model, which we denote as Home and Foreign and that following Krugman and Venables (1996) we consider symmetric, the cost function of a typical home firm j is:

$$C[x_j] = (F + a_M x_j) w^{1-\mu} P^{\mu} \qquad (5)$$

where x_j is the output of variety j, F and a_M are, respectively, the fixed and variable cost components of M-sector production, w is the wage and μ is the Cobb-Douglas cost share for intermediate inputs in the M-sector.

As usual with Dixit-Stiglitz monopolistic competition, mill pricing is optimal, so the producer price for each variety is the same for all destinations. Given that the elasticity is identical in consumer and intermediate aggregates, producer prices are also identical across the two types of customers. Using these facts, applying the Sheppard and Hotelling lemmas, and adding the total demand for purchasers located in nation-d, we have an expression that is isomorphic to (2) except the definition of E now includes purchases by customers using the goods as intermediates:

$$V_{od} = p_o^{1-\sigma} n_d \frac{(\mu_{od} \tau_{od})^{1-\sigma}}{P_d^{1-\sigma}} E_d \; ; \qquad E_d \equiv \mu I_d + \mu n_d C_d \qquad (6)$$

where I_d is nation-d's consumer income and C_d is the total cost of a typical M-sector variety.

As before, we solve for the endogenous price, p_o, using the market clearing condition. In this case it is:

$$C_o = p_o^{1-\sigma} \Sigma_d n_d \frac{(\mu_{od} \tau_{od})^{1-\sigma}}{P_d^{1-\sigma}} E_d \; ; \qquad C_o \equiv w_o L^M_o + \int_{i=0}^{n^w} p_i q_{oi} di \qquad (7)$$

Here we have used the fact that profits are zero under monopolistic competition so an M-firm's revenue equals its costs, C[xi]; these costs are the sum of value added in manufacturing (the M-sector) and of purchased intermediate inputs from all sources. Solving (7) for p_o, and using it in (6), we have:

Solving this, $p_o^{1-\sigma} = C_o / \Omega_o$ where $\Omega_o = \sum_d n_d \frac{(\mu_{od} \tau_{od})^{1-\sigma}}{P_d^{1-\sigma}} E_d$, and plugging this into (6) yields a gravity equation modified to allow for intermediates goods trade, namely:

$$V_{od} = \tau_{od}^{1-\sigma} E_d C_o \frac{1}{P_d^{1-\sigma}} \frac{1}{\Omega_o} \qquad (8)$$

where E_d is defined in (6) and C_o is defined in (7).

3. BREAKDOWN OF THE STANDARD GRAVITY MODEL

The theory suggests that the standard practice of using the GDP of origin and destination countries as the 'mass' variables in the gravity equations is inappropriate for bilateral flows where parts and components are important. This is the case because expenditure (proxied by GDP) in the country of destination fails to capture demand for intermediate goods used in exports. Moreover, the origin nation's GDP is no longer a good proxy for the total value of goods that must be sold as this value now contains imported intermediates. For this reason, we expect that origin-country's GDP and destination country's GDP will have diminished explanatory power for those countries where value-chain trade is important.

This generates a number of testable hypotheses.

- The estimated coefficient on the GDPs should be lower for nations where parts trade is important, and should fall as the importance of parts trade rises.
- As vertical specialisation trade has become more important over time, the GDP point estimates should be lower for more recent years.
- In those cases where the GDPs of the trade partners lose explanatory power, bilateral trade should be increasingly well explained by demand in third countries. For example, China's imports should shift from being explained by China's GDP to being explained by its exports to, say, the US and the EU. There are two ways of phrasing this hypothesis. First, China's imports are a function of its exports rather than its own GDP. Second, China's imports are a function of US and EU GDP rather than its own, since US and EU GDP are critical determinants of their imports from China.

To check these conjectures, we estimate the standard gravity model for different sets of countries and sectors in the years from 1967 to 2007. We evaluate empirically our theoretical proposition that the standard gravity equation model performs poorly by some measures when it is applied to bilateral flows where parts and components trade is important. Accordingly, we expect it to successfully explain trade flows of a traditional type, i.e. where the importer is also the consumer of the good and to fail where the importer is mainly importing for then re-exporting the processed imports. In Section 3.1 we describe the empirical specification and the dataset used to estimate the gravity relationship while in section 3.2 we provide the empirical results and evaluate the validity of the hypotheses.

3.1. *Specification and data*

To evaluate the hypotheses, we run standard log-linear gravity equations using pooled cross-section time series data. The estimated reduced-form base-specification of bilateral imports between country *o* and country *d* at time *t* is:

$$\ln(m_{odt}) = G + \alpha_1 \ln\left(\frac{Y_{ot}}{\Omega_{ot}} * \frac{E_{dt}}{P_{dt}}\right) + \alpha_2 \ln\left(\tau_{odt}\right) + \varepsilon \quad (9)$$

G represents the gravitational constant. The term Y_{ot} is nation-*o*'s output, i.e. its GDP. Ω_{ot} represents the average of all importers′ market demands weighted by trade costs – which is something like the market-potential index for nation-*o*.[5] E_{dt} is the expenditure in country-*d* at time *t*. P_{dt} is the nations-*d*'s CES price index at time *t*, τ_{odt} is the bilateral time-varying trade cost factor, i.e. 1 plus the *ad-valorem* tariff equivalent of all natural and manmade barriers.

The most popular way of estimating the gravity equation is by means of fixed effects. The advantage of using fixed effect specification lies in the fact that they are by far the simplest solution to testing a theoretically sound gravity equation, even though they do not control for the time-varying aspects of the terms Ω_{ot} and P_{dt}. Specifically, the fixed effect specification is parsimonious in terms of data demand, avoids the imposition of *ad hoc* structural assumptions on the underlying model, and requires only simple OLS econometrics. However, the use of exporter and importer fixed effects is suitable only if the variable of interest is pair-specific. If, by contrast, the latter is specific to the exporter or to the importer, then exporter and importer specific variables should be introduced explicitly and other means of avoiding the omitted variables bias (i.e. of controlling for Ω_{ot} and P_{dt}) should be devised.

As our main purpose is to investigate how the key size and distance coefficients perform for different types of trade flows, we need to avoid problems of over-parameterisation of the model linked to the use of fixed effects estimators. Hence our baseline specification accounts for the terms Ω_{ot} and P_{dt} explicitly. Yet, precise measures of Ω_{ot} and P_{dt} are hard to construct, hence, for robustness purposes, when feasible we will also check if results are consistent with fixed effects specifications. To ensure comparability with the fixed effects specification, in the key specifications we enter the importer's and exporter's economic mass as a single product-term into the equation, with the shortcoming of forcing the coefficient of the importer and exporter mass variables to be the same.

Specifically, the term accounting for the product of the trade partners' economic mass is the product of importer-*d* real GDP (so to account for P_{dt}) and of exporter-*o*'s nominal GDP divided by a proxi for Ω_{ot}, constructed adapting a method first introduced by Baier and Bergstrand (2001): $\Omega_{ot} = \left[\sum_d GDP_{dt} * \left(Dist_{od}\right)^{1-\sigma} \right]^{\frac{1}{1-\sigma}}$. The elasticity value in the Ω_{ot} relationship has been set as σ=4, which corresponds to estimates proposed in empirical literature (e.g. Obstfeld and Rogoff, 2001 and Carrere 2006).

Turning to the other RHS variables, those accounting for the trade costs τ_{odt}, we introduce standard trade frictions, including log of bilateral distance between countries, weighted by the distribution of population within the country and dummy variables for contiguity and common language. Moreover for robustness purposes we also test for additional time-varying trade frictions measured as *cif-fob* ratios, as proposed by Bergstrand and Egger (2010).

Trade data used for the LHS variable and to compute the cif-fob ratios are from the UN COMTRADE database. GDPs are from the World Bank's World Development Indicators. Bilateral distances, contiguity and common language are from the CEPII database. Data for Taiwan, which are missing from the UN databases, are from CHELEM (CEPII) and national accounts.

[5] It has been called in many different ways in the literature, including market potential (Head and Mayer 2004, Helpman, Melitz and Rubinstein 2008), market openness (Anderson and Van Wincoop 2003) or remoteness (Baier and Bergstrand 2009).

3.2. *Empirical results*

Table 2 reports the gravity equation estimates for total goods, as well as for intermediate and final goods separately. Intermediate and final goods have been identified according to the UN Broad Economic Categories Classification (See appendix). Coefficients are all rightly signed and statistically significant. The elasticity estimates confirm that bilateral trade in intermediate and consumption goods alike is positively related to the economic size of the two trade partners, and inversely related to the bilateral trade costs. From these aggregate estimates it also appears that the size of all coefficients does not differ across type of trade. These results are similar to Bergstrand and Egger (2010).

Table 2: Bilateral flows of total, intermediate and final goods between 187 world countries, 2000-2007.

VARIABLES	(1) All goods $imports_{odt}$	(2) All goods $imports_{odt}$	(3) Intermediate goods $imports_{odt}$	(4) Intermediate goods $imports_{odt}$	(5) Consump. goods $imports_{odt}$	(6) Consump. goods $imports_{odt}$
ln ($GDPo_t \cdot GDPd_t / \Omega ot{*}Pdt$)	0.860***	0.865***	0.898***	0.905***	0.791***	0.796***
	(0.00596)	(0.00609)	(0.00664)	(0.00679)	(0.00787)	(0.00802)
ln trade costs $imports_{odt}$ (cif/fob ratio)	-0.0833***	-0.0798***	-0.189***	-0.184***	-0.341***	-0.338***
	(0.0129)	(0.0129)	(0.0149)	(0.0149)	(0.0168)	(0.0169)
ln $Distance_{od}$, weighted	-0.775***	-0.777***	-0.851***	-0.855***	-0.758***	-0.760***
	(0.0194)	(0.0194)	(0.0218)	(0.0218)	(0.0250)	(0.0250)
$Contiguity_{od}$	1.575***	1.565***	1.711***	1.697***	1.356***	1.347***
	(0.105)	(0.105)	(0.119)	(0.119)	(0.127)	(0.127)
Common official $language_{od}$	0.966***	0.972***	0.997***	1.005***	1.186***	1.192***
	(0.0456)	(0.0457)	(0.0524)	(0.0524)	(0.0586)	(0.0586)
Constant	-28.61***	-28.74***	-30.84***	-31.03***	-26.87***	-27.02***
	(0.359)	(0.363)	(0.400)	(0.404)	(0.456)	(0.459)
Time dummies		yes		yes		yes
Observations	62875	62875	62875	62875	58468	58468
R-squared	0.627	0.628	0.585	0.587	0.479	0.480

Source: Authors' calculations; Note: Standard errors are clustered by bilateral pair. Robust standard errors are reported in parenthesis: *** $p<0.01$, ** $p<0.05$, * $p<0.1$

However, an inspection at the evolution over time of the GDP coefficients for bilateral trade between pairs of Factory Asia countries (i.e. Japan, Indonesia, Rep. of Korea, Malaysia, Philippines, Thailand, and Taiwan) reveals a different story (Figure 1): GDP elasticities fall over time, with two clear breaks in the estimated coefficients: 1985 and 1998.

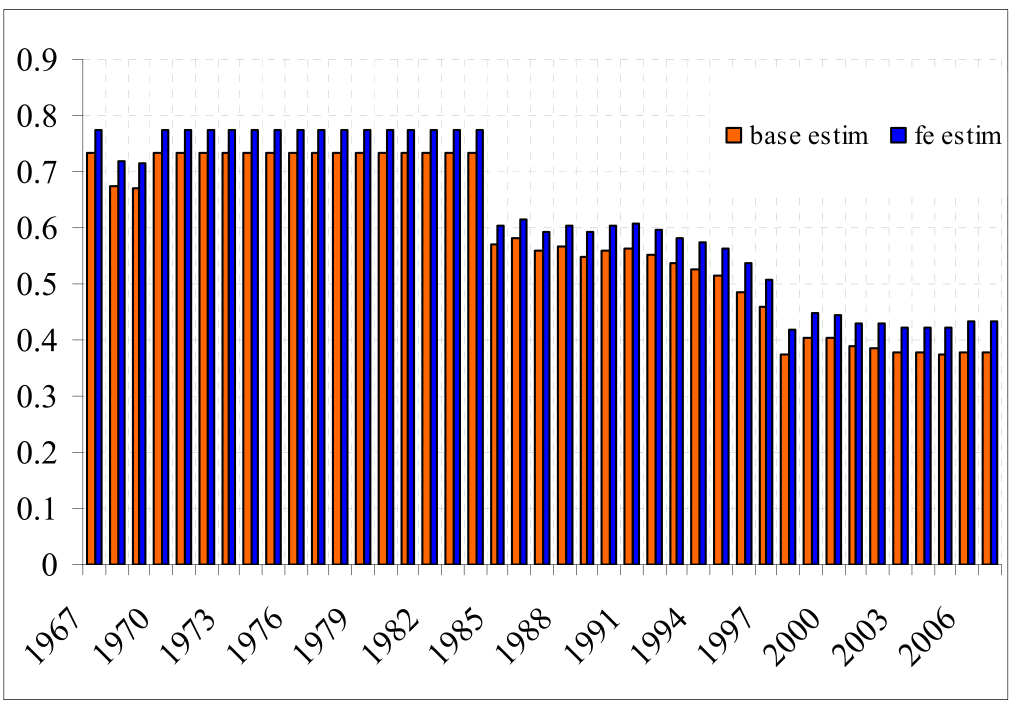
The timing and direction of these structural changes are very much in line with the literature on the internationalisation of production. According to many studies, production unbundling started in the mid-1980s and accelerated in the 1990s (e.g. Hummels, Rapport and Yi 1998). The idea is that the various stages of manufacturing were spatially glued together due to coordination costs, not transportation costs (Baldwin 2006). Coordinating the manufacturing process involved a continuous two-way flow among the production stages of things, people and information. The local clustering was driven by the fact that it is just easier, faster, surer, and cheaper to undertake complex activities that involve many people when those people are physically close to each other.

Some of this coordination glue is related to communications, so as telecommunications became cheaper, more reliable and more widely spread from the mid-1980s onwards, the coordination glue began to loosen.

The communication revolution came in two phases. The internet first came on line in a massive way in the mid-1980s, and then, in the 1990s, the price of telecommunications plummeted with various ITC related technical innovations and widespread deregulation. The upshot of all these changes was that it became increasingly economical to geographically separate manufacturing stages. Stages of production that previously were performed within walking distance to facilitate face-to-face coordination could be dispersed without an enormous drop in efficiency or timeliness. Once this was feasible, scale economies and comparative advantage made it inevitable. Manufacturing supply chains were internationalised. This is globalisation's "second unbundling". The ICT revolution was to the second unbundling what the steam power revolution was to the first.

As far as the Figure 1 results are concerned, the notion is that as trade was increasingly focused on intermediates, GDP became an increasingly poor determinant of trade flows – as suggested by our theory. The impact of the mid-1980s changes and the mid-1990s changes are clear from the estimated GDP elasticities.

Figure 1: GDP coefficients for Factory Asia countries, 1967-2008.



Source: own estimations; Note: Figures report the estimated coefficients of α_1 (product of GDPs) with year dummies and two different gravity equation specifications. Base estimation is specificed as in (9). Fixed effects estimation is specificed as in (10). Factory Asia countries: Japan, Indonesia, Republic of Korea, Malaysia, Thailand, and Taiwan.

More specifically, from 1967 to 1985 the elasticity of these countries' bilateral imports to GDP was stable, with a coefficient of about 0.77. Between 1985 and 1997, it steadily decreased to reach a coefficient value of about 0.60, and after 1998, it further dropped to a figure close to 0.40. The coefficient estimates for the different periods in Factory Asia are summarised inTable 3, columns (4) and (5). Estimation results also show unusually low coefficients for distance.

Table 3: Bilateral flows of total goods between Factory Asia countries (1967-2008).

VARIABLES	(1) All goods $imports_{odt}$	(2) All goods $imports_{odt}$	(3) All goods $imports_{odt}$	(4) All goods $imports_{odt}$	(5) All goods $imports_{odt}$
ln ($GDPo_t$*$GDPd_t$/Ωot*Pdt)	0.725***	0.725***	0.764***	0.425***	0.504***
	(0.00880)	(0.0283)	(0.0260)	(0.0546)	(0.0510)
*years 1967-1986				0.318***	0.278***
				(0.0475)	(0.0476)
*years 1987-1996				0.177***	0.164***
				(0.0274)	(0.0315)
*years 1998-2002				0.00679	0.00274
				(0.0149)	(0.0170)
ln $Distance_{od}$, weighted	-0.258***	-0.258		-0.0414	
	(0.0570)	(0.298)		(0.297)	
Contiguity	0.188***	0.188		0.167	
	(0.0682)	(0.386)		(0.367)	
Colony	-0.487***	-0.487		0.0695	
	(0.101)	(0.388)		(0.405)	
Common coloniser	-0.620***	-0.620*		-0.296	
	(0.116)	(0.325)		(0.324)	
Constant	-7.218***	-7.218***	-8.825***	-1.465	-2.632**
	(0.433)	(2.281)	(0.485)	(2.279)	(1.178)
Observations	1722	1722	1722	1722	1722
R-squared	0.833	0.833	0.936	0.851	0.948
Time effects	yes	yes		yes	
Exporter*time effects			yes		yes
Importer*time effects			yes		yes
Pair effects			yes		yes
Observations	820	820	820	820	820
R-squared	0.932	0.932	0.978	0.934	0.978
Clustered Standard Errors		yes	yes	yes	yes

Source: Authors' calculations; Note: Standard errors are clustered by bilateral pair. Robust standard errors are reported in parenthesis: *** p<0.01, ** p<0.05, * p<0.1

For sake of comparison we also report results of time-year interactions with GDP for bilateral trade between countries where casual observation suggests that bilateral trade is dominated by consumption goods, i.e. bilateral trade between each of the EU15 and two Anglo-Saxon countries (the USA and Australia). As predicted by our theory, we find no breaks over time in the trade coefficients while distance coefficients have elasticity levels which are closer to unit. See Table 4.

These two sets of results are highly suggestive when it comes to the hypothesis that bilateral flows dominated by intermediate imports fail to obey the standard laws of trade gravity.

Table 4: Estimates for EU15 and US, Canada, Australia and New Zealand, 1967-2008.

VARIABLES	(1) All goods $imports_{odt}$	(2) All goods $imports_{odt}$	(3) All goods $imports_{odt}$	(4) All goods $imports_{odt}$	(5) All goods $imports_{odt}$
ln ($GDPo_t$*$GDPd_t$/Ωot*Pdt)	0.659***	0.659***	0.632***	0.725***	0.703***
	(0.00926)	(0.0254)	(0.0276)	(0.0583)	(0.0340)
*years 1967-1986				-0.0408	-0.0503
				(0.0505)	(0.0444)
*years 1987-1996				-0.0376	-0.0444
				(0.0358)	(0.0319)
*years 1998-2002				0.0132	0.00534
				(0.0172)	(0.0143)
ln $Distance_{od}$, weighted	-0.843***	-0.843***		-0.688**	
	(0.0593)	(0.233)		(0.276)	
Constant	-1.630**	-1.630	-8.819***	-4.966	-10.72***
	(0.726)	(2.284)	(0.657)	(3.733)	(0.917)
Time effects	yes	yes		yes	
Exporter*time effects			yes		yes
Importer*time effects			yes		yes
Pair effects			yes		yes
Observations	820	820	820	820	820
R-squared	0.932	0.932	0.978	0.934	0.978
Clustered Standard Errors		yes	yes	yes	yes

Source: Authors' calculations; Note: Standard errors are clustered by bilateral pair. Robust standard errors are reported in parenthesis: *** p<0.01, ** p<0.05, * p<0.1

To explore this more systematically, we re-estimate the gravity equation on the full sample of 187 countries for the years 2000-2007, but allow interaction with a deciles dummy, i.e. dummies that selects bilateral flows where the proportion of intermediate imports is in the top deciles, second deciles, etc. The idea here is that GDP as a measure for economic mass should work less well for those bilateral flows that are marked by relatively high shares of intermediates trade. By estimating the effect on the full sample, we avoid the problem of identifying the exact sources of the variation in the coefficients. Table 5 reports the estimated results for the coefficients of interest.

For the variable of greatest interest, the economic mass variable, the coefficient for the base-case decile (the first one) is 0.85, i.e. of the expected sign and highly significant. The additional effects picked up by the interactions with the deciles dummies are insignificant at the 5% level – and in many cases even at the 1% level – for all deciles except the two highest ones – i.e. the flows with the highest concentration of intermediate goods. These interaction terms are negative (around -0.1) and highly significant.

This confirms the more informal tests based on an a priori separation of the sample. That is to say, we find that GDP has a lower than usual coefficient for bilateral flows that have a higher than usual share of parts and components.

Table 5: All countries, 2000-2007, by share of intermediate imports.

	ln ($GDP_{it*}GDP_{jt}/\Omega it*Pjt$)	ln($Distance_{ij}$, weighted)	$Contiguity_{ij}$	Common off. language
Base effect	0.850***	-0.642***	1.583***	0.722***
	(0.0215)	(0.0683)	(0.423)	(0.134)
Base effect X q2	0.0197	-0.109	-0.102	0.0817
	(0.0245)	(0.0778)	(0.546)	(0.154)
Base effect X q3	0.0461*	-0.0685	0.392	0.136
	(0.0247)	(0.0760)	(0.579)	(0.154)
Base effect X q4	0.0146	-0.0746	-0.156	0.326**
	(0.0243)	(0.0746)	(0.478)	(0.155)
Base effect X q5	-0.0239	-0.121	-0.322	0.379**
	(0.0246)	(0.0741)	(0.445)	(0.155)
Base effect X q6	-0.00870	-0.184**	-0.426	0.482***
	(0.0245)	(0.0752)	(0.453)	(0.160)
Base effect X q7	0.0445*	-0.188**	0.166	0.419***
	(0.0254)	(0.0780)	(0.467)	(0.159)
Base effect X q8	-0.0204	-0.205**	0.0362	0.243
	(0.0277)	(0.0808)	(0.465)	(0.164)
Base effect X q9	-0.0898***	-0.0143	0.355	0.0969
	(0.0273)	(0.0862)	(0.462)	(0.171)
Base effect X q10	-0.102***	0.0445	-0.212	-0.0715
	(0.0327)	(0.111)	(0.859)	(0.215)

Source: Authors' estimations; Note: deciles categorise countries bilateral imports by increasing shares of intermediate imports over total imports. Hence q10 indicates the 10% bilateral import relationships where the share of intermediate imports in total imports is highest and the base effect the 10% bilateral import relationships where the share of intermediate imports in total imports is lowest. Standard errors are clustered by bilateral pair. Robust standard errors are reported in parenthesis: *** p<0.01, ** p<0.05, * p<0.1

4. ESTIMATING THE GRAVITY EQUATION WHEN INTERMEDIATES ARE IMPORTANT

The previous section provides clear evidence that the standard gravity equation is "broken" when it comes to bilateral flows where intermediate goods trade is important. Here we explore some empirical strategies that might provide practical "fixes". The basic thrust is to use the theory in Section 2 to develop some proxies for economic mass variables that better reflect the fact that the demand for intermediates depends upon gross output, not value added.

Although we have undertaken a number of experiments, we have not yet identified a set of proxies for economic mass that is both practical – in the sense of being based on data that is widely available – and works well for a data set that includes bilateral flows with a varying share of intermediates.

5. CONCLUDING REMARKS

In this paper we present empirical evidence that the standard gravity model performs poorly by some measures when it is applied to bilateral flows where parts and components trade is important. The paper also provides a simple theoretical foundation for a modified gravity equation that is suited to explaining trade where international supply chains are important. In future drafts, we shall suggest ways that the theoretically model can be implemented empirically.

6. Appendix

Classification for intermediate and final goods

	BEC categories
Intermediate goods:	111 - Primary food and beverages, mainly for industry 121 - Processed food and beverages, mainly for industry 21 - Primary industrial supplies not elsewhere specified 22 - Processed industrial supplies not elsewhere specified 32 - Processed fuels and lubricants 42 - Parts and accessories of capital goods (except transport equipment) 53 - Parts and accessories of transport equipment
Consumption goods:	112 - Primary food and beverages, mainly for household consumption 122 – Processed food and beverages, mainly for industry 51 - Passenger motor cars 6 - Consumer goods not elsewhere specified
Other:	31 - Primary fuels and lubricants 41 - Capital goods, excluding parts and components 51 - Other transport equipment 7 - Other

Source: Comtrade's Broad Economic Categories; for details see http://unstats.un.org/unsd/tradekb/Knowledgebase/Intermediate-Goods-in-Trade-Statistics

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