Short Run Gravity*

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Abstract

The short run gravity model is based on mobile labor combined with fixed bilateral capacities (marketing capital). Efficient capacity allocation yields long run gravity. Rising efficiency of bilateral capacity allocation is estimated to raise world manufacturing trade 162% in the globalization era, 1988-2006. Counter-factual calculation of long run efficient capacity allocation reveals real income gains to all countries from 25% to 47%. Results give solutions to the 'distance puzzle' and the 'missing globalization puzzle'. The estimated short run trade elasticity is about 1/4 the long run trade elasticity, 1/4 being the micro-founded buyers' incidence elasticity parameter.

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1 Introduction

The short run gravity model developed in this paper solves several time invariance puzzles posed by the recent empirical gravity literature. In brief, where is the globalization?[1] The model and its application give an answer. Invariant gravity coefficients are consistent with trade costs that vary with volume in the short run due to diminishing returns to a variable factor paired with a bilaterally specific fixed factor. Log-linear gravity results under plausible restrictions as a static equilibrium structure that shifts over time as capacities (marketing capital allocations) move. The structure of the model makes natural a new question – how far can globalization go? The estimated model implies that increasing efficiency of allocation of marketing capital in 1988-2006 manufacturing increased world trade 162%. The 2006 equilibrium is nevertheless a long way from efficiency. Counterfactual long run efficient equilibrium allocation of marketing capital implies real income gains to countries ranging from 25% to 47% relative to the 2006 base.

Short run gravity nests (the now-standard) long run gravity model interpreted here as characterized by efficient allocation of marketing capital. Short run shipments from origin i to destination z at time τ relative to hypothetical frictionless shipments (size-adjusted trade flows) are shown below to be given by:

$$[\textbf{Long Run Gravity}(\mathbf{i},\mathbf{z})]^{\rho}\,\lambda(\mathbf{i},\mathbf{z},\tau)^{\mathbf{1}-\rho}. \tag{1}$$

[1] Gravity's emergence from the shade [e.g. Head and Mayer (2014)] highlights empirical and conceptual puzzles. On one hand gravity-fitted bilateral trade flows come very close to the data and estimated coefficients are stable over time. On the other hand, this fit and stability violate intuition and observation about trade cost behavior over time. Secular invariance of coefficients is a puzzle in light of big technological improvements in transportation and communications over the past 60 years. Cyclic invariance is a puzzle in light of cyclic variation of shipping rates and delivery lags. Coe et al. (2002) define the 'Missing Globalization Puzzle' as "the failure of declining trade-related costs to be reflected in estimates of the standard gravity model of bilateral trade" (p.1). Higher frequency invariance and good fit is further puzzling in light of business cycle movement of ocean shipping rates and delivery lags. Imperfectly correlated national expenditures over the business cycle and big secular shifts in the location of economic activity suggest cyclical and trend variation in bilateral trade costs over time and space. Time invariance also appears to conflict with the richly patterned adjustment over time in bilateral trade links of French export firms emphasized by Chaney (2014), and the random entry and exit in US 10-digit trade emphasized by Besedes and Prusa (2006).

[**Long Run Gravity** $(\cdot)$] is the standard gravity model expression for the trade depressing effect of bilateral relative to multilateral resistance in the long run equilibrium.[2] $\lambda(i, z, \tau)$ is a bilateral capacity variable – the 'marketing capital' allocation. An important part of $\lambda(i, z, \tau)$ is origin-destination-specific investment in bilateral links.[3] ρ is the buyers' short run incidence elasticity, the fraction of trade cost variation borne by buyers.[4] ρ is a combination of the elasticity of substitution in demand and the elasticity of supply, itself micro-founded in the joint supply of output delivered to many destinations at increasing cost due to diminishing marginal product of a variable factor on each link. The model encompasses heterogeneous productivity, of industries (as in Eaton and Kortum (2002)) or of firms (as in Chaney (2008)). When $\lambda(i, z)$ is at efficient levels everywhere, short run gravity trade flows equal their long run gravity values – long run gravity is the outer envelope of short run gravity.

The key conceptual object introduced in this paper is the micro-founded incidence elasticity parameter $\rho \in (0, 1)$ in (1) that distinguishes the short run trade elasticity from the long run trade elasticity. We seek an estimate of ρ from the movement of bilateral trade patterns over the era of globalization 1988-2006 when traders everywhere plausibly increased efforts to find foreign counter-parties. Inference of ρ requires disentangling the speed of adjustment of $\lambda(i, z, \tau)$s from the magnitude of the effect of $\lambda(i, z, \tau)$ changes on bilateral trade changes

[2]As demonstrated by Arkolakis et al. (2012), [**Long Run Gravity**$(\cdot)$] derives from a wide array of theoretical microfoundations. Anderson (1979) is the first to offer a theoretical economic foundation for the gravity equation in an Armington-CES setting. Other early contributions to gravity theory include Krugman (1980) and Bergstrand (1985), who obtain gravity from a monopolistic competition and a Heckscher-Ohlin foundations, respectively. Eaton and Kortum (2002), who derive gravity in a Ricardian framework with intermediate goods, and Anderson and van Wincoop (2003), who popularize the Armington-CES model and emphasize the importance of the general equilibrium effects of trade costs, are arguably the most influential gravity theories. More recently, the gravity model has been derived in a heterogeneous firm setting by Chaney (2008) and Helpman et al. (2008). See Anderson (2011), Arkolakis et al. (2012), Head and Mayer (2014), and Costinot and Rodriguez-Clare (2014), and Yotov et al. (2016) for recent surveys of the evolution of the theoretical gravity literature.

[3]Bilateral capacity here is a notion consistent with the network link dynamics modeled by Chaney (2014) and with the link between managers' experience in previous firms and the export performance of their current company described by Mion and Opromolla (2014) as well as the 'marketing capital' notion of Head et al. (2010). The property of rising short run marginal cost of trade here resembles the increasing cost model of Arkolakis (2010), but differs in the cause. Rising long run trade cost in Arkolakis (2010) is due to increasing difficulty of reaching new customers. Long run trade costs are constant in our model.

[4]The term incidence elasticity is chosen to distinguish it from the passthrough elasticity used to describe incomplete incidence of exchange rate changes on prices, a higher frequency behavior that may reflect other causes than are the focus of this paper.

from origin i to destination z. Thus some dynamic structure is needed.

There is no settled theory of trade link dynamics. Our approach is thus to combine simple ad hoc dynamic devices with the short run gravity model to allow econometric inference. Our strategy is to lean heavily on structural gravity and associated regularities of geography while being agnostic about dynamic structure in our panel data. In contrast, Sampson (2016) develops and calibrates a technology flows structural dynamic gravity model, made feasible only by assuming uniform sized countries and uniform trade costs.

A reduced form dynamic approach uses cross-border-time fixed effects with panel gravity data to control for the effect of globalization. The estimated border-time fixed effects move smoothly over time while the gravity coefficients are stable. In the context of the short run gravity model, this suggests that a single dynamic adjustment parameter combines with ρ to fit the data. An external adjustment parameter estimate then yields an estimate of ρ from the reduced form approach. An alternative *ad hoc* structural dynamic device (explained below) infers the effect of globalization from lagged dependent variables, with standard treatments for endogeneity. The same external value of the speed of adjustment combined with the estimated structural model yields another estimate of ρ. Using the results of the two approaches simultaneously yields a third estimate of ρ and an estimate of the speed of adjustment. The various estimates of ρ are close to each other. This empirical success is presumably because the era of globalization is so dominated by smooth adjustment toward greater cross-border trade that any plausible dynamic model with a constant rate of adjustment comes close to the trade data. Concerns about the *ad hoc* dynamic devices are thus mitigated.

Application of the model to manufacturing trade data for 52 countries yields a good fit with intuitively plausible parameters. The reduced form results suggest that the growing efficiency of trade capacity increased trade volume by 162%. Our estimation procedures suggests $\rho \in (0.20, 0.37)$, narrowed to $(0.20, 0.24)$ in our favored specifications with a preferred value 0.24. In all robustness checks ρ is significantly far below 1, statistically and economically. Most importantly, the consistency of results on ρ and the goodness of fit tend to confirm that a parametric incidence elasticity comes close to the data. Beyond the present paper the results suggest the usefulness of short run gravity in modeling bilateral trade even in eras where dynamic adjustment may be more complex.

The focus of the paper on marketing capital efficiency naturally leads to the question of how far globalization can go. To provide an answer the estimates of ρ and the other gravity parameters are used to quantify the potential real income gain from long run efficient allocation of marketing capital. The counterfactual experiment compares two static equilibria, one short run and the other the long run hypothetical equilibrium with base endowments, preferences, trade costs and parameters held constant except for efficient reallocation of marketing capital. Gains from efficient globalization are universally big – real manufacturing income rises everywhere, ranging from 25% to 47%.

The paper also contributes to the literature on measuring trade elasticities. Cross section trade elasticity estimates are usually interpreted as long run elasticities. Expression (1) implies that the standard cross section gravity model may suffer from omitted variable bias, but will be an unbiased estimator of long run elasticities when standard covariates adequately control for the missing bilateral capacities $\lambda(i, z, \tau)$. Short run gravity given by (1) along with the no bias property generates a simple prediction about the relationship between short run (SR) and long run (LR) gravity elasticities:

$$\beta_l^{SR} = \beta_l^{LR} \rho, \tag{2}$$

where l denotes any gravity covariate, e.g. distance, tariffs, etc. A test statistic based on equation (2) yields results below consistent with no bias in long run elasticities from the standard gravity literature. Long run elasticity estimates usually range between 4 and 12. Our estimates of ρ around 1/4 suggest a range for short run elasticities between 1 and 3.[5]

[5]See Eaton and Kortum (2002), Anderson and van Wincoop (2003), and Broda et al. (2006). The corresponding short run elasticities from the IRBC macro literature are usually between 1 and 2. See Backus et al. (1994), Zimmermann (1997), Heathcote and Perri (2002) and Feenstra et al. (2012).

Equation (2) is a time-invariant relationship between short run and long run trade elasticities. The related literature in contrast links short run time-varying to static long run elasticities. Ruhl (2008) reconciles the difference between short run and long run elasticities in a model based on cyclical fluctuations being temporary whereas trade cost changes are permanent. Arkolakis et al. (2011) offer an explanation capable of handling the many country gravity context. A fraction of boundedly rational (myopic) consumers switch to cheaper suppliers at each point in time. In contrast, our model assumes perfectly efficient spatial equilibrium given the marketing capital allocation. Closest to our model, Crucini and Davis (2016) explain the discrepancy between the short run and long run elasticities with distribution capital that is specific to the origin of the good, domestic or foreign. In comparison to our model, theirs allows for CES production of distribution whereas ours restricts the elasticity of substitution to 1 (i.e. Cobb-Douglas). This simplification buys time-invariance of the short run trade elasticity. (Their structure is embedded in a two country real business cycle model and their application calibrates the model to moments of price dispersion data for 6 sectors in 13 US cities.)

A second implication of equation (2) suggests an explanation of the broad 'missing globalization puzzle' (Coe et al., 2002): the effects of geographic impediments such as distance and other geographic impediments to estimated gravity equations have been stable, or even increasing over time. Time invariance of estimated coefficients of standard cross section gravity regressions is explained by iceberg trade cost proxies that control well for the omitted bilateral capacity variables. Bilateral capacity adjusts over time toward an efficient level that is shown below to depend on the same iceberg trade costs as in the standard cross section model.[6] We estimate highly significant declining border effects associated with rising investment in cross-border capacities relative to domestic capacities. The missing globalization is in the omitted dynamic adjustment of bilateral capacities driven by the same geographic

[6]The puzzles of time-invariant gravity estimates have attracted significant attention in the literature. A series of papers have proposed purely empirical solutions to the puzzles. See Buch et al. (2004), Carrre and Schiff (2005), Brun et al. (2005), Boulhol and de Serres (2010), Lin and Sim (2012), Yotov (2012) Carrre et al. (2013), Bergstrand et al. (2015) and Larch et al. (2016).

forces that drive spatial variation of bilateral trade flows. The omission is concealed by standard static gravity estimation that is an unbiased estimate of long run gravity.

The short run gravity model also implies a theory of the many zeroes observable in bilateral trade flows, some persistent and some flickering on and off. (Empirical investigation of the theory of zeroes is left to future research.) Changes in persistent zeroes are due to investments in bilateral capacity on the extensive margin as capacity moves toward an efficient long run extensive margin of markets served. Flickering zeroes are due to demand changes combined with period-by-period fixed cost components of variable trade costs such that the origin-destination pair representative firm flips from one side to the other of the break-even point for serving a particular destination. In the heterogeneous firms version of the model, the breakeven point for not serving a destination applies to the least productive active firm on an interior extensive margin.[7]

Section 2 presents the basic theoretical model of joint trade costs of production and delivery to many destinations. Section 3 applies the model to the multi-country setting, yielding the short run gravity model. Section 4 develops and tests two complementary empirical versions of the model. Supplemental online Appendix A shows that the basic model encompasses heterogeneous productivities (as in Eaton and Kortum (2002)) and heterogeneous firms (as in Chaney (2008)). Appendix A also draws out the implications of model for a theory of endogenous trade costs such as may be applied to model inference from price comparisons for homogeneous goods across many locations. Supplemental Appendix B reports on sensitivity experiments with the main empirical models. The main results are robust.

[7]Helpman et al. (2008) (HMR) offer the first model of zeroes based on fixed export costs. Firms draw productivities from a Pareto distribution with an upper bound such that zeroes are explained by a sufficiently low upper bound such that no firm at a particular origin receives a draw high enough to cover the fixed cost of entering a particular destination market. Our model for short run zeroes differs only in that fixed capacity implies increasing opportunity cost of serving small markets, hence a U-shaped full average cost curve that can lie everywhere above a small destination market's willingness to pay, even with an unbounded Pareto productivity distribution. The equilibrium extensive margin thus depends only on technology and taste parameters. Short run entry and exit flickering on the extensive margin are induced by demand or technology shocks that can have any distribution. Other models use demand systems with choke prices to explain zeroes, e.g. quadratic as in Melitz and Ottaviano (2008), or translog as in Novy (2013). While choke prices are realistic, such systems appear to do worse (according to Novy's, 2013, results) at fitting the data than the standard CES gravity equation.

2 A Model of Joint Trade Costs

An origin region produces and ships a product to potentially many destinations. Distribution on each link requires labor and capital in variable proportions, multiplicatively amplified by iceberg trade and production cost factors. The scalar iceberg cost factors differ across destinations according to bilateral geographical features such as distance and borders and other familiar variables in the gravity literature. Cost-minimizing allocation of resources implies that bilateral trade destinations are imperfect substitutes. One factor is variable in the short run (labor that can be freely allocated across destination markets that have positive capacity) and one is fixed in the short run (capacity in each potential network link).

The variable labor requirement to each destination served includes a fixed labor component, interpretable as an office staff required to monitor trade on each active bilateral link. The fixed labor requirement is normalized to one for expositional ease. For simplicity the office staff labor is perfectly substitutable for 'line' labor assigned to produce and distribute goods on each link. Labor, including the office staff labor, is mobile in the short run across production for destinations actively served.

The trade activity also requires destination-specific "marketing capital" that is committed (sunk) before the allocation of labor, though it is variable *ex ante*. Marketing capital is thus bilaterally specialized and fixed in the short run. The details of destination specialization, while interesting and important (e.g., Chaney, 2014), are outside the scope of this paper. "Marketing capital" is left vague to encompass both human capital in the form of network connections and physical capital particularized to serve a particular destination. The idea of a retail network in Crucini and Davis (2016) is similar.

Bilateral production and trade of a generic firm in a generic origin and sector to destination z is formally modeled as a Cobb-Douglas function of line (non-office) labor $L(z) - 1$ and capital $K(z)$: $x(z) = (1/t(z))K(z)^{1-\alpha}(L(z) - 1)^{\alpha}$. The functional form implies that the office staff of 1 unit, is required.[8] $x(z)$ is delivered product. $t(z) > 1$ is the technological

[8] The office staff story is just one justification of the formal requirement of a fixed labor cost for each

iceberg-melting parameter from the given origin to destination z, a penalty imposed by 'nature' relative to the frictionless benchmark $t = 1$. $t(z)$ also reflects a productivity penalty in the usual sense that would apply to all destinations z uniformly. With all inputs variable (in the long run), the production function exhibits economies of scale. In the short run with $K(z)$ fixed, decreasing returns dominate.[9] For now, all firms are identical in any origin, aggregating to an industry with the generic firm's characteristics. Appendix Section A.1.1 shows that the short run gravity model extends in all essentials to include the heterogeneous firms model with firm productivities drawn from a Pareto distribution. (Essentially the same short run gravity model extends to incorporate fixed infrastructure at each location and time, adding location-time-specific productivity shifters controlled for econometrically with location-time fixed effects.)

For the generic sector as a whole, labor is drawn from a national labor market in an amount satisfying the value of marginal product condition at the national wage rate. The labor market constraint on short run allocation across destinations is $L = \sum_0^n L(z)$, where L is labor supply to the sector and destination $z = n$ is at the extensive margin. n units of office staff labor assigned to a total of n destinations are included in L. Labor is efficiently allocated across destination activities with value of marginal product equal to the common wage. Office staff are drawn from the common labor pool and are paid the common wage.

The price for delivered output at destination z is $p(z)$. Delivered price $p(z)$ in competitive equilibrium covers costs: $w[L(z) - 1] + r(z)K(z) + w = p(z)x(z)$ where $r(z)$ is the realized (residual) return on the specific capital for delivery to destination z. The first term on the left hand side of the equation is the line workers wage bill, the second term the payments to sector specific capital and the third term the payment to the office staff.

The extensive margin destination n is reached when the wage required for the office staff

destination served. Normalization of the fixed cost input to 1 unit of labor is a harmless convience. Heterogeneity across destinations in the amount of fixed input required is readily introduced, whence the production function has the Stone-Geary form.

[9]To see the long run economies of scale, consider a scalar expansion of $K(z), L(z)$. The elasticity of $x(z)$ with respect to a one % rise in $K(z), L(z)$ is equal to $1 - \alpha + \alpha L(z)/[L(z) - 1] > 1$ in the long run. The marginal product of labor is diminishing in the short run, $\partial^2 x(z)/\partial L(z)^2 = (\alpha - 1)\alpha x(z)/[L(z) - 1] < 0$.

exceeds the value of sales minus the wage bill for line workers labor; i.e., profits are negative. Even with positive profits, destination z may not be served if $K(z) = 0$, no destination-specific capital is allocated. Destination-specific capital $K(z)$ is allocated prior to production and delivery to $n^* \geq n$ potentially active destinations, accounting for $K = \sum_0^{n^*} K(z)$ units of capital. The allocation shares of capital are $\lambda(z) = K(z)/K$. Long run efficient allocation of capital and its extensive margin n^* is analyzed in Sections 3.2-3.3.

The value of production at delivered prices in the generic region and sector is the sum over destinations z of the payments to labor (line and office staff) and the payment to non-managerial capital given by[10]

$$Y = (L - n)^\alpha K^{1-\alpha} C, \tag{3}$$

where

$$C \equiv [\sum_0^n \lambda(z)(p(z)/t(z))^{1/(1-\alpha)}]^{1-\alpha}. \tag{4}$$

The real activity level

$$R = (L - n)^\alpha K^{1-\alpha}$$

in (3) is multiplied by a price index C embedding efficient allocation of the joint activity to delivered output at the many destinations. The setup thus yields a Constant Elasticity of Transformation (CET) joint revenue function for delivered output. (The level of activity R can be taken as exogenous for gravity model purposes, hence it is not necessary to assume that activity R is a Cobb-Douglas function of labor and specific human capital.)

The equilibrium share of sales to each destination z that is served, by Hotelling's Lemma

[10] The setup here extends the specific factors production model of Anderson (2011) to include a fixed cost. In Anderson (2011) the environment is a GDP function where z denotes a sector in a continuum of fixed size, $t(z)$ is a productivity penalty and there is no fixed cost.

Competitive equilibrium implies that labor is paid a common wage in serving all markets, equal to the value of marginal product of labor in each market. Aggregate labor employed is L, taken as an endowment in solving for Y in (3) below. Price index $C(\cdot)$ results from solving the labor market clearance condition for the wage, then replacing the wage with the resulting reduced form in evaluation aggregate revenue.

(applied to (3) using (4)), is

$$s(z) = \lambda(z)\left(\frac{p(z)/t(z)}{C}\right)^{1/(1-\alpha)}. \qquad (5)$$

It is convenient for later purposes to sort destinations by rank order, beginning with the largest (so in equation (5) $z \in [0, n]$). The local delivery market is $s(0)$ by convention because empirically it is almost universally the largest.

The short run extensive margin n is determined by the value of marginal product of labor in sector n falling below its value on the intensive margin for sectors $z < n$. This implies that the extensive margin is efficient in the sense of maximizing (3) with respect to n. For simplicity, temporarily think of a continuum of destinations (with 'shares' being densities) and differentiate (3) with respect to n. The first order condition yields

$$\alpha Y/(L-n) = (1-\alpha)s(n)Y.$$

The left hand side is the value of marginal product of line labor, equal to the wage. The right hand side is the value of marginal product of the extensive margin office staff. Manipulating the first order condition, the implication is:

Proposition 1: Extensive Margin. *The smallest market served in short run equilibrium is unique and characterized by:*

$$n = \{z : s(z) = \frac{\alpha}{1-\alpha}[L-z]^{-1}\}. \qquad (6)$$

Ordering markets by decreasing size, the extensive margin is the smallest market that can be served.

Equation (6) implies that office staff paid w exhausts the entire residual payment in sector n. The wage $= \alpha Y/(L-n)$ is rising in n, while $(1-\alpha)s(n)Y$ decreasing in n; hence the equilibrium extensive margin exists and is unique. (6) readily rationalizes the flickering on and off of bilateral trade that is observable in highly disaggregated data: capacity is in place but insufficient revenue to cover the overhead cost of office staff indicate temporary shutdown. Section 3.2 analyzes the long run extensive margin of installed capacity.

An implication of extensive margin model (6) is that volume equations for positive trade are not subject to selection bias. That is because firms are identical, in contrast to heterogeneous firms literature. When the model is extended to heterogeneous firms with productivities drawn from an unbounded Pareto distribution following Melitz (2003), the volume of positive trade on any link combines smooth action on both extensive and 'interior' intensive margins in a closed-form structural gravity equation. With proxies for fixed costs that differ from the proxies for iceberg trade costs, the action can be decomposed into the component intensive and extensive margins. (The condition (6) for the extensive margin destination remains the same, with the slight complication that the simple fixed cost normalized to 1 for each destination served is replaced by the mass of firms $S(z)$ that are productive enough to serve destination z. n in (3) becomes $N = \int_0^n S(z)dz$, the accumulated mass of all firms serving active destinations. The details are developed below in Appendix Section A.1.1.)

For any market that is served, the equilibrium delivered price $p(z)$ is endogenously determined by the supply side forces described in (3)-(5) interacting with demand forces described by Constant Elasticity of Substitution preferences or technology (in the case of intermediate goods). The intuitive notion of a bilateral trade cost corresponds to $p(z)/p(0)$, a clear idea when $t(0) = 1$, so bilateral trade cost is endogenous. In practice, this is a dangerous simplification because internal delivery costs are not zero, differ across countries and are endogenous just as the bilateral costs are endogenous, cf. Agnosteva et al. (2014) and Ramondo et al. (2016).

Description of the demand side of the market requires an expansion of notation to designate the location of the originating sector. The CES expenditure share for goods from origin

i in destination z is given by

$$\frac{X(i,z)}{E(z)} = \left(\frac{\beta(i)p(i,z)}{P(z)}\right)^{1-\sigma}. \tag{7}$$

Here, $X(i,z)$ denotes the bilateral flow at end user prices, $E(z)$ denotes the total expenditure in destination z on goods from all origins serving it, $\beta(i)$ is a distribution parameter of the CES preferences/technology, σ is the elasticity of substitution, and $P(z)$ is the CES price index for destination z.

The market clearing condition for positive bilateral trade from i to z is

$$Y(i)s(i,z) = X(i,z).$$

Using (5) for $s(i,z)$ and (7) for $X(i,z)$ in the market clearing condition to solve for the equilibrium price $p(i,z)$ yields:

$$p(i,z) = \left[\frac{E(z)P(z)^{\sigma-1}\beta(i)^{1-\sigma}[t(i,z)C(i)]^{\eta}}{Y(i)\lambda(i,z)}\right]^{1/(\eta+\sigma-1)}, \tag{8}$$

where $\eta = 1/(1-\alpha) > 1$ is the supply elasticity. The short run equilibrium price in an active origin-destination pair in (8) is an intuitive constant elasticity function of demand shifters $E(z)P(z)^{\sigma-1}$, supply shifters $Y(i)$ and $C(i)$, and the exogenous bilateral friction components in $t(i,z)$ and the contemporaneously exogenous bilateral capacity $\lambda(i,z)$.

Incidence of trade costs to buyers is incomplete: the buyers' incidence elasticity is $d\ln p(i,z)/d\ln t(i,z) = \eta/(\eta+\sigma-1) \equiv \rho$. The incidence elasticity ρ (dropping "buyers" for brevity) plays a key role in the gravity representation of the model. ρ has a deep micro-foundation as a combination of the demand elasticity parameter σ and the supply elasticity parameter η, itself microfounded in the equilibrium of distribution based on the Cobb-Douglas specific factors model. ρ is increasing in η and decreasing in σ.[11]

[11]Equation (8) can, in principle, account for substantial variation in prices across time and space. Rents to the sector specific factor similarly vary (see Section 3.2). Rents are competitive in the model, so pricing to

3 Gravity in Short Run and Long Run

The gravity representation of short run equilibrium trade yields a gravity model with a short run trade cost elasticity equal to the product of the long run trade cost elasticity times the incidence elasticity ρ. The short run elasticity applies everywhere. The short run trade flow and multilateral resistance equations are additionally altered relative to long run gravity by the volume effects of bilateral specific capacity everywhere.

Multilateral resistance for sellers is derived from the global market clearing condition for $Y(i)$. Substitute (8) into (7), then multiply by $E(z)$ and sum over z to obtain the global demand for $Y(i)$. Collect the terms for $Y(i)$ on the left hand side of the market clearance condition and simplify the exponents $1-\rho(\sigma-1)/\eta = \rho$ on $Y(i)$ and $(\sigma-1)/(\eta+\sigma-1) = 1-\rho$ on $\lambda(i,z)$. The result is

$$Y(i)^{\rho} = [\beta(i)C(i)]^{\rho(1-\sigma)} \sum_z [E(z)P(z)^{\sigma-1}]^{\rho} t(i,z)^{\rho(1-\sigma)} \lambda(i,z)^{1-\rho}.$$

Divide both sides by Y^{ρ}. The result is

$$\left[\frac{Y(i)}{Y}\right]^{\rho} = [\beta(i)C(i)\Pi(i)]^{\rho(1-\sigma)} \Rightarrow \frac{Y(i)}{Y} = [\beta(i)C(i)\Pi(i)]^{1-\sigma}, \tag{9}$$

where outward multilateral resistance

$$\Pi(i)^{(1-\sigma)\rho} = \sum_z \left(\frac{E(z)}{Y}\right)^{\rho} \left(\frac{t(i,z)}{P(z)}\right)^{(1-\sigma)\rho} \lambda(i,z)^{1-\rho}. \tag{10}$$

The left hand side of (9) is recognized as a CES share equation for a hypothetical world buyer on the world market, with a world market price index for all goods equal to 1. Short run multilateral resistance in (10) is a CES function of bilateral relative trade costs $t(i,z)/P(z)$, where the elasticity of short run substitution is $(1-\sigma)\rho$. $\Pi(i)$ is homogeneous of degree one

market behavior in the usual sense is not implied. The model can be extended to monopolistic competition by treating each origin i as a firm. With CES demand, markups are constant when firms shares are small.

in $\{t(i,z)\}$ for given $\{P(z)\}$.

The gravity representation of trade also requires a relationship between the buyers' price index and relative trade costs. Substitute (8) in the CES price definition $P(z)^{1-\sigma} = \sum_i [\beta(i)p(i,z)]^{1-\sigma}$. Then use (9) to substitute for $[\beta(i)C(i)]^{1-\sigma}$ in the resulting equation. After simplification this gives the short run price index as

$$P(z)^{(1-\sigma)\rho} = \left(\frac{E(z)}{Y}\right)^{-(1-\rho)} \sum_i \frac{Y(i)}{Y}\left(\frac{t(i,z)}{\Pi(i)}\right)^{(1-\sigma)\rho} \lambda(i,z)^{1-\rho}.$$

Buyers' price index $P(z)$ is the product of a size effect $[E(z)/Y]^{-(1-\rho)}$ and a CES function of the set of bilateral buyers' incidences:

$$\widetilde{P}(z)^{(1-\sigma)\rho} = \sum_i \frac{Y(i)}{Y}\left(\frac{t(i,z)}{\Pi(i)}\right)^{(1-\sigma)\rho} \lambda(i,z)^{1-\rho},\ \forall z, \tag{11}$$

with short run elasticity of substitution $(1-\sigma)\rho$. $\widetilde{P}(z)$ is the buyers' short run multilateral resistance, also interpreted as the buyers' short run incidence of trade costs. Simplifying the CES price index, $P(z) = [E(z)/Y]^{(1-\rho)/(\sigma-1)\rho}\widetilde{P}(z)$. Higher relative demand $E(z)/Y$ raises $P(z)$ given $\widetilde{P}(z)$ due to fixed capacities $\{\lambda(i,z)Y(i)\}$. In long run gravity, as effectively $\eta \to \infty$, $\rho \to 1$ and the buyers' market size effect vanishes from the price index $P(z)$.

Use $P(z)^{(1-\sigma)\rho} = [E(z)/Y]^{-(1-\rho)}\widetilde{P}(z)^{(1-\sigma)\rho}$ in sellers' multilateral resistance (10) to yield the more intuitive equivalent form

$$\Pi(i)^{(1-\sigma)\rho} = \sum_z \frac{E(z)}{Y}\left(\frac{t(i,z)}{\widetilde{P}(z)}\right)^{(1-\sigma)\rho} \lambda(i,z)^{1-\rho},\ \forall i. \tag{12}$$

The final step in deriving short run gravity is to substitute the right hand side of (8) for $p(i,z)$ in (7) and use (9) to substitute for $[\beta(i)C(i)]^{1-\sigma}$ in the resulting expression. After simplification using incidence elasticity $\rho = \eta/(\eta+\sigma-1)$, this gives:[12]

[12] $X(i,z) = E(z)(\beta(i)p(i,z))^{1-\sigma} = E(z)^{\rho}[t(i,z)/P(z)]^{(1-\sigma)\rho}\lambda(i,z)^{1-\rho}H(i)$ where $H(i) = [\beta(i)C(i)]^{(1-\sigma)\rho}Y(i)^{1-\rho}$. Substitute $[Y(i)/Y\Pi(i)^{1-\sigma}]^{\rho}$ for $[\beta(i)C(i)]^{(1-\sigma)\rho}$ in $H(i)$ and replace $P(z)^{(1-\sigma)\rho}$ with $[E(z)/Y]^{-(1-\rho)}\widetilde{P}(z)^{(1-\sigma)\rho}$. Rearranging the result yields equation (13).

Proposition 2: Short Run Gravity. *Short run gravity is a geometric weighted average of long run gravity and a bilateral capacity variable* $\lambda(i,z)$ *. Short run gravity trade flows are given by:*

$$X(i,z) = \frac{Y(i)E(z)}{Y}\left[\frac{t(i,z)}{\Pi(i)\widetilde{P}(z)}\right]^{(1-\sigma)\rho} \lambda(i,z)^{1-\rho}. \tag{13}$$

where the multilateral resistances $\Pi(i)$, $\widetilde{P}(z)$ *are given by (11)-(12)*

The first term on the right hand side of (13) is the frictionless benchmark flow at given sales $\{Y(i)\}$ and expenditure $\{E(z)\}$. The middle term is the familiar effect of gravity frictions, the ratio of bilateral to the product of buyers' and sellers' multilateral resistance. The difference is that the short run trade elasticity is reduced in absolute value to $(1-\sigma)\rho$. The last term $\lambda(i,z)^{1-\rho}$ is the 'friction' due to inefficient investment in capacity on link i,z. Dividing both sides of (13) by the frictionless benchmark, size adjusted trade is

$$\frac{X(i,z)}{Y(i)E(z)/Y} = \left[\frac{t(i,z)}{\Pi(i)\widetilde{P}(z)}\right]^{(1-\sigma)\rho} \lambda(i,z)^{1-\rho},$$

a geometric weighted average of long run gravity frictional displacement and inefficient link capacity allocation.

Intuition about short run gravity system (11)-(13) is aided by considering an equiproportionate change in all bilateral trade costs $t(i,z)$: $t^1(i,z) = \mu t^0(i,z)$. Intuitively, bilateral trade flows should be unchanged because no relative price changes. Checking the system (11)-(12), $\{\widetilde{P}(z), \Pi(i)\}$ are homogeneous of degree 1/2 in $\{t(i,z)\}$, hence buyers' and sellers' multilateral resistances change by $\mu^{1/2}$ so indeed bilateral trade flows are constant. As with long run gravity, system (11)-(12) solves for multilateral resistances up to a normalization. Multilateral resistances retain their interpretation as sellers' and buyers' incidence of trade costs.

Over time the allocation of destination specific capital $\{\lambda(i,z)\}$ presumably moves toward the efficient level analyzed below in Section 3.2. The efficient allocation matches the long run demand pattern, so that the short run gravity equation (13) approaches the long run gravity equation, intuitively equivalent to $\rho \to 1$.

The preceding derivation of (13) combined with (10) and (11) uses for simplicity the Armington CES/endowments setup of Anderson and van Wincoop (2003), but the same short run gravity structure derives from two alternative structures with endogenous production and heterogeneous productivities. Online Appendix Section A.1.1 shows that the form of short run gravity in equations (10)-(13) holds for the alternative interpretation of gravity based on heterogeneous productivity draws in a Ricardian model due to Eaton and Kortum (2002). It also extends to the heterogeneous firms gravity model of Chaney (2008),[13] understanding that the composite supply elasticity combines intensive margin elasticity η above with an extensive margin elasticity based on the dispersion parameter θ of the Pareto productivity distribution. The composite supply elasticity is $\tilde{\eta} = \eta(1 + \theta - \eta) > \eta$ for the intuitive case $\theta > \eta$, the necessary and sufficient condition for the extensive margin of firms serving a destination to be rising in price. The incidence elasticity becomes $\tilde{\rho} = \tilde{\eta}/(\tilde{\eta} + \sigma - 1) > \rho$ for $\theta > \eta$. Thus, the short run gravity adjustment developed here applies to the wide class of models that have been described in Arkolakis et al. (2012).

3.1 Short vs. Long Run Gravity Elasticities

Short run gravity (13) nests long run gravity and thus can address three prominent empirical puzzles. Gravity-based inference of the effect of a bilateral friction on a cross section of bilateral trade is interpretable as a long run elasticity under the no-bias hypothesis. Panel gravity estimation of the short run model with the methods described below yields a short run elasticity.

Bilateral trade costs $t(i, z)$ are specified as a loglinear function of standard gravity variables:

[13] The extension is exact for competitive firms and a close approximation for monopolistically competitive firms.

$$t(i,z) = \prod_{l=1}^{L} (1 + tar(i,z)) d(i,z)_l^{\psi_l},$$

where $tar(i,z)$ denotes *ad valorem* tariffs and the vector $d(i,z)$ includes a set of binary and continuous determinants of bilateral trade. Proposition 2 delivers the relationship between short run (SR) gravity coefficients and their long run (LR) counterparts as:

$$\beta_l^{SR} = (1-\sigma)\psi_l \rho = \beta_l^{LR} \rho. \tag{14}$$

Notably, the relationship between short run and long run elasticities in (14) is time invariant.[14] Equation (14) under the constraint $\rho \in (0,1)$ applied to direct price shifters such as tariffs at least partially resolves the empirical puzzle posed by estimates of the trade elasticity in cross-section gravity estimations that are much larger than short run estimates used in the macro literature. (See Footnote 5.) (14) combined with estimates of ρ partly reconciles the difference, with remaining differences isolated from that due to the missing incidence elasticity. Some portion of remaining difference may be due to incomplete passthrough to high frequency price changes.

Second, equation (13) helps resolve the time invariant distance elasticity puzzle. Suppose that the iceberg trade cost proxies control very well for the capacity variables in (13) that are omitted from the standard cross section gravity regression. Time invariant estimated trade cost elasticities may be found by standard gravity regressions in that case. We replicate that finding below. The intuition that the effect of distance on trade *should* be falling over time can be interpreted here as intuition that marketing capital λ relative to its efficient level, having started lower in more distant destination markets, is rising faster in the globalization era. Then the effect of distance on trade, including its effect on capacity, should be falling

[14] Equation (8) is the short run gravity model buyers' price equation, as developed further in Appendix A. The model assumes perfect arbitrage equilibrium in the background, and in the foreground imposes structure on production-cum-distribution restrictive enough to yield short run elasticities that are time-invariant. Imperfect arbitrage (e.g. due to search frictions) or non-Cobb-Douglas production-cum-distribution structure (e.g. Crucini and Davis (2016)) can lead to short run time-varying trade elasticities.

in absolute value in a globalization era. In contrast, *uniform* globalization reduces trade cost at all distances equiproportionately, an inference that cannot be rejected in our results below.

Third, the missing globalization puzzle is the broader version of the distance puzzle, applying to all the long run gravity covariates together. This paper finds the missing globalization in the evolution of marketing capital allocation, but in a sense the puzzle is removed to the black box labeled λ.

Given ρ estimates, equation (14) offers several opportunities to test the hypothesis that standard gravity variables control for the omitted λs in standard long run gravity estimation. (14) suggests the test $\beta^{SR} - \rho\beta^{LR} = 0$, one for each of the gravity regressors in vector $d(i, z)$. Structural estimation can identify ρ under assumptions discussed below.

3.2 Long Run Efficient Allocation

The allocation of capital to destinations z is outside the static model developed above under the realistic assumption that investment is predetermined and generally inefficient relative to current realizations of random variables. It is nevertheless useful to construct a benchmark efficient allocation as an aid to intuition and to learning something about the inefficiency of allocation. A key, though in some sense obvious result is that the general gravity model under inefficient investment nests the standard iceberg trade cost model as a special case of efficient allocation. The difference between actual and hypothetical efficient allocation is presumably due to un-modeled frictions hampering investment in the face of various risks and imperfect information about realizations of natural bilateral resistance and other components of the realized equilibrium. The development of the benchmark allocation provides structure to the econometric application that generates inferred differences between actual and benchmark allocations as residuals.

Economic intuition suggests that standard iceberg trade costs should emerge as a reduced form of all efficient equilibrium production and distribution models because it is consistent with the envelope theorem in the allocation of all relevant resources in distribution. Effectively, geography dictates the allocation of capital as well as the distribution of goods given that efficient allocation of capital. Development of the benchmark special case demonstrates how this works.

Efficient capital allocation achieves equal returns on investment in each destination served. The average return on investment for the generic sector and economy of Section 2 is given by $\bar{r} = Y_K = (1-\alpha)Y/K$. The return on capital relative to the average for destination z is given by $s(i,z)/\lambda(i,z)$ (Anderson, 2011). If investors perfectly foresee bilateral natural trade costs and the extensive margin, then $\lambda(i,z) = s(i,z)$ in the capital allocation equilibrium actually realized. Then $\lambda^*(i,z) = s(i,z) = \lambda^*(i,z)[p(i,z)/t(i,z)C(i)]^\eta \Rightarrow p(i,z) = t(i,z)C(i)$. Combine this restriction with equation (8) for the market clearing price to solve for the efficient allocation

$$\lambda^*(i,z) = \frac{E^*(z)}{Y^*(i)}\left(\frac{\beta(i)C^*(i)t(i,z)}{P^*(z)}\right)^{1-\sigma} = \frac{E^*(z)}{Y^*}\left(\frac{t(i,z)}{\Pi^*(i)P^*(z)}\right)^{1-\sigma}. \qquad (15)$$

Note that (15) is a general equilibrium concept: the multilateral resistances imply that all origins solve for efficient allocation simultaneously. Efficient allocation share $\lambda^*(i,z)$ is decreasing in the cross section of trade pairs in natural trade friction $t(i,z)$, increasing in destination market potential $E(z)P(z)^{\sigma-1}$ and origin utility weight $\beta(i)^{1-\sigma}$. Each of these effects is intuitive. It is also increasing in the 'average economic distance' of the origin from its markets, $\Pi^*(i)$, implying that for markets actually served, relationship-specific investments must be larger to overcome the average resistance.

Notice that $\eta = 1/(1-\alpha)$ plays no role in the efficient allocation equilibrium. This arises because no short run reallocation of labor is needed; the trade flows are generated by efficiently allocated bilateral capacities as well as bilateral labor, yielding the standard long run gravity model. The long run trade cost elasticity is $1-\sigma$, which exceeds in absolute value the 'short run' elasticity $(1-\sigma)\eta/(\eta+\sigma-1) = (1-\sigma)\rho$, a familiar implication of the envelope theorem. The short run gravity model of Section 2 is related to the long run model as the elasticity of transformation η is infinite, corresponding to the Ricardian case where there is instantaneous efficient reallocation of specific investment.

3.3 Efficient Extensive Margin

In efficient equilibrium, the extensive margin is determined by equation (6) with $s(i,n) = \lambda^*(i,n)$. Order the destinations with ordering $Z(i)$ such that the efficient destination investment shares defined by (15) are decreasing in z: $Z(i) = \mathbf{P}(\{z\})$: $d\lambda^*(i,z)/dz < 0$, where $\mathbf{P}(\{z\})$ denotes a permutation of the ordering of $\{z\}$. Then $n(i)^*$ is defined by

$$n^*(i) = z : L(i) - z - \frac{\alpha}{(1-\alpha)\lambda^*(i,z)} = 0; z \in Z(i).$$

Existence and uniqueness of the fixed point $n^*(i)$ is guaranteed because

$$L(i) - z - \frac{\alpha}{(1-\alpha)\lambda^*(i,z)}$$

is decreasing in z. More intuitively,

$$\underline{s}^*(i,\tau) = \frac{\alpha}{1-\alpha}[L(i,\tau) - n^*(i,\tau)]^{-1}. \tag{16}$$

Evidently the efficient equilibrium extensive margin $n(i)^*$ is increasing in origin size $L(i)$ and increasing in origin average economic distance $\Pi^*(i)$, the latter effect because it reduces the relative difficulty of entering the marginal market $t(i,z)/\Pi^*(i)$. A more steeply rising profile of bilateral trade costs for an origin country reduces its extensive margin. Destination size distribution (market potential) $E(z)P(z)^{\sigma-1}$ affects all exporters equally; as markets are more equal, more are served by every origin. The intuitive results on origin and destination size accord with observed characteristics of the extensive margin of trade. The more subtle implications of (16) remain to be explored in applications. Notice that this theory of the extensive margin imposes no structure on the distribution of productivity that contributes implicitly to the variation of $t(i,z)$.

4 Empirical Analysis

Short run gravity theory generates a series of testable predictions. Taking the predictions to data faces two challenges. First, there is no direct data on bilateral capacity. Proxies must be found to substitute for missing data. Second, there is no fully developed theory of the investment trajectory.[15] To maintain focus on short run forces, the application abstracts from details about the progress of formal globalization aside from treatment of FTA implementation and tariff changes. Results here should be viewed as 'proof of concept' rather than an accounting exercise. Knowledge gained will guide further empirical tests and extensions of SR gravity, discussed in the conclusion and the Appendices.

The application focuses on the intensive margin, for two reasons. First, equation (13) for positive trade flows is central as a theory nesting long run gravity with forces departing from long run gravity. Second, the key incidence elasticity parameter ρ can be inferred from equation (13). The empirical investigation of SR gravity on the intensive margin is a natural first step.

Start from the idea that bilateral capacities are approaching efficient capacity allocation in the era of globalization. Uncoordinated buyers' and sellers' agents grope forward to form links, expanding high rent links and contracting low rent links. Extend short run gravity model (13) to add a time dimension τ:

$$X(i,z,\tau) = \frac{Y(i,\tau)E(z,\tau)}{Y(\tau)} \left(\left[\frac{t(i,z,\tau)}{\Pi(i,\tau)P(z,\tau)} \right]^{1-\sigma} \right)^{\rho} \lambda(i,z,\tau)^{1-\rho}. \tag{17}$$

[15]The investments that plausibly form parts of $\lambda(i,z)$ are the result of uncoordinated decisions of many actors on N^2 links where N is the number of countries. See Chaney (2014) for evidence on export dynamics of French firms. Information network theories of links suggest search and random matching conditioned on anticipated probabilities of a match. Full rational expectations development is a chimera. Simple *ad hoc* structures are thus applied here to empirically fit an investment trajectory.

Established econometric techniques and standard proxies control for bilateral trade costs ($t(i,z,\tau)$), the multilateral resistances ($\Pi(i,\tau)$ and $P(z,\tau)$), and the size effects ($Y(i,\tau)$, $E(z,\tau)$, and $Y(\tau)$). The unobservable bilateral capacity variable $\lambda(i,z,\tau)$ evolves over time, and the pattern of bilateral trade shifts with it at rate $1-\rho$. The challenge is to infer something ρ from panel trade data based on specification (17) combined with some simple dynamic device that gives information about the rate of change of unobservable $\lambda(i,z,\tau)$.

We use two complementary approaches. The reduced form approach uses cross-border-time fixed effects to pick up the trade volume effect of evolving bilateral capacity.[16] A fully general bilateral-time fixed effect set fits the data perfectly but gives no information about economic structure, so restriction is necessary to discover anything. The restricted set applied here uses uniform cross-border fixed effects that vary over time without restriction to allow for non-smooth effects of globalization. The evidence suggests a smooth evolution of the estimated fixed effects, and hence suggests that a single dynamic adjustment parameter combines with ρ. Applying an external adjustment parameter estimate then yields an estimate of ρ.

The alternative structural approach models the dynamics of $\lambda(i,z,\tau)$ based Lucas and Prescott (1971) who model a parametric adjustment elasticity. Sales shares proxy the unobservable λs based on the efficient allocation theory of Section 3.2. The inferred parameter is a combination of the adjustment parameter and ρ, so in combination with an external adjustment parameter it yields an estimate of ρ. The advantages and disadvantages of the two approaches are discussed with the findings in sections 4.2 and 4.3, respectively. Before that we briefly describe the data.

[16]Bergstrand et al. (2015) also use time-varying border dummies, designed to capture the impact of globalization on bilateral trade. A similar border-time fixed effects strategy is used by Head et al. (2010) to estimate the decline in 'marketing capital' in the trade of ex-colonies with their former masters relative to continuously non-colonial international trade. In contrast to the current approach, these earlier reduced form specifications have no theoretical foundation pointing to structural interpretation of the estimated fixed effects.

4.1 Data: Description and Sources

In order to obtain the main empirical results we use the dataset of Baier et al. (2016), which covers total manufacturing bilateral trade among 52 countries over the period 1988-2006.[17] In addition to spanning over a relatively long time period, the dataset of Baier et al. (2016) has two advantages. First, it includes data on intra-national trade flows.[18] As will become clear shortly, availability of intra-national trade flows data is crucial for the implementation of the reduced form approach to test SR gravity theory. Second, the dataset includes data on applied tariffs, which will enable us to identify the estimate of the trade elasticity of substitution directly from the empirical gravity specification, and to compare it between the short run vs. long run gravity specifications. The original source of the tariff data is the United Nation's TRAINS database. In addition to trade and tariff data and a rich set of fixed effects, we also employ data on standard gravity variables (bilateral distance, colonial ties, etc.), which come from the CEPII distances database (see Mayer and Zignago (2011)), and data on free trade agreements (FTAs), which come from the NSF-Kellogg Database on Economic Integration Agreements of Jeff Bergstrand. For further description of the main dataset we refer the reader to Baier et al. (2016).

In the sensitivity analysis we also experiment with an alternative database. Specifically, we employ the latest edition of the WIOD database, which covers 43 countries over the period 2000-2014. Similar to the dataset from Baier et al. (2016), the WIOD data includes consistently constructed international and intra-national trade flows.[19] The disadvantages of

[17]The 52 countries/regions in the sample include: Argentina, Australia, Austria, Bulgaria, Belgium-Luxembourg, Bolivia, Brazil, Canada, Switzerland, Chile, China, Colombia, Costa Rica, Cyprus, Germany, Denmark, Ecuador, Egypt, Spain, Finland, France, United Kingdom, Greece, Hungary, Indonesia, Ireland, Iceland, Israel, Italy, Jordan, Japan, South Korea, Kuwait, Morocco, Mexico, Malta, Myanmar, Malaysia, Netherlands, Norway, Philippines, Poland, Portugal, Qatar, Romania, Singapore, Sweden, Thailand, Tunisia, Turkey, Uruguay, United States

[18]Intra-national trade flows are constructed as apparent consumption, i.e. as the difference between the gross value of total production and total exports. The original trade data come from the UN COMTRADE database, accessed via WITS. The data on total gross production come from the CEPII TradeProd database and UNIDO IndStat database.

[19]The intra-national trade flows in the WIOD database are constructed using input-output linkages. See Timmer et al. (2015) and Timmer et al. (2016) for further details.

WIOD dataset, as compared to the data used to obtain the main results, are that the WIOD data cover a shorter time period and a smaller number of countries. However, the WIOD dataset also has two main advantages. First, it offers a complete sectoral coverage for each of the countries in the sample. Thus, summing across all sectors will enable us to cover total trade (including international and intra-national trade flows) for each country in the sample. Second, on a related note, we will use the WIOD data to test our theory at the sectoral level. We do take advantage of these features of the WIOD data in the sensitivity analysis that we present in Appendix B, where we demonstrate that our findings are confirmed with the WIOD dataset.

4.2 A Reduced Form Approach to Short Run Gravity

Start with the intuition that in an era of globalization (1988-2006 or 2000-2014 depending on the dataset), cross-border trade capacities $\lambda(i,z,\tau)$ are inefficiently small (network links are inefficiently sparse) while domestic capacities $\lambda(i,i,\tau)$ are inefficiently large (trade links are relatively too dense). Over time capacity investment presumably evolves toward efficiency, so cross-border investment in trade links rises relative to domestic investment in trade links. The reduced from approach looks for evidence in cross-border time fixed effects without imposing any time path of adjustment.

Cross-border-time fixed effects averaged over the cross-destination variation for an origin are structurally interpreted as:

$$[\lambda(i,z,\tau)/\lambda(i,i,\tau)]^{1-\rho} = [\lambda(i,z,0)/\lambda(i,i,0)]^{1-\rho}\mu(i,\tau),\ z \neq i$$

where $\mu(i,\tau) > 1$ is the growth factor of $[\lambda(i,z,\tau)/\lambda(i,i,\tau)]^{1-\rho}$.[20] No structure is imposed over time, so $\mu(i,\tau)/\mu(i,\tau-1)$ is not restricted over τ. Initially we average across all cross-

[20] The adding up condition $\sum_z \lambda(i,z,\tau) = 1$ combined with the uniform growth factor assumption implies that $d\ln\lambda(i,z) = \mu(i,\tau)\lambda(i,i,\tau)$ and $d\ln\lambda(i,i,\tau) = -\mu(i,\tau)[1-\lambda(i,i,\tau)]$. In the panel gravity regressions the effect of $\lambda(i,i,\tau)$ on $d\ln\lambda(i,z,\tau)$ is absorbed by the origin-time fixed effects.

border pairs at each point in time, $\mu(i,\tau) = \mu(\tau)$. Subsequently we allow for differential rates of adjustment for origin countries specialized to a difference between developed and developing countries. Other uniformity restrictions are plausible as well in order to supply degrees of freedom to identify the average time variation of primary concern. Idiosyncratic variation of growth of $\lambda(i,z,\tau)/\lambda(i,i,\tau)$ that deviates from the uniform growth assumption is associated with effects that go into the error term of the gravity equation.

A useful benchmark estimation is a panel gravity model that does not control for the efficiency improvements to be looked for based on the short run gravity theory. Thus $\rho = 1$ and the econometric model run in logs with OLS is:[21]

$$\begin{aligned} LN\_X_{ij,\tau} &= \beta_1 LN\_DIST_{ij} + \beta_2 CNTG_{ij} + \beta_3 CLNY_{ij} + \beta_4 LANG_{ij} + \beta_5 FTA_{ij,\tau} + \\ &\quad \beta_6 LN\_TARIFF_{ij,\tau} + \beta_7 INTL\_BRDR_{ij} + \pi_{i,\tau} + \chi_{j,\tau} + \epsilon_{ij,\tau}, \end{aligned} \tag{18}$$

The dependent variable in (18) is the logarithm of nominal bilateral trade flows. The regressors are the standard gravity variables including the logarithm of bilateral distance between countries i and j (LN_DIST_{ij}), and indicator variables for contiguous borders ($CNTG_{ij}$), common language ($LANG_{ij}$), colonial ties ($CLNY_{ij}$), and free trade agreements ($FTA_{ij,\tau}$). In addition, we include the log of applied tariffs ($LN\_TARIFF_{ij,\tau}$).[22] $INTL\_BRDR_{ij}$ is an indicator variable that takes a value of one for international trade and it is equal to zero for internal trade. Specification (18) includes exporter-time and importer-time fixed effects to control for the multilateral resistances of Anderson and van Wincoop (2003) and will absorb any other observable and unobservable country-specific characteristics on the exporter and on the importer side, respectively. Finally, following the recommendation of Cheng and Wall (2005), we use 3-year intervals instead of consecutive years in order to obtain our main

[21]Specification (18) is consistent with the traditional empirical approach to estimate gravity with the OLS estimator. We show in the sensitivity experiments that our results are robust to using the PPML estimator instead, which, as demonstrated by Santos Silva and Tenreyro (2006, 2011), simultaneously accounts for heteroskedasticity and takes into account the information contained in zero bilateral trade flows.

[22]Since tariffs are a direct price shifter, the estimate of the tariff elasticity equals the trade elasticity σ.

estimates.[23]

Estimates obtained from specification (18) are reported in column (1) of Table 1. With an $R^2 = 0.88$, gravity delivers its usual strong fit. In addition and as expected, distance and tariffs[24] are strong impediments to trade, while the presence of colonial ties, sharing a common official language, and having FTAs in force all promote bilateral trade. The negative, large, and significant estimate on $INTL\_BRDR$ is also expected, and it confirms the strong presence of international borders, even after controlling for the impact of distance and tariffs. Apart from the insignificant estimate on $CNTG$, all other estimates from column (1) of Table 1 are readily comparable to corresponding estimates in the literature (see the meta analysis estimates from Head and Mayer (2014)). In sum, the results from column (1) of Table 1 are long run benchmarks that confirm the representativeness of our sample and provide long run responses to compare to the short run responses that follow.

The estimates from column (2) of Table 1 are obtained with time-varying cross-border trade fixed effects. A series of year-specific border dummies, $\sum_{\tau=1991}^{2006} \beta_\tau INTL\_BRDR\_\tau_{ij}$, are introduced to (18):

$$\begin{aligned} LN\_X_{ij,\tau} &= \beta_1 LN\_DIST_{ij} + \beta_2 CNTG_{ij} + \beta_3 CLNY_{ij} + \beta_4 LANG_{ij} + \beta_5 FTA_{ij,\tau} + \beta_6 LN\_TARIFF_{ij,\tau} + \\ &\quad \beta_7 INTL\_BRDR_{ij} + \sum_{\tau=1991}^{2006} \beta_\tau INTL\_BRDR\_\tau_{ij} + \pi_{i,\tau} + \chi_{j,\tau} + \epsilon_{ij,\tau}, \end{aligned} \tag{19}$$

The theoretical interpretation of each of the time-varying border estimates is $\beta_\tau = (1-\rho)\Delta \ln[\lambda(i,z,\tau)/\lambda(i,i,\tau)] = (1-\rho)\Delta \ln \mu(\tau)$ and, by construction, these estimates should be interpreted as deviations from the estimate of β_7. Due to perfect collinearity, we omit the border for the first year of the sample, 1988.

The estimates in column (2) of Table 1 show that the estimates on $INTL\_BRDR_{ij}$ are all positive, statistically significant, and gradually increasing over time. SR gravity theory in

[23] We demonstrate in the sensitivity experiments below that our main results and conclusions are robust to using all years in the sample. We refer the reader to Head and Mayer (2014) and Yotov et al. (2016) for further discussion of the challenges with the estimation of empirical gravity models and their solutions.

[24] The estimated tariff elasticity suggests a value of σ that is low relative to previous estimates. We suspect this is due to aggregation bias for such a heterogeneous sector as manufacturing.

an era of globalization is consistent with this finding, hence the model provides a structural interpretation of the "missing globalization" that places the "puzzle" in a plausible marketing capital black box. Second, the estimates of the standard gravity variables are statistically unchanged from column (1), implying that the uniform growth assumption imposed in (19) is approximately valid (non-uniform growth would likely be correlated with cross-section variation in bilateral distance, etc.). Third, the R^2 is essentially the same in columns (1) and (2).[25] The reason is that the border-time fixed effects control for globalization effects that were controlled for in column (1) by the origin-time fixed effects. Omitted variable bias in the benchmark specification is thus confined to the origin-time fixed effects.[26] This result is intuitively consistent with exporters altering λs to exploit the globalization opportunity, although the analytic comparative static derivative is too complex for proof.

The estimates from column (3) of Table 1 are obtained after allowing for the effects of distance to vary over time. Specifically, we interact the distance variable with dummy variables for each year on our sample.[27] In order to ease the interpretation of our results, we keep the original distance variable and do not include the distance variable for 1988. Thus, the estimate on LN_DIST should be interpreted as the effect of distance in 1988, and all other time-varying distance estimates should be interpreted as deviations from the estimate on LN_DIST. Column (3) implies that distance elasticities are stable over time. The "distance puzzle" of non-declining distance elasticities in international trade (Disdier and Head (2008)) remains.

The estimates from columns (4) and (5) of Table 1 employ pair fixed effects. The motivation for the use of the time-invariant bilateral dummies is twofold. First, these variables will completely account for the impact of all observable and unobservable determinants of bilateral trade, cf. Agnosteva et al. (2014) and Egger and Nigai (2015). Second, on a related

[25] We thank Thomas Chaney for pushing us to explain this.

[26] Examination of the origin- and destination-time fixed effects (not shown) for columns (1) and (2) reveal almost no change in the destination-time fixed effects and substantial changes in the origin-time fixed effects.

[27] In principle, we could allow for the effects of all gravity variables to vary over time. We chose to focus on distance only for expositional simplicity and because the distance variable has been used most prominently to capture trade costs and their changes.

note and as demonstrated by Baier and Bergstrand (2007), the use of the pair fixed effects will help mitigate endogeneity concerns related to the trade policy variables in our specification. The main findings from columns (4) and (5) are that (i) the estimates of the trade policy variables are unchanged across the two specifications; and (ii) we observe the gradual and economically and statistically significant increase in the estimates on the international border dummies. Exponentiating the border-time cumulative efficiency change estimate in column (5) of Table 1 (0.965) yields an overall efficiency of trade gain from 1988-2006 of 162%: world cross-border trade is 162% larger in 2006 than it would have been with the more inefficient bilateral capacities of 1988.

For purposes of generating estimates of the key incidence parameter ρ, we average the $\mu(\tau)$s to a smooth exponential increase in efficiency, $\tilde{\mu}(\tau) = e^{b_\tau \tau}$ where b_τ equals $1-\rho$ times the growth rate of $\lambda(i,z)/\lambda(i,i)$. Smooth growth actually turns out to be a close approximation in our results below. We first recover $\hat{b}_\tau = (1-\rho)\delta$ as the slope of the fitted line of the estimates of the changes in the effects of international borders, from our preferred specification with paired fixed effects from column column (5) of Table 1. The best-fit line in the β_τ–τ coordinate space is plotted in Figure 1. The regression implies that the slope is $\hat{b}_\tau = 0.046$. In combination with an external value of $\delta = 0.061$,[28] the estimate $\hat{b}_\tau = 0.046$ enables us to recover $\hat{\rho} = 1 - \hat{b}_\tau/\delta = 0.246$.

Column (6) relaxes the uniform efficiency growth restriction to allow for efficiency growth to vary across 'rich' vs. 'poor' exporters, as classified by the World Bank.[29] The estimates from column (6) of Table 1 reveal significant efficiency improvements for each group of coun-

[28]This value for δ is the average adjustment cost parameter estimate from the structural gravity setting of Anderson et al. (2015), obtained under the same assumptions for investment. Specifically, Anderson et al. (2015) recover δ from a second stage regression that links trade openness to capital accumulation. These authors also obtain a distribution of country-specific capital adjustment cost parameters that vary between 1.6 and 13.6.

[29]Note that non-uniform efficiency growth does not violate the structural assumptions used to specify short run gravity. In principle origin-specific estimates of the efficiency-improvement effects $\beta_\tau(i)$'s can be identified from variation across destinations z under a uniformity condition imposed on the external (foreign) destinations vs. internal trade. The original World Bank classification includes five income categories: 'High Income OECD', 'High Income Non-OECD', 'Upper Middle Income', 'Lower Middle Income', and 'Low Income' countries. We used the top three categories to form our sample of 'rich' countries, and the bottom two categories to form the group of 'poor' countries.

tries captured by the positive, significant, and gradually increasing over time estimates on $INTL\_BRDR\_HIGH$ and $INTL\_BRDR\_LOW$. More importantly, low income countries have converged faster toward more efficient trade during the period of investigation. (The result may not be robust to further country level disaggregation, plausibly being driven by few outliers such as China. The difference between high income and developing countries may also an artifact of composition effects, as the sectoral composition of manufacturing changes differently across countries. Sectoral disaggregation is indicated as part of investigating country differences.)

A series of sensitivity experiments demonstrate the robustness of our main results, summarized here with a full report in Appendix B. Motivated by the work of Santos Silva and Tenreyro (2006, 2011) advocating the PPML estimator as an alternative to OLS with the log of gravity, Table 2 replaces the main estimates from Table 1 with those based on the PPML estimator. PPML estimates confirm the OLS results: all border-time estimates are positive, significant and increasing over time. Another experiment uses size-adjusted trade as the dependent variable. The size-adjusted dependent variable specification is consistent with theory and tends to reduce the problem of heteroskedasticity associated with the level of trade specification (19). The OLS and PPML estimates using size-adjusted trade as dependent variable confirm the robustness of our main findings. A third experiment uses data for all years rather than 3 year intervals. The OLS and PPML results are very similar to the main estimates from Table 1. The next experiment employs the newly available 2016 WIOD data.[30] Again, the main results from Tables 1 and 2 are closely matched with OLS and PPML estimators respectively. Finally, exploiting the sectoral dimension of the WIOD data we reproduce our main results for Crop and Animal Production, Forestry and Logging, Fishing and Aquaculture, Mining and Quarrying, Manufacturing, and Services. The results naturally vary by sector, but the main finding for the presence of efficiency improvement is present in each sector.

[30] See Data section for a description and details on the WIOD data.

4.3 A Structural Approach to Short Run Gravity

The complementary structural approach to estimating short run gravity adds a simple *ad hoc* theory of investment in bilateral capacity. The investment structure in combination with external values of an adjustment speed parameter enables inference about the buyers' incidence parameter ρ. This can be compared with inference of ρ from the reduced form model as a consistency check between the two complementary approaches.[31] Alternatively, inference from the two approaches simultaneously provides estimates of ρ and the adjustment parameter. The structural and the reduced form approaches come quite close in the estimates of ρ detailed below. The structural model also permits tests of implication (14).

Suppose that intensive margin investment in pair-specific capital moves the current level from its past level toward the efficient level at some rate of log-linear adjustment that is implied by a Cobb-Douglas function of efficient and past levels.[32] The adjustment process specification is inspired by *inter alia* Lucas and Prescott (1971), Hercowitz and Sampson (1991), and Anderson et al. (2015) and Eaton et al. (2016) in the gravity context:

$$\lambda(i,z;\tau) = \lambda^*(i,z)^{\delta}\lambda(i,z;\tau-1)^{1-\delta};\ \delta \in (0,1). \tag{20}$$

The parameter δ reflects both costs of adjustment and depreciation, the higher is δ the faster the movement to the efficient level. In the steady state, $\lambda = \lambda^*$.

[31] There are advantages and disadvantages to the treatment of efficiency improvements with border-time dummies. A big advantage is that dummy variables are exogenous by construction, hence avoid the endogeneity issues raised by the complementary structural approach to dynamic adjustment. Another advantage of the dummy variable approach relative to the structural approach is a comprehensive accounting for all forces that could have contributed to improved efficiency over time, including those omitted from the structural approach. Thus, while (19) imposes a uniform efficiency improvement across destinations $z \neq i$ at each time τ, the specification does not impose any pattern whatever on efficiency variation over time. The disadvantage of the efficiency treatment with border-time dummies is that it does not permit identification of ρ, but only the effect of adjustment of cross-border capacity toward the long run over time.

[32] The approach developed here is a first cut at a difficult problem. It leaves out plausibly important effects. Investment in bilateral trade may be systematically affected in a differential fashion by a number of variables reflecting allocations subject to credit constraints. Exchange rate risk's effects on trade flows can be hedged for many sectors with minimal cost, but hedging over longer intervals appropriate for fixed commitments is expensive. This suggests that bilateral exchange rate volatility may significantly affect investment in bilateral trade but not variable trade cost. Similarly, bilateral covariance of business cycles may affect investment but not variable trade cost. Such refinements are beyond the scope of this project.

Operationalization of the adjustment process requires finding observables to replace the unobservable λs. The agents know that efficient allocation implies that $\lambda^*(i,z) = s^*(i,z)$. This suggests that $\lambda(i.z,\tau) \to s(i,z,\tau)$. Groping ahead toward the eventual efficient allocation suggests a specification of the dynamic process replacing $s^*(i,z)$ with $s(i,z,\tau)$. Moving toward operationality, replace the unobservable $\lambda^*(i,z) = s^*(i,z)$ in (20) with $s(i,z,\tau)$. Similarly, replace the unobservable $\lambda(i,z,\tau-1)$ with $s(i,z,\tau-1)$. (Note that $\lambda(i,z)$ is likely unobservable by individual competitive firms in i exporting to multiple zs, as well as by the econometrician.) Then the costly adjustment specification in the spirit of Lucas and Prescott is:[33]

$$\lambda(i,z,\tau) = s(i,z,\tau)^{\delta} s(i,z,\tau-1)^{1-\delta}.$$

The steady state of this process reaches the efficient allocation of long run gravity, is plausible as an approximation to more sophisticated expectations mechanisms, and its simplicity preserves the simple loglinear features of structural gravity.

Substitute the right hand side of the preceding equation for the (implicit) contemporaneous value of $\lambda(i,z,\tau)$ in gravity equation (13). The result is

$$X(i,z,\tau) = \frac{Y(i,\tau)E(z,\tau)}{Y(\tau)} \left[\frac{t(i,z,\tau)}{\Pi(i,\tau)\widetilde{P}(z,\tau)}\right]^{(1-\sigma)\rho} \left[s(i,z,\tau)^{\delta} s(i,z,\tau-1)^{1-\delta}\right]^{1-\rho}.$$

The presence of contemporaneous trade share $s(i,z,\tau)$ on the right hand side of the preceding equation requires solution for contemporaneous bilateral trade flows to yield:

$$X(i,z,\tau) \;=\; Y(i,\tau)\left(\frac{E(z,\tau)}{Y(\tau)}\right)^{\frac{1}{1-\delta(1-\rho)}} \left[\frac{t(i,z,\tau)}{\Pi(i,t)\widetilde{P}(z,\tau)}\right]^{\frac{(1-\sigma)\rho}{1-\delta(1-\rho)}} \left(\frac{X(i,z,\tau-1)}{Y(i,\tau-1)}\right)^{\frac{(1-\delta)(1-\rho)}{1-\delta(1-\rho)}}. \quad (21)$$

[33]The specification here is in part an expedient to deal with the problem of unobservable capacity allocations, but on a conceptual level it violates rational expectations. The alternative of super-humanly rational expectations is implausible considering the extremely high dimensionality where each bilateral link has potentially many uncoordinated agents and there are very many links with simultaneous interaction. In a simpler environment of perfect information, Anderson et al. (2015) combine the Lucas-Prescott adjustment mechanism with the consumer's inter-temporal maximization problem to derive the optimal accumulation of country-specific physical capital. In contrast, the present case involves a bilateral capacity adjustment on each link, N^2 adjustment paths compared to N in the simpler case.

Use the standard gravity proxies for bilateral trade costs introduced in the previous section, log-linearize specification (21), and add an error term in order to obtain the econometric model:[34]

$$\begin{aligned} LN\_X_{ij,\tau} \;=\; & \tilde{\beta}_1 LN\_DIST_{ij} + \tilde{\beta}_2 CNTG_{ij} + \tilde{\beta}_3 CLNY_{ij} + \tilde{\beta}_4 LANG_{ij} + \tilde{\beta}_5 FTA_{ij,\tau} + \tilde{\beta}_6 LN\_TARIFF_{ij,\tau} + \\ & \tilde{\beta}_7 INTL\_BRDR_{ij} + \tilde{\beta}_8 LN\_X_{ij,\tau-1} + \tilde{\pi}_{i,\tau} + \tilde{\chi}_{j,\tau} + \tilde{\epsilon}_{ij,\tau}. \end{aligned} \tag{22}$$

Note that the exporter-time fixed effects in the preceding expression will absorb and control for all contemporaneous as well as lagged exporter-specific characteristics, including the structural contemporaneous and lagged size terms, that may affect bilateral trade.[35]

The structural interpretation of the estimated coefficient on $LN\_X_{ij,\tau-1}$ is:

$$\tilde{\beta}_8 = \frac{(1-\delta)(1-\rho)}{1-\delta(1-\rho)}. \tag{23}$$

(23) is used below to recover the structural efficiency parameter ρ in combination with information on δ.

Specification (22) for short run gravity estimation differs in two important ways from long run gravity specification (18).[36] The first difference between the two estimating equations is the appearance of the lagged dependent variable as a regressor in the SR gravity specification (22). From an econometric perspective short run gravity implies that the standard estimation of gravity without lagged variables may suffer from omitted variable bias. Hypothesizing that the standard gravity estimator controls also control for the omitted capacity variables, the standard estimator may be an unbiased estimator of long run gravity. The no-bias

[34] Similar to the analysis in the previous section, in the sensitivity analysis we also experiment by estimating the model with the PPML estimator.

[35] In contrast, exporter specific δ_i must be treated with exporter-specific $\beta_1 - \beta_8$. An exporter-type δ_i consistent with the evidence that border-time fixed effects differ between high income and developing economies. We impose a common δ here since our use of aggregate manufacturing trade confounds dynamic adjustment cost effects with changing composition effects that vary across exporters. A proper investigation of origin variation in δ should be done with disaggregated data.

[36] In addition to the two estimation-related differences, the structural interpretation of the fixed effects will also be different in the SR gravity specification since the size variables no longer appear with unitary elasticities in the theoretical SR gravity model. However, this has no consequences for gravity estimations.

hypothesis can be tested jointly with the structural implications of short run gravity, the second difference between specifications (18) and (22).

The theoretical relationship between long run and short run gravity coefficients in Corollary 2.1, extended to accommodate the theory of investment developed here is:

$$\tilde{\beta}_{SR} = \beta_{LR}\frac{\rho}{1-\delta(1-\rho)}, \tag{24}$$

where, the subscripts SR and LR denote estimates from the short run (SR) and from the long run (LR) empirical gravity specifications, respectively. For any given gravity variable coefficient, the combination of equations (23) and (24) enable a joint test of SR gravity structure and the no-bias hypothesis for estimates of long run gravity by checking whether:

$$\frac{\tilde{\beta}_{SR}}{\beta_{LR}} = 1 - \tilde{\beta}_8. \tag{25}$$

Because the gravity specifications include six gravity covariates, test (25) is performed six times, and reported below.

The natural starting point for estimation is a standard/long run gravity model:

$$\begin{aligned} LN\_X_{ij,\tau} \;=\;& \beta_1 LN\_DIST_{ij} + \beta_2 CNTG_{ij} + \beta_3 CLNY_{ij} + \beta_4 LANG_{ij} + \beta_5 FTA_{ij,\tau} + \beta_6 LN\_TARIFF_{ij,\tau} + \\ & \beta_7 INTL\_BRDR_{ij} + \pi_{i,\tau} + \chi_{j,\tau} + \epsilon_{ij,\tau}, \end{aligned} \tag{26}$$

The only difference between specifications (22) and (26) is the absence of lagged trade in the latter specification. The standard gravity estimates from column (1) of Table 3 are readily comparable to their counterparts from the previous section. The estimates from column (2) of Table 3 are obtained from specification (22) with a lagged dependent variable.

An important potential issue is the dynamic panel bias from the use of a lagged dependent variable, i.e. the Nickell (1981) bias. As explained in Roodman (2009a), the use of sufficiently long time spans may mitigate and even eliminate the Nickell bias by construction. The analysis in this section employs every year in the dataset[37] motivated by this observation. Importantly, even if the time coverage is not long enough to eliminate the dynamic panel bias completely, the 'naive' OLS results from column (2) are useful for our purposes because they establish an upper bound for the key estimate of the coefficient $\tilde{\beta}_8$ on the structural efficiency term $LN\_X_{ij,\tau-1}$.[38] This, in combination with expression (23), will enable us to draw inference about the bounds for the structural efficiency parameter ρ. In particular, we will use the estimates from column (2) to establish a lower bound for ρ. Finally, note that the OLS results from column (2) will be supported by the findings from the more sophisticated econometric specifications that we employ below.

The estimates in column (2) of Table 3 reveal a positive and significant estimate of $\tilde{\beta}_8 = 0.788$ (std.err. 0.009). While the estimate of $\tilde{\beta}_8$ seems fairly large in magnitude, it is quite low to be explained solely by the capital adjustment cost δ from our theory. Capitalize on the structural restriction (23) in combination with an external estimate $\delta = 0.061$ in order to recover the incidence elasticity parameter $\rho = 0.202$ (std.err. 0.008). Three implications follow.

First, column (2) of Table 3 implies that gravity estimates that do not control for efficiency improvements and adjustment may suffer significant biases. The estimates from column (1) are very significantly larger than the estimates from column (2). This result reinforces the findings of Olivero and Yotov (2012) and Eichengreen and Irwin (1996) who conclude that they "will never run another gravity equation that excludes lagged trade flows" (p.38). But the possible bias may be one of interpretation under a valid 'no-bias' hypothesis that standard gravity covariates also control for variation of the omitted variable.

Second, SR gravity theory as captured by equation (24) implies at least partial solution to the trade elasticity puzzle – the gap between estimates of the trade elasticity σ from the

[37]In the sensitivity experiments we also employ the 3-year interval data from the previous section and we demonstrate that our main results are robust to employing this alternative sample.

[38]Specification (26) will deliver an upward bound for the estimate on $\tilde{\beta}_8$ due to positive correlation between the lagged dependent variable and the pair fixed effects in the error term, which will inflate the estimate on $LN\_X_{ij,\tau-1}$ by attributing additional predictive power to it. See Roodman (2009a) for further details and a very informative discussion.

trade and the macro literatures, cf. Ruhl (2008), Arkolakis et al. (2011) and Crucini and Davis (2016).

Third, column (2) of Table 3 implies support for the quantitative structural predictions of SR gravity theory and the 'no-bias' hypothesis. Expression (25) implies the hypothesis test:

$$1 - \tilde{\beta}_8 - \tilde{\beta}_{SR}/\beta_{LR} = 0 \tag{27}$$

The test statistic in column (3) of Table 3 uses the estimated coefficients of columns (1)-(2) of Table 3 in (27) for each of the gravity variables. The null hypothesis cannot be rejected at high levels of significance for all six tests.[39]

The results from the lagged dependent variable empirical model are complements to the border-time dummy variable model under the strong assumption that the Lucas-Prescott adjustment model (20) applies to both. In that case, the border-time dummy variable coefficient $\beta_7+\beta_\tau$ should in theory be declining at rate $b_\tau = (1-\rho)\delta$.[40] The lagged dependent variable model implies $\beta_8 = (1-\rho)(1-\delta)/[1-\delta(1-\rho)]$. This structure can be used in two ways. First, for a given δ, compare the implied value of ρ from the lagged dependent variable model to the implied value of ρ from the border-time dummy variable model. Second, solve the two equations simultaneously for the unique values of ρ and δ that satisfy the equations: $\hat{\rho} = (1-\hat{\beta}_8)(1-\hat{b}_\tau)$ and $\hat{\delta} = \hat{b}_\tau/[\hat{\beta}_8 + \hat{b}_\tau(1-\hat{\beta}_8)]$.

We first recover $\hat{b}_\tau = (1-\rho)\delta$ as the slope of the fitted line of the estimates of the changes in the effects of international borders, from our preferred specification with paired fixed effects from column column (5) of Table 1. The best-fit line in the β_τ–τ coordinate space is plotted in Figure 1. The regression implies that the slope is $\hat{b}_\tau = 0.046$. In combination with the adopted value of $\delta = 0.061$, the estimate of $\hat{b}_\tau = 0.046$ enables us to recover $\hat{\rho} = 1 - \hat{b}_\tau/\delta =$

[39]The largest estimate that we obtain in column (3) is for $CLNY$. However, as can be seen from columns (1) and (3) of Table 3, the estimate of the effect of sharing a common border is insignificant to start with. Thus, even though the corresponding estimate in column (3) is insignificant and supports our theory, we discount this finding.

[40]Divide both sides of (20) by $\lambda(i,z,\tau-1)$ to yield $\lambda(i,z,\tau)/\lambda(i,z,\tau-1) = [\lambda^*(i,z)/\lambda(i,z,\tau-1)]^\delta$ with growth rate δ.

0.246. This value is somewhat larger but comparable in magnitude to the preceding estimate of $\rho = 0.202$ from the structural approach above. Finally, use the estimates of $\hat{\beta}_8$ and $\hat{b}_\tau$ in the simultaneous equations $\hat{\rho} = (1 - \hat{\beta}_8)(1 - \hat{b}_\tau)$ and $\hat{\delta} = \hat{b}_\tau / [\hat{\beta}_8 + \hat{b}_\tau(1 - \hat{\beta}_8)]$ in order to simultaneously recover unique values of $\hat{\rho} = 0.202$ (std.err. 0.008) and $\hat{\delta} = 0.058$ (std.err. 0.001). ρ is statistically and quantitatively indistinguishable from the estimate of using the external value of $\delta = 0.061$ while the internally generated estimate of δ differs statistically significantly but quantitatively insignificantly from the external value. The close magnitudes of the various inferences of the value of ρ are compelling. Pushing inference to the limit, we note that the lower value of $\hat{\delta} = 0.058$ obtained from the simultaneous solution corresponds more closely to the interest rate values that are used for calibrations in the macroeconomic literature.

Estimates of $\hat{\rho}$ imply restrictions on the deep structural parameters of supply η and demand σ because

$$1/\rho - 1 = (\sigma - 1)/\eta.$$

Using the estimate $\hat{\rho} = 0.20 \Rightarrow \hat{\eta} = (\sigma - 1)/4$. Estimate of σ in the literature[41] range from 4 to 10, implying $\hat{\eta} \in [0.75, 2.25]$. The finite short run supply elasticities implied pass a smell test (with heterogeneous firms, $\tilde{\eta} < 1$ is readily possible) and provide an intuitive foundation for thinking about short run gravity.

Columns (4)-(8) of Table 3 report results from alternative estimators. Columns (4) and (5) use pair fixed effects for two reasons. First, the pair fixed effects will absorb and control for any omitted time-invariant determinants of bilateral trade. Second, the use of pair fixed effects has proven to be a useful method to address possible endogeneity of FTAs and trade policy in general. In the context of dynamic panel bias caused by the lagged dependent variable (Roodman (2009a)), an additional advantage of pair fixed effects is mitigation of the dynamic panel bias. The so-called Least Square Dummy Variable (LSDV) treatment of the Nickell bias is especially effective for samples with long time coverage.

[41] The estimate of $1 - \sigma$ inferred in our regressions is lower but we assume it is biased downward.

Finally, as demonstrated in Roodman (2009a), in case the LSDV estimator does not eliminate completely the bias in the estimate of the lagged dependent variable, then the remaining bias would be a downward bias owing to a negative correlation between the lagged dependent variable and the remaining error. This, in combination with expression (23), enables us to establish an upper bound for ρ. Using external value $\delta = 0.061$, the result in column (5) give an upper bound $\bar{\rho} = 0.371$ (std.err. 0.011) to pair with the lower bound from column (2) $\underline{\rho} = 0.202$.

Two further results stand out from columns (4)-(6). First, the SR gravity theory test (27) reported in column (6) offer strong support for the theory. Second, in combination with the estimates from the border-time dummy variable model, the results from column (5) imply $\hat{\rho} = 0.368$ (std.err. 0.011) and $\hat{\delta} = 0.072$ (std.err. 0.001). The incidence elasticity estimate of ρ is almost unchanged by the switch from externally to structurally generated δ.

The relatively long time coverage of our sample attenuates endogeneity bias in the LSDV estimator of SR gravity of column (5), but may not eliminate it. Column (7) of Table 3 thus implements an IV estimation along the lines of Frankel and Romer (1999). We construct an instrument for lagged trade by using a reduced form gravity specification that only includes the standard gravity variables, which are exogenous by definition, and also exporter and importer population, which also are arguably exogenous. We use the second to fifth lags of the newly constructed trade variable as instruments for the lagged dependent variable in specification (22). The estimation results from column (7) support our theory. First, the instruments are good since, based on the specification tests that we perform in the bottom of Table 3, they pass all IV tests. Second, once again, we obtain a positive and significant estimate on the lagged trade term. In combination with (23) and the external value of $\delta = 0.061$, $\rho = 0.242$ (std.err. 0.120). We calculate $\hat{\rho} = 0.242$ (std.err. 0.118) and $\hat{\delta} = 0.061$ (std.err. 0.009) when we combine the estimates from column (7) with those from the main results from the border-time dummy variable model. The close approximation of the two estimated parameter vectors is remarkable. Pushing the results of the various specifications hard, our preferred range for the key incidence elasticity is $\rho \in (0.20, 0.24)$ and our preferred value is 0.24, while we report a conservative range $\rho \in (0.20, 0.37)$.

Note finally that the SR test for the LSDV IV estimation reported in column (8) weakly supports the theory. We cannot reject the null hypothesis for the FTA variable. In contrast, the test statistic on LN_TARIFF rejects the null. We are suspicious of all estimates of the tariff parameter due to aggregation bias and low variation.

We conclude with a brief description of robustness checks. Detailed results and descriptions for each experiment can be found in Appendix B. The first experiment uses interval data instead of yearly data. The second experiment uses size-adjusted trade as the dependent variable. Use of the trade share instead of the level of trade tends to reduce the problem of heteroskedasticity. The third sensitivity experiment uses international trade data only. All three experiments confirm robustness of the main findings. We also experiment with the PPML estimator, yielding estimates that correspond to the upper and lower bound results from Table 3. The next experiment employs the system-GMM estimator of Arellano and Bond (1991) and Arellano and Bover (1995)/Blundell and Bond (1998). Here the results for ρ are higher, though remaining well inside the unit interval. (We suspect the poorer small sample properties of the system-GMM estimator are to blame.) Finally, the main results are reproduced with the aggregate WIOD data as well as for each of the main sectors that are covered in the WIOD dataset. In each case, the new estimates are consistent with and comparable to the main results from Table 3.

4.4 Real Income in the Short vs. Long Run

The model is next used to quantify the potential real income gain from long run efficient allocation of marketing capital – gains from globalization in the limit. The counterfactual experiment compares two static equilibria, one short run that represents the 2006 estimated short run model of the economy and the other long run with all parameters and variables except for marketing capital held constant. Importantly, constancy means all 2006 bilateral links that are empty remain empty in the long run. Results suggest that gains are universally big – welfare rises everywhere, ranging from 25% to 47%. This impression seems likely to be right given the model, though details would change as the many variables held constant in this counter-factual analysis would change during any actual transition to the long run.

The computation proceeds in three steps. First, the structural approach from Section 4.3 is used in combination with our preferred estimate of the efficiency parameter ρ, to solve the short run gravity model in baseline year 2006 (i.e., the last year in our sample). Second, we solve the standard gravity system in the long run equilibrium. Third, we construct country-specific real income measures as the ratio of real expenditure in the short run equilibrium to real expenditure in the long run equilibrium. This ratio measures how far countries currently are from where they could be with universally efficient (i.e. long run) allocation of marketing capital. Details on the construction of the real income (welfare) percentage changes that we present and describe here are included in Section B.3 of the Supplementary Appendix.

Our findings are presented in Table 4, which reports in percentage terms for the countries listed how far they were in 2006 from the level of real income they could achieve in a universally efficient world economy. All indexes of the real income changes are significantly smaller than one. With an average value of 61.5%, and ranging between 53% and 75%, the indexes imply welfare gains of 25% to 47% are possible from efficient allocation of 'marketing capital'. The variation across countries in real income percentage changes in Table 4 suggests that smaller and less developed countries are further from efficient equilibrium. Such countries (e.g., Malta, Philippines, Ireland, and Costa Rica) are mostly in the lower tail of the distribution while the upper tail contains some larger and more developed economies (e.g. the United States and the United Kingdom). In contrast, Qatar, Ecuador and Colombia are relatively closer to the LR equilibrium. An at least partial explanation for Qatar's star ranking is its exports dominated by natural gas and oil exported to other Asian economies in close proximity. Deeper explanations are beyond the scope of this paper.

5 Conclusion and Extensions

Short run gravity features (i) joint trade costs endogenous to bilateral volumes, (ii) long run gravity as a limiting case of efficient investment in bilateral capacities, (iii) tractable short and long run models of the extensive margin, and (iv) a structural ratio of short run to long run trade elasticities. Despite the complexity, bilateral trade is a geometric weighted average of long run gravity and a bilateral capacity variable, where the weight on long run gravity is the short run buyers' incidence elasticity. The incidence elasticity is itself micro-founded. The theoretical short run gravity model finds strong support in the data and the empirical analysis resolves several empirical puzzles.

The short run gravity model here suggests several extensions. (i) The model can be applied at the firm level, where indeed its assumption of a common Cobb-Douglas distribution 'production' function is most natural. (ii) Another potential extension is to the explanation of income inequality. The rents to destination-specific managerial labor may be linked to inefficient investment and costs of adjustment, inducing income inequality within firms and across firms in a sector. (iii) The model also extends upward to embedding in a multi-sector general equilibrium setting. The stock of labor and human capital is simply the sectoral allocation, possibly with differentials due to search costs. (iv) Empirical implementation and tests of the short run and long run extensive margin implications of SR gravity is an important challenge.

More challenging, perhaps leading outside the scope of the present model, is opening the black box of bilateral capacity. This paper treats capacity investment as effectively on the exporter side only. Since some investment is on the importer side, this may affect the short run statics and dynamics of the model. Firm level data and modeling suggests more carefully modeling the 'manager' input, sources of heterogeneity across markets and also across modes of organization: arms length contracting, joint ventures or horizontal integration in a multinational structure. The Arkolakis (2010) model extended to a dynamic setting may be a useful starting point.

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Table 1: SR Gravity with Efficiency Improvements, OLS Estimates

	(1) Standard	(2) Efficiency	(3) DistPuzzle	(4) PairFEs	(5) Efficiency2	(6) Development
LN_DIST	-1.184	-1.185	-1.183			
	(0.049)**	(0.049)**	(0.057)**			
CNTG	-0.047	-0.048	-0.047			
	(0.189)	(0.189)	(0.189)			
CLNY	0.460	0.459	0.460			
	(0.159)**	(0.159)**	(0.159)**			
LANG	0.782	0.782	0.781			
	(0.107)**	(0.107)**	(0.107)**			
FTA	0.413	0.406	0.419	0.165	0.147	0.139
	(0.062)**	(0.062)**	(0.065)**	(0.041)**	(0.041)**	(0.041)**
LN_TARIFF	-1.723	-1.704	-1.719	-1.311	-1.283	-0.990
	(0.443)**	(0.442)**	(0.445)**	(0.308)**	(0.306)**	(0.260)**
INTL_BRDR	-3.235	-3.733	-3.737			
	(0.299)**	(0.324)**	(0.336)**			
INTL_BRDR_1991		0.215	0.381		0.231	
		(0.091)*	(0.116)**		(0.092)*	
INTL_BRDR_1994		0.462	0.551		0.511	
		(0.098)**	(0.158)**		(0.098)**	
INTL_BRDR_1997		0.622	0.508		0.713	
		(0.122)**	(0.166)**		(0.121)**	
INTL_BRDR_2000		0.685	0.664		0.812	
		(0.132)**	(0.174)**		(0.131)**	
INTL_BRDR_2003		0.722	0.713		0.864	
		(0.149)**	(0.197)**		(0.144)**	
INTL_BRDR_2006		0.799	0.680		0.965	
		(0.160)**	(0.209)**		(0.158)**	
LN_DIST_1991			-0.051			
			(0.030)$^{+}$			
LN_DIST_1994			-0.027			
			(0.040)			
LN_DIST_1997			0.034			
			(0.037)			
LN_DIST_2000			0.006			
			(0.038)			
LN_DIST_2003			0.002			
			(0.041)			
LN_DIST_2006			0.035			
			(0.042)			
INTL_BRDR_HIGH_1991						0.314
						(0.237)
INTL_BRDR_HIGH_1994						0.589
						(0.187)**
INTL_BRDR_HIGH_1997						0.800
						(0.258)**
INTL_BRDR_HIGH_2000						1.009
						(0.262)**
INTL_BRDR_HIGH_2003						1.065
						(0.267)**
INTL_BRDR_HIGH_2006						1.287
						(0.306)**
INTL_BRDR_LOW_1991						0.438
						(0.177)*
INTL_BRDR_LOW_1994						0.939
						(0.214)**
INTL_BRDR_LOW_1997						1.235
						(0.226)**
INTL_BRDR_LOW_2000						1.237
						(0.275)**
INTL_BRDR_LOW_2003						1.351
						(0.322)**
INTL_BRDR_LOW_2006						1.520
						(0.351)**
N	18345	18345	18345	18344	18344	18336
r2	0.880	0.881	0.881	0.935	0.936	0.955

Notes: This table reports results from the international-borders dummy variable approach to test SR gravity theory. All estimates are obtained with the OLS estimator and with exporter-time and importer-time fixed effects, whose estimates are omitted for brevity. The dependent variable in each specification is the log of nominal bilateral trade. Column (1) reports standard (long run) gravity estimates. The estimates from column (2) are obtained with time-varying international border dummies, designed to capture relative efficiency improvements. Column (3) allows for time-varying distance effects, in addition to the time-varying border dummies. Columns (4) and (5) reproduce the results from columns (1) and (2) but with pair fixed effects. Finally, column (6) uses the specification from column (5) but allows for heterogeneous efficiency improvements across developed vs. developing countries. Standard errors are clustered by country pair and are reported in parentheses $^{+}$ $p < 0.10$, * $p < .05$, ** $p < .01$. See text for further details.

Table 2: SR Gravity with Efficiency Improvements, PPML Estimates

	(1) Standard	(2) Efficiency	(3) DistPuzzle	(4) PairFEs	(5) Efficiency2	(6) Development
LN_DIST	-0.648	-0.662	-0.640			
	(0.065)**	(0.065)**	(0.074)**			
CNTG	0.488	0.500	0.500			
	(0.148)**	(0.146)**	(0.145)**			
CLNY	-0.049	-0.064	-0.066			
	(0.109)	(0.108)	(0.108)			
LANG	0.325	0.343	0.345			
	(0.139)*	(0.138)*	(0.138)*			
FTA	0.142	0.073	0.073	0.318	0.112	0.214
	(0.123)	(0.118)	(0.117)	(0.077)**	(0.067)$^{+}$	(0.062)**
LN_TARIFF	-7.438	-6.803	-6.859	-4.842	-2.699	-2.122
	(1.167)**	(1.227)**	(1.238)**	(0.588)**	(0.547)**	(0.448)**
INTL_BRDR	-2.635	-3.032	-3.069			
	(0.154)**	(0.152)**	(0.164)**			
INTL_BRDR_1991		0.202	0.182		0.147	
		(0.023)**	(0.057)**		(0.016)**	
INTL_BRDR_1994		0.324	0.297		0.249	
		(0.028)**	(0.055)**		(0.024)**	
INTL_BRDR_1997		0.449	0.394		0.401	
		(0.044)**	(0.086)**		(0.035)**	
INTL_BRDR_2000		0.543	0.595		0.481	
		(0.055)**	(0.106)**		(0.041)**	
INTL_BRDR_2003		0.491	0.561		0.498	
		(0.062)**	(0.106)**		(0.043)**	
INTL_BRDR_2006		0.510	0.621		0.570	
		(0.065)**	(0.090)**		(0.040)**	
LN_DIST_1991			0.011			
			(0.023)			
LN_DIST_1994			0.013			
			(0.023)			
LN_DIST_1997			0.028			
			(0.031)			
LN_DIST_2000			-0.029			
			(0.036)			
LN_DIST_2003			-0.039			
			(0.038)			
LN_DIST_2006			-0.061			
			(0.036)$^{+}$			
INTL_BRDR_HIGH_1991						0.436
						(0.054)**
INTL_BRDR_HIGH_1994						0.750
						(0.078)**
INTL_BRDR_HIGH_1997						0.967
						(0.150)**
INTL_BRDR_HIGH_2000						0.988
						(0.227)**
INTL_BRDR_HIGH_2003						0.972
						(0.208)**
INTL_BRDR_HIGH_2006						1.118
						(0.205)**
INTL_BRDR_LOW_1991						0.512
						(0.084)**
INTL_BRDR_LOW_1994						1.162
						(0.123)**
INTL_BRDR_LOW_1997						1.368
						(0.132)**
INTL_BRDR_LOW_2000						1.520
						(0.172)**
INTL_BRDR_LOW_2003						1.900
						(0.187)**
INTL_BRDR_LOW_2006						2.062
						(0.193)**
N	18928	18928	18928	18928	18928	18928

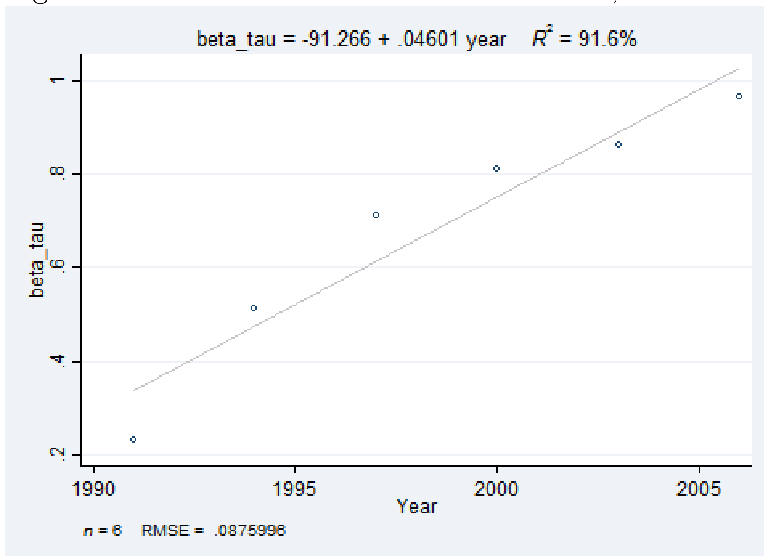
Notes: This table reports results from the international-borders dummy variable approach to test SR gravity theory. All estimates are obtained with the PPML estimator and with exporter-time and importer-time fixed effects, whose estimates are omitted for brevity. The dependent variable in each specification is nominal bilateral trade. Column (1) reports standard (long run) gravity estimates. The estimates from column (2) are obtained with time-varying international border dummies, designed to capture relative efficiency improvements. Column (3) allows for time-varying distance effects, in addition to the time-varying border dummies. Columns (4) and (5) reproduce the results from columns (1) and (2) but with pair fixed effects. Finally, column (6) uses the specification from column (5) but allows for heterogeneous efficiency improvements across developed vs. developing countries. Standard errors are clustered by country pair and are reported in parentheses $^{+}$ $p < 0.10$, * $p < .05$, ** $p < .01$. See text for further details.

Table 3: SR Gravity & Efficiency

	(1) Standard	(2) SR Gravity	(3) SR Test1	(4) LSDV	(5) SR LSDV	(6) SR Test2	(7) LSDV IV	(8) SR Test3
LN_DIST	-1.186	-0.248	0.003					
	(0.049)**	(0.016)**	(0.008					
CNTG	-0.036	0.005	0.358					
	(0.189)	(0.039)	(1.097)					
CLNY	0.457	0.092	0.112					
	(0.158)**	(0.034)**	(0.074)					
LANG	0.773	0.147	0.022					
	(0.105)**	(0.022)**	(0.028)					
FTA	0.418	0.108	- 0.046	0.170	0.070	- 0.024	0.029	0.081
	(0.062)**	(0.013)**	(0.032)	(0.037)**	(0.016)**	(0.097)	(0.017)+	(0.130)
LN_TARIFF	-1.513	-0.348	- 0.018	-1.114	-0.446	0.014	-0.579	-0.265
	(0.378)**	(0.100)**	(0.066)	(0.259)**	(0.118)**	(0.105)	(0.149)**	(0.097)**
INTL_BRDR	-3.229	-0.635	0.015					
	(0.297)**	(0.064)**	(0.019)					
L.LN_TRADE		0.788			0.614		0.746	
		(0.009)**			(0.011)**		(0.124)**	
N	49916	46868		49916	46868		35411	
R^2	0.882	0.959		0.936	0.964		0.964	
ρ		0.202			0.371		0.242	
		(0.008)**			(0.011)**		(0.120)**	
Under Id χ^2							13.595	
p-val							(0.009)	
Weak Id χ^2							3.394	
p-val							(0.009)	
Over Id χ^2							1.350	
p-val							(0.717)	

Notes: This table reports results from the structural investment approach to test SR gravity theory. All estimates are obtained with exporter-time and importer-time fixed effects, whose estimates are omitted for brevity. The dependent variable in each specification is the log of nominal bilateral trade. Column (1) reports standard (long run) gravity estimates. The estimates from column (2) are obtained with lagged trade added as a covariate. Column (3) reports the results from a test of the SR gravity theory according to equation (27). Columns (4)-(6) reproduce the results from columns (1)-(3) but with pair fixed effects, thus implementing the LSDV estimator. Column (7) implements an IV LSDV estimation, and column (8) reports the results from test (27). The "weak identification" (Weak Id) statistics are based on Kleibergen-Paap Wald F values, which are appropriate when the standard error i.i.d. assumption is not met and the usual Cragg-Donald Wald statistic is no longer valid. (The corresponding Cragg-Donald Wald F statistic is 3.781.) Robust standard errors are reported in parentheses $^+$ $p < 0.10$, * $p < .05$, ** $p < .01$. See text for further details.

Figure 1: Evolution of International Borders, 1988-2006.



Note: This figure plots the evolution of the international border estimates from column (5) of Table 1, which are obtained with the OLS estimator and pair fixed effects, over time. The figure also reports the slope of the fitted line, which corresponds to the parameter b_τ from the main text.

Table 4: Real Income in SR Relative to LR

(1) Country	(2) Ratio (%)	(3) Country	(4) Ratio (%)	(5) Country	(6) Ratio (%)
MLT	52.761	ISR	58.598	CHN	63.88
PHL	54.525	SWE	58.919	ROM	63.928
IRL	55.962	KWT	59.51	BRA	64.021
CRI	56.047	PRT	60.32	DEU	64.195
CHL	56.115	NLD	60.446	CYP	64.455
URY	56.147	BGR	60.502	FRA	64.607
DNK	56.348	ISL	60.516	AUS	64.768
MMR	56.711	BOL	60.56	ITA	64.947
IDN	57.271	NOR	61.355	GRC	65.049
SGP	57.403	MAR	61.485	JOR	65.101
THA	57.652	JPN	61.891	ESP	65.622
FIN	57.879	KOR	62.413	GBR	66.095
TUN	57.907	CHE	62.442	TUR	66.837
HUN	58.057	CAN	62.753	COL	68.485
MYS	58.198	MEX	62.762	ECU	68.933
AUT	58.376	POL	63.196	USA	71.719
ARG	58.544	EGY	63.43	QAT	74.738

Notes: This table reports the ratio (in percent) between the short-sun welfare indexes and the corresponding long run welfare indexes based on the structural estimates from Section 4.3. Columns (1), (3), and (5) list the countries in our sample and columns (2), (4), and (6) list the corresponding welfare indexes. Countries are ranked based on how far they are, in terms of welfare, from the hypothetical long run equilibrium. For further details on the construction of the welfare indexes and for a discussion these results, see Section 4.4 of the main text and Section B.3 of the Supplementary Appendix.

Supplementary Appendix

This document is the Supplementary Appendix to "Short Run Gravity" (2018), by J. E. Anderson and Y. V. Yotov. The appendix is not intended for publication and will appear on the authors' web sites.

Appendix A: Theoretical Extensions

A.1 Heterogeneous Productivities and Short Run Gravity

Short run gravity can equivalently represent a foundation based on heterogeneous productivities generated by a probability distribution (Eaton and Kortum, 2002). With productivity draws from a Frechet (Type II extreme value) distribution, it is well known that the same long run gravity equation system results with the trade cost elasticity $1 - \sigma$ reinterpreted as the dispersion parameter θ of the Frechet distribution and the taste parameter β_i reinterpreted as the location parameter of the productivity distribution for origin i. The CES demand system is used in the Eaton-Kortum model but σ ends up in a background constant term due to the infinite elasticity of transformation of the Ricardian model.

The simplicity of the Cobb-Douglas production model here allows short run long run gravity to be interpreted in terms of either foundation. For the Eaton-Kortum interpretation, each origin supplies potentially an infinite number of varieties to each destination. Each variety has the same basic Cobb-Douglas production function up to a productivity draw parameter divided by an iceberg trade factor. The proportion of draws favorable enough to permit shipments to destination j relative to shipments from all origins to destination j is a CES-type share function of unit cost of delivered output from origin i relative to an index of unit costs of delivered output to j from all origins. The key link between the two models is that the unit cost of delivered output in equilibrium in the short run model plays the same role in either model. Note also that the long run Cobb-Douglas model with efficient capacities becomes Ricardian, as in the Eaton-Kortum model.

Feenstra (2016) following Chaney (2008) shows that with constant iceberg bilateral trade costs and Melitz (2003) Pareto distributed productivities, a version of the structural gravity model emerges, with the trade cost elasticity having a different interpretation and fixed costs playing a role. The key step in reaching this conclusion is that the combination of Pareto distribution and iceberg bilateral costs leads to a log-linear closed form solution for the productivity of the least productive firm in any origin able to serve each destination from that origin. The Pareto distribution then yields a log-linear expression for the proportion of firms from each origin that serve each destination.

For *purely competitive* firms with Pareto distributed productivities, fixed costs of exporting to a destination, and the increasing variable bilateral trade costs modeled in this paper, Section A.1.1 below shows that the optimized (restricted) profit function has a constant elasticity with respect to productivity. This implies a closed form solution for the minimum productivity firm and thus the proportion of firms that can serve any market. In this case, the heterogeneous purely competitive firms model again yields a standard structural gravity equation. The trade cost elasticity is now a function of the elasticity of substitution σ, the Pareto distribution dispersion parameter θ and the elasticity of transformation $1/(1-\alpha)$.

The monopolistic competition case is examined in Section A.1.3. Unfortunately, the combination of heterogeneous productivities and selection of *monopolistically* competitive firms due to fixed costs does not lead to a tractable short run gravity model. There is generally no closed form solution for the productivity of the least productive firm able to serve a destination. This is because in monopolistic competition the elasticity of optimized (restricted) revenue with respect to productivity is smaller than the elasticity of optimized variable cost with respect to productivity. The implicit relationship between the proportion of firms serving a market on the one hand and market size and origin wage on the other hand retains the qualitative properties of the Melitz-Chaney model, but the implicit function substantially departs from log-linearity. Nevertheless, Section A.1.3 shows that the purely competitive firms model closely approximates the monopolistic competition model as σ is large. Numerical evaluation reveals the two models are close.

A.1.1 Short Run Gravity with Competitive Heterogeneous Firms

Each firm draws a Hicks-neutral productivity scalar $\varrho \geq 1$ from a Pareto distribution $G(\varrho) = 1 - \varrho^{-\theta}$. Index the firms in an (implicit) origin by their productivity draws ρ. Firms have (by assumption) previously committed capital $K(z)$ to each destination z in the same pattern based on expected demand because prior to receiving their productivities, all firms are identical. The profit of firm ϱ is

$$\varrho \frac{p(z)}{t(z)} L(z,\varrho)^{\alpha} K(z)^{1-\alpha} - wL(z,\varrho).$$

Profit maximization by a price taking firm implies the restricted profit function $\varrho^{1/(1-\alpha)}\bar{R}(z)$ where

$$\bar{R}(z) = \left(\frac{p(z)}{t(z)}\right)^{1/(1-\alpha)} K(z)[\alpha^{\alpha/(1-\alpha)} - w^{-\alpha/(1-\alpha)}\alpha^{1/(1-\alpha)}]$$

is the variable profit of the least productive firm (whether it ships to destination z or not).

The zero profit cutoff value of ϱ occurs at

$$\underline{\varrho}(z) = [f(z)/\bar{R}(z)]^{1-\alpha}$$

where $f(z)$ is the fixed cost of exporting to z. The proportion of firms with $\varrho \geq \underline{\varrho}$ is given by $1 - G(\varrho) = \int_{\underline{\varrho}}^{\infty} \theta \varrho^{-\theta-1} d\varrho$. Then the aggregate value shipped to destination z is given by

$$\left(\frac{p(z)}{t(z)}\right)^{1/(1-\alpha)} K(z)\alpha^{\alpha/(1-\alpha)} S(z) \tag{28}$$

where the mass of firms serving destination z

$$S(z) = \int_{\underline{\varrho}}^{\infty} \theta \varrho^{1/(1-\alpha)-\theta-1} d\varrho = \frac{\theta}{\theta + 1 - \eta} \left(\frac{f(z)}{\bar{R}(z)}\right)^{\eta-\theta} \tag{29}$$

using $\eta = 1/(1-\alpha)$. Relative to the text version of short run gravity, $S(z)$ enters everywhere that $K(z) = \lambda(z)K$ appears. $\bar{R}(z)$ is proportional to $[p(z)/t(z)]^{\eta}$. Using this expression in (29), $p(z)/t(z)$ affects the extensive margin of trade through $S(z)$ with elasticity $\eta(\theta - \eta)$. The intensive margin response to a fall in trade cost $t(z)$ acts to crowd out the extensive margin response in (29), completely so at $\theta = \eta$. The mass of active firms falls and average productivity rises when $\eta > \theta$, which is the famous Melitz (2003) case where effectively $\eta \to \infty$.

(29) combines in (28) with the effect of $p(z)/t(z)$ on the intensive margin of trade with elasticity η. The combined effect of $p(z)/t(z)$ on shipments has composite supply elasticity $\tilde{\eta} = \eta(1 + \theta - \eta)$. This composite supply side elasticity combines with the demand side elasticity in the short run equilibrium model of the text to yield a buyers' incidence elasticity equal to

$$\tilde{\rho} = \frac{\eta(1 + \theta - \eta)}{\eta(1 + \theta - \eta) + \sigma - 1} > \rho \tag{30}$$

for $\theta > \eta$, the intuitive case where the extensive margin of firms $S(z)$ is increasing in price $p(z)$. In the special case $\theta = \eta$, the responses of firms on the intensive and extensive margins are perfect substitutes.

The extensive margin of destinations is essentially the same as in the identical firms case. The normalization to 1 of the fixed labor requirement to serve a destination is replaced by the mass of firms productive enough to serve that destination $S(z)$. Suppressing the variation $f(z)$ introduced above and normalizing it to 1, the fixed labor requirement n for the identical firms case becomes $N = \int_0^n S(z)dz$. Condition (6) yielding the smallest destination able to be served becomes

$$\alpha \frac{Y}{L - N} S(n) = (1 - \alpha)s(n)Y.$$

This has the same meaning, only adding the slight complication that the mass of firms requiring a fixed labor input $S(z)$ is presumably falling as $z \to n$.

In empirical applications, the extensive margin component can be identified if proxies for fixed export costs can be found that are not also proxies for variable trade costs. In the absence of such proxies, estimated trade elasticities have to be considered combinations of intensive and extensive margin responses.

A.1.2 Empirical Implications

The development of the firm level model here points to a rationale for the simple econometric procedure adopted for the empirical work. First, the $\lambda(z)$ allocations are assumed to be the same for any firm, under the assumption that all heterogeneity is in ϱ draws. We can extend the logic to assume that all $z > 0$ external markets are ex post under-supplied to a uniform extent, $\lambda(z)$ is too small by a common fraction and correspondingly $\lambda(0)$ is too large. This permits drawing inferences from multiple observations on the movement of external vs. internal trade over time.

A second aspect of the model with empirical content is that the zeroes in bilateral trade flows can simply be rationalized as the absence, for whatever reason, of a finite positive λ.

A.1.3 Monopolsitic Competition Case

The production function for delivered output by monopolistic competitive firm ϱ to destination z from a representative origin is the same as in the competitive case, $y(z, \varrho) = \varrho L(z, \varrho)^\alpha K(z)^{1-\alpha}/t(z)$, where $K(z)$ is assumed to be committed before ϱ is drawn from the Pareto distribution with dispersion parameter θ. The firm faces willingness to pay for its shipments to destination z equal to

$$p(z, \varrho) = y(z, \varrho)^{-1/\sigma} E(z)^{1/\sigma} P(z)^{1-1/\sigma}.$$

Once ϱ is drawn, the firm hires labor (including the manager) to maximize profits (including the premium paid to the manager). The efficient level of labor is such that the wage w is equal to the marginal revenue product of labor:

$$L(z,\varrho) = \varrho^{(1-1/\sigma)/(1-\alpha(1-1/\sigma))}\left(\alpha(1-1/\sigma)E(z)^{1/\sigma}(P(z)/t(z)^{1-1/\sigma}K(z)^{(1-\alpha)(1-1/\sigma)}/w\right)^{1/(1-\alpha(1-1/\sigma))} \tag{31}$$

The wage bill of firm ϱ on shipments to z is w times the right hand side of (31). The value of sales at destination prices follows from substituting the right hand side of (31) into the production function for delivered output and the willingness to pay function for delivered output. The restricted profit function is equal to sales minus the wage bill. It is convenient for present purposes to define the sales $\underline{y}(z)$ and labor $\underline{L}(z)$ of the minimally productive firm with $\varrho = 1$, suppressing the unnecessary details. The restricted profit function of firm ϱ on sales to z is

$$R(z,\varrho) = \underline{y}(z)\varrho^{(1-1/\sigma)(1+\alpha)/(1-\alpha(1-1/\sigma))} - \underline{L}(z)\varrho^{(1-1/\sigma)/(1-\alpha(1-1/\sigma))}. \tag{32}$$

The least productive firm able to serve market z must be productive enough to pay fixed cost $f(z)$. The cutoff firm has productivity

$$\underline{\varrho}(z) = \min \varrho : R(z,\varrho) - f(z) = 0.$$

The definition imposes a plausible restriction that the monopolistic competitive firm will find the smallest root $\underline{\varrho}$ when there are multiple roots solving the equation.

Expression (32) does not yield a closed form solution for ϱ for a given profit level, so it will not yield a convenient structural gravity equation for the mass of firms serving market z from the origin in focus here. In contrast, perfectly competitive firms yield a closed form solution. The monopolisitic competition case comes close to the competitive case as σ grows large, hence $1 - 1/\sigma \to 1$ in the exponents of (32).

Quantitatively, the difference between the monopolistic competition case and the pure competition case can be numerically evaluated by comparing solutions for $\underline{\varrho}(z)$ given reasonable range values of σ with the competitive equivalent solution with $\sigma \to \infty$. Plugging the pair of solutions for into equation (29), the ratio of the mass of sales of monopolistic to competitive firms can be computed, given a value of θ. A representative evaluation case used $f/\underline{Y} = 0.5,\ w\underline{L}/\underline{y} = 0.6,\ \alpha = 0.67,\ \theta = 4$. At $\sigma = 2$, monopolistic firms total sales are 91% of competitive firms sales. At $\sigma = 10$, they are 99% of competitive firms sales. The ratio is monotonic (and equilibrium $\underline{\varrho}$ is unique), convex and 'nearly' linear in $\sigma \in (1, \infty)$.

A.2 Short Run Trade Cost Endogeneity

The short run gravity model implies a theory of short run endogenous trade costs. Equation (8) yields a structure that potentially connects inference about trade costs from price variation to inference from trade flow variation.

Relative price $T(i,z) \equiv p(i,z)/p(i,i)$ is common direct measure of trade cost variation. Use (8) and the result on the CES price index $P(z) = (E(z)/Y)^{-(1-\rho)}\,\widetilde{P}(z)$ from Section 3 where $\widetilde{P}(z)$ is the buyer's multilateral resistance. Simplify the exponents of the result to give:

$$T(i,z) = \left(\frac{t(i,z)}{t(i,i)}\right)^{\rho} \left(\frac{\lambda(i,z)}{\lambda(i,i)}\right)^{-\rho/\eta} \left(\frac{\widetilde{P}(z)}{\widetilde{P}(i)}\right)^{1-\rho} \left(\frac{E(z)}{E(i)}\right)^{1/\eta}. \tag{33}$$

$T(i,z) \to t(i,z)/t(i,i)$ as $\lambda(i,z)/\lambda(i,i)$ adjusts to its efficient level (see Section 3.2). $t(i,z)/t(i,i)$ is inferred from standard (i.e. long run) gravity equations, while (33) implies that spatial variation of $T(i,z)$ includes the effect of inefficient bilateral capacities and the spatial variation of demand conditions. Demand variation in the last two terms on the right is direct in $E(z)/E(i)$ and indirect through its general equilibrium effects on buyers' relative multilateral resistance $\widetilde{P}(z)/\widetilde{P}(i)$. (33) can potentially reconcile the time invariance of $t(i,z)$ inferred from gravity and the obvious time variation of direct price measures, and also differences in elasticities inferred from the spatial variation of prices and the spatial variation of trade flows. Future research on disaggregated price and trade flow data can test the consistency of (13) and (33).[42]

Spatial arbitrage is assumed to be perfect in (33). Violations of the Law of One Price are are unimportant in the empirical work reported in this paper if they are unsystematic. Higher frequency data on disaggregated price and trade flow data is likely to reveal systematic deviations from the Law of One Price, with intertemporal behavior that is informative about dynamics of arbitrage.

[42]The application of this paper to aggregate manufacturing data is not suitable for use of (33) because composition effects contaminate the spatial variation of manufacturing price indexes.

Appendix B: Empirical Analysis

This appendix reports the results from a series of sensitivity experiments that demonstrate the robustness of our main results. Following the development of the exposition in the main text of the manuscript, we present successively robustness experiments for each the two econometric methods that we employ to test the SR gravity theory.

B.1 Sensitivity Experiments: Econometric Approach

We start this section with a brief summary of the main empirical findings from Section 4.2, where we tested the short run gravity theory with an estimation approach that employed international border dummies under the assumption that cross-border trade capacities $\lambda(i, z, \tau)$ are inefficiently small, while domestic capacities $\lambda(i, i, \tau)$ are inefficiently large and, over time, capacity investment evolves toward efficiency so that cross-border investment in trade links rises relative to domestic investment in trade links. The two main findings from the estimates in Section 4.2 were that (i) the estimates of the standard gravity variables remained statistically unchanged once we introduced the bilateral border dummies; and, more importantly for our purposes, (ii) we obtained estimates on the bilateral border dummies that were all positive, statistically significant, and gradually increasing over time, which, consistent with our theory we interpreted as improvement in efficiency. The following experiments confirm the robustness of our main findings from Section 4.2:

- The estimates in Table 5 are obtained with size-adjusted trade, $X_{i,z,\tau}/Y_{i,\tau}$, as dependent variable. The motivation for using size-adjusted trade is twofold. First, such specification is consistent with theory. Second, using size-adjusted trade as dependent variable mitigates heteroskedasticity concerns by construction, cf. Anderson and van Wincoop (2003). The estimates from columns (1)-(4) of Table 5 are obtained with the OLS estimator. Columns (1) and (2) reproduce the estimates with standard gravity variables from columns (1) and (2) of Table 1. Columns (3) and (4) reproduce the estimates with pair fixed effects from columns (4) and (5) of Table 1. Columns (5)-(8) reproduce the estimates from columns (1)-(4) with the PPML estimator. All results are obtained with exporter-time and importer-time fixed effects, whose estimates are omitted for brevity. Both the OLS and the PPML estimates from Table 5 confirm the two main findings as summarized at the beginning of this section.

- Figure 2 reports estimates of the evolution of the international border estimates from column (2) of Table 1, which are obtained with OLS and standard gravity variables, over time. The figure also obtains the slope of the fitted line, which corresponds to the parameter b_τ from the main text. The estimate of $b_\tau = 0.036$ from Figure 2 is smaller but comparable to the estimate of $b_\tau = 0.046$ from the main text. The results in Figure 3 are constructed based on the estimates from column (5) of Table 2, which are obtained with the PPML estimator and pair fixed effects, over time. Once again, we obtain a similar value for the parameter $b_\tau = 0.028$.

- Table 6 reproduces the main results from Table 1 with data for all years. The estimates from columns (1)-(4) are obtained with the OLS estimator. Columns (1) and (2) reproduce the estimates with standard gravity variables from columns (1) and (2) of Table 1. Columns (3) and (4) reproduce the estimates with pair fixed effects from columns (4) and (5) of Table 1. Columns (5)-(8) of this table reproduce the estimates from columns (1)-(4) of the same table with the PPML estimator. All results are obtained with exporter-time and importer-time fixed effects, whose estimates are omitted for brevity. In addition, also for brevity, we have omitted the estimates on the bilateral border dummies for the odd years in the sample. These are available by request. The estimates from Table 6, once again, confirm our main findings as summarized at the beginning of this section.

- Table 7 reproduces the results from column (3) of Table 1 with data for all years. We remind the reader that the estimates from column (3) of Table 1 depicted and resolved the 'distance puzzle' in international trade. The estimates in column (1) of Table 7 are obtained with the OLS estimator and the estimates in column (2) of Table 7 are obtained with the PPML estimator. All results are obtained with exporter-time and importer-time fixed effects, whose estimates are omitted for brevity. In addition, also for brevity, we have omitted the estimates on the time-varying distance variables and the estimates on the bilateral border dummies for the odd years in the sample for each group of countries. The omitted estimates are available by request. In each case we allow for time-varying distance effects and, in each case, we find no evidence for time-varying effects of distance. This is consistent with the distance puzzle in international trade. However, similar to the discussion of our main results, our theory suggests that the correct interpretation of the effects of distance should combine the joint impact that is captured by the distance estimates and by the estimates of the efficiency improvements. Thus, combined with the decreasing border effects (captured by the positive, significant and increasing estimates on the border dummies), our theory implies that the impact of distance have steadily decreased over time. In sum, the estimates from Table 7 confirm that our theory can indeed resolve the famous 'distance' and 'missing globalization' puzzles in the international trade literature.

- Table 8 reproduces the results from column (6) of Table 1 with data for all years. We remind the reader that the estimates from column (6) of Table 1 distinguished between capacity improvement for the developed vs. developing countries in our sample. The estimates in column (1) of Table 8 are obtained with the OLS estimator and the estimates in column (2) of Table 8 are obtained with the PPML estimator. In each case we allow for different efficiency improvement rates depending on whether a country is developed or developing. All results are obtained with exporter-time and importer-time fixed effects, whose estimates are omitted for brevity. In addition, also for brevity, we have omitted the estimates on the bilateral border dummies for the odd years in the sample for each group of countries. The omitted estimates are available by request.

The estimates from columns (1) and (2) of Table 8 deliver results that are very similar to our main corresponding findings from Table 1. Specifically, and most important, we do observe efficiency improvements for both groups of countries. In addition, we see that the low income countries have actually converged faster toward more efficient trade during the period of investigation.

- Table 9 reproduces the main results from Table 1 with with the latest edition of the WIOD data, as described in the data section. The WIOD dataset covers the period 2000-2014 and we use 2-year intervals to obtain the estimates in Table 9. The estimates from columns (1)-(4) are obtained with the OLS estimator. Columns (1) and (2) reproduce the estimates with standard gravity variables from columns (1) and (2) of Table 1. Columns (3) and (4) of Table 9 reproduce the estimates with pair fixed effects from columns (4) and (5) of Table 1. Columns (5)-(8) of Table 9 reproduce the estimates from columns (1)-(4) of the same table with the PPML estimator. All results are obtained with exporter-time and importer-time fixed effects, whose estimates are omitted for brevity. The estimates from Table 9 confirm our main findings, as summarized at the beginning of this section, with the WIOD data.

- Table 10 reproduces the main results from Table 1 by capitalizing on the sectoral dimension of the latest edition of the WIOD data, as described in the data section. Once again, we use 2-year interval data. For brevity, for each of the six main sectors in the WIOD database (including Crop and Animal Production, Forestry and Logging, Fishing and Aquaculture, Mining and Quarrying, Manufacturing, and Services), we only reproduce the main specifications with pair fixed effects, which correspond to those in columns (4) and (5) of Table 1. All results are obtained with the OLS estimator and with exporter-time and importer-time fixed effects, whose estimates are omitted for brevity. The main finding from the results in Table 10 is that the estimates of the time-varying bilateral border dummies are positive, statistically significant, and increasing over time for each sector in our sample. These results are consistent with our main findings and support the SR gravity theory. In addition, we note that while there is certain heterogeneity in the bilateral border estimates across sectors, the efficiency improvements have been significant at the sectoral level and similar in magnitude.

In sum, based on the sensitivity experiments that we employed in this section, we conclude that our main findings from Section 4.2 represent robust results.

B.2 Sensitivity Experiments: Structural Approach

We start this section with a brief summary of the main empirical findings from Section 4.3, where we tested the short run gravity theory by developing a formal model of investment, which resulted in the addition of the lagged dependent variable as a covariate in the estimating equation for SR gravity. Three main findings stood out from the estimates in Section 4.3. First, we obtained a large, positive and statistically significant estimate of the coefficient on the structural efficiency term. Second, we recovered estimates of the structural efficiency parameter ranging from 0.202 to 0.371. Third, as predicted by the SR gravity theory, the estimates that controlled for efficiency improvements were significantly smaller in magnitude as compared to their long run counterparts. The following experiments confirm the robustness of our main findings from Section 4.2:

- Table 11 uses 3-year interval data to reproduce the results from Table 3 of the main text. All results are obtained with exporter-time and importer-time fixed effects, whose estimates are omitted for brevity. The dependent variable in each specification is the log of nominal bilateral trade. Column (1) reports standard (long run) gravity estimates. The estimates from column (2) are obtained with lagged trade added as a covariate. Column (3) reproduces the results from column (2) but with pair fixed effects, thus implementing the LSDV estimator. Column (4) implements an IV LSDV estimation. Finally, column (5) implements the Arellano-Bond estimator. In sum, the estimates from Table 11 are in support of all main findings listed at the beginning of this section. Specifically: (i) We obtain positive and significant estimates of the structural efficiency term; (ii) Taking into account the use of 3-year interval data, which implies $\tilde{\beta}_8 = \frac{(1-\delta)^3(1-\rho)}{1-\delta(1-\rho)}$, we recover $\hat{\rho} \in [0.250, 0.534]$ across the different specifications, which can be found in the bottom panel of Table 11; (iii) The estimates from each specification that controls for efficiency improvements are significantly smaller in magnitude as compared to their long run counterparts from column (1) of Table 11. Finally, we note that the bounds for ρ that we obtain with sample that includes all years are tighter as compared to the bounds with the 3-year interval data. This is evidence in support of using the full sample over using data with intervals.

- Table 12 uses size-adjusted trade as dependent variable and reproduces the results from Table 3 of the main text. All results are obtained with exporter-time and importer-time fixed effects, whose estimates are omitted for brevity. The dependent variable in each specification is the log of nominal bilateral trade. Column (1) reports standard (long run) gravity estimates. The estimates from column (2) are obtained with lagged trade added as a covariate. Column (3) reproduces the results from column (2) but with pair fixed effects, thus implementing the LSDV estimator. Column (4) implements an IV LSDV estimation. The estimates from Table 12 confirm our main results as summarized at the beginning of this section.

- Table 13 reproduces the results from Table 3 of the main text with 3-year interval data on international trade only. All results are obtained with exporter-time and importer-time fixed effects, whose estimates are omitted for brevity. The dependent variable in each specification is the log of nominal bilateral trade. Column (1) reports standard (long run) gravity estimates. The estimates from column (2) are obtained with lagged trade added as a covariate. Column (3) reproduces the results from column (2) but with pair fixed effects, thus implementing the LSDV estimator. Column (4) implements an IV LSDV estimation. Once again, the estimates from Table 13 confirm our main results as summarized at the beginning of this section.

- Table 14 uses the system-GMM estimator, which will account for the dynamic features of our model.[43] The estimates from column (1) of Table 14 are obtained with data for all years and pass the Arellano-Bond test for autocorrelation in the disturbances by rejecting (as expected) the null hypothesis of no AR(1) errors with $z = -10.268$, but passing the test for second-order serial correlation AR(2) with $z = 1.302$. However, the instruments do not pass the Sargan test of overidentifcation restrictions with $\chi^2_{15} = 168.99$ (p-value=0.025). Furthermore, we obtain a suspiciously small estimate of the coefficient on $LN\_X_{ij,\tau-1}$ ($\tilde{\beta}_8 = 0.254$, std.err. 0.045), which is clearly outside of the bounds that we established in columns (2) and (4) of Table 3 from th main text. The Arellano-Bond estimates from column (2) of Table 14 are obtained with 3-year interval data and they improve on the estimates from column (1) by delivering an estimate on $LN\_X_{ij,\tau-1}$ ($\tilde{\beta}_8 = 0.603$, std.err. 0.161), from which we recover $\hat{\rho} = 0.303$ (std.err. 0.178), which is not statistically different from our main estimates.

- Table 16 uses the latest edition of the WIOD data and reproduces the results from Table 3 of the main text. All results are obtained with exporter-time and importer-time fixed effects, whose estimates are omitted for brevity. The dependent variable in each specification is the log of nominal bilateral trade and we use 2-year interval data. Column (1) reports standard (long run) gravity estimates. The estimates from column (2) are obtained with lagged trade added as a covariate. Columns (3) and

[43] Anderson and Hsiao (1982) are the first to achieve consistency in short time period setting by using appropriate lagged levels and differences of the dependent variable as instruments for the lagged dependent variable. Arellano and Bond (1991) and Arellano and Bover (1995)/Blundell and Bond (1998) extend the Anderson-Hsiao estimator to the difference-GMM and the system-GMM estimators, respectively, which use larger sets of orthogonality conditions in order to obtain consistent estimates in dynamic panels with lagged dependent variable such as ours. We refer the interested reader to Roodman (2009a) for a detailed discussion and step-by-step implementation of alternative dynamic estimators in Stata. Roodman (2009b) An additional advantage of this estimation method for our analysis is that it will enable us to obtain estimates of the coefficient of all gravity variables, which will be used to perform test (27) multiple times. discusses problems associated with the proliferation of instruments in similar settings.

(4) reproduce the results from columns (1) and (2) but with pair fixed effects, thus implementing the LSDV estimator. The estimates with the WIOD data are consistent with the main results and they deliver $\hat{\rho} \in [0.070, 0.598]$. Both the upper and the lower bounds for ρ are wider as compared to the main estimates, but they are within the theoretical limits. We offer two possible explanations for the wider bounds. First, the main sample has longer time coverage, which, according to Roodman (2009a) leads to more precise estimates. Second, similar to the estimates with the 3-year interval sample of the main data, the WIOD estimates from Table 16 are obtained with 2-year interval data.

- Table 17 reproduces the main results from Table 3 by capitalizing on the sectoral dimension of the latest edition of the WIOD data, as described in the data section. For brevity, for each sector we only focus on reproducing the main specifications (i) with lagged trade and standard gravity variables and (ii) with lagged trade and pair fixed effects. All results are obtained with 2-year interval data, with the OLS estimator, and with exporter-time and importer-time fixed effects, whose estimates are omitted for brevity. The sectoral SR gravity estimates are relatively homogeneous and they confirm our main findings.

In sum, based on the sensitivity experiments that we employed in this section, we conclude that our main findings from Section 4.3 represent robust results.

B.3 Welfare Calculation Metods

This section describes the methods that we employ in order to construct the welfare indexes from Table 4, which we presented and discussed in section 4.4 of the main text. We proceed in three steps.

1. Take the last year in the sample, i.e., 2006, as baseline and solve the system in the short run. Let $R(i, sr)$ denote the initial/baseline value of $Y(i, 2006)$ with the units choice

$C(i,sr)=1$. Base expenditures are given in the data, but imply an awkward empirical reality of trade imbalance everywhere. Closing the counterfactual model is met with a crude static mechanism $E(z)=\psi(z)Y(z)$ subject to $\sum_z \psi(z)Y(z)=Y$ where the base equilibrium calibrates $\psi(z)=E(z,2006)/Y(z,2006)$ for each destination z as a set of positive parameters, to be held constant in the counterfactual simulation.

Use the costly adjustment specification of Lucas-Prescott for the structural short run model from Section 4.3,

$$\lambda(i,z,\tau)^{1-\rho}=\left(X(i,z,2006)/Y(i,2006)\right)^{\delta(1-\rho)}\left(X(i,z,2005)/Y(i,2005)\right)^{(1-\delta)(1-\rho)/[1-\delta(1-\rho)]},$$

to solve for the short run multilateral resistances from equations (11) and (12) in Section 3. Then, impose market clearance with the units choice $C(i,sr)=1$. The baseline SR gravity system becomes:

$$\breve{P}(z,sr)^{\frac{(1-\sigma)\rho}{1-\delta(1-\rho)}} = \sum_i \frac{R(i,sr)}{\sum_i R(i,sr)}\left(\frac{t(i,z,sr)}{\Pi(i,sr)}\right)^{\frac{(1-\sigma)\rho}{1-\delta(1-\rho)}}\left(\frac{X(i,z,2005)}{Y(i,2005)}\right)^{\frac{(1-\delta)(1-\rho)}{1-\delta(1-\rho)}}, \quad (34)$$

$$\Pi(i,sr)^{\frac{(1-\sigma)\rho}{1-\delta(1-\rho)}} = \sum_z \frac{\psi(z)R(z,sr)}{\sum_z R(z,sr)}\left(\frac{t(i,z,sr)}{\breve{P}(z,sr)}\right)^{\frac{(1-\sigma)\rho}{1-\delta(1-\rho)}}\left(\frac{X(i,z,2005)}{Y(i,2005)}\right)^{\frac{(1-\delta)(1-\rho)}{1-\delta(1-\rho)}}, \quad (35)$$

$$\beta(i)\Pi(i,sr) = \left(\frac{R(i,sr)}{\sum_i R(i,sr)}\right)^{\frac{1}{1-\sigma}} \quad (36)$$

System (34)-(36) is a system of $3\times N$ equations and $3\times N$ unknowns, which include the $2\times N$ SR multilateral resistances and the N preference parameters $\beta(i)$. As usual, solving system (34)-(36) requires a normalization. Our choice is

$$\sum_i \Pi(i)^{1-\sigma}=1=\sum_i\left[\frac{R(i)}{\sum_i R(i)}\beta(i)^{\sigma-1}\right]. \quad (37)$$

Finally, to solve system (34)-(36) we use initial output data, $R(i,sr)$, lagged trade data, $X(i,z,2005)$, and lagged output data, $Y(i,2005)$. In addition, we need values for the short run and for the long run bilateral trade costs, as well as for the parameters ψ_i, σ, δ, and ρ.

- $\psi(i)$ is calibrated as described above, i.e., $\psi(i) = E(i, 2006)/Y(i, 2006)$.
- $\sigma = 7$ is a representative value for the elasticity of substitution from the existing trade literature, e.g., see Head and Mayer (2014).
- As discussed in the main text, $\delta = 0.061$ is from Anderson et al. (2015).
- The estimate of the bilateral trade costs and the efficiency parameter $\rho = 0.242$ come from the most preferred structural specification from the empirical analysis in Section 4.3.

The solution to system (34)-(36) subject to normalization (37) delivers estimates for the SR multilateral resistances as well as for the preference parameters $\beta(i)$. In addition, using the estimates of the inward SR multilateral resistance, we also obtain the SR ideal consumer price index $P(i,sr) = \breve{P}(i,sr)\left(\frac{\psi(i)R(i,sr)}{\sum_i R(i,sr)}\right)^{\frac{(1-\delta)(1-\rho)}{(\sigma-1)\rho}}$.

2. Obtain LR multilateral resistances and endogenous $C(i)$s in the LR equilibrium by setting $\rho = 1$ and by solving the following LR gravity system:

$$\Pi(i,lr)^{(1-\sigma)} = \sum_z \frac{\psi(i)C(z,lr)R(z,sr)}{\sum_z \psi(z)C(z,lr)R(z,sr)}\left(\frac{t(i,z,sr)}{P(z,lr)}\right)^{(1-\sigma)}, \quad (38)$$

$$P(z,lr)^{(1-\sigma)} = \sum_i \frac{C(i,lr)R(i,sr)}{\sum_i C(i,lr)R(i,sr)}\left(\frac{t(i,z,sr)}{\Pi(i,lr)}\right)^{(1-\sigma)}, \quad (39)$$

$$C(i,lr)\hat{\beta}(i)\Pi(i,lr) = \left(\frac{C(i,lr)R(i,sr)}{\sum_i C(i,lr)R(i,sr)}\right)^{\frac{1}{1-\sigma}}. \quad (40)$$

System (38)-(40) is a system of $3\times N$ equations and $3\times N$ unknowns, which include the $2\times N$ LR multilateral resistances and the N endogenous $C(i,lr)$.[44] The $3\times N$ equations have to be solved simultaneously. The only new vector of parameters needed

[44]Equation (38) contains $\psi(z)$ weights in the denominator as a result of closing the model by relating expenditures to income via $E(z) = \psi(z)Y(z)$. Global adding up is automatically met in the initial equilibrium, hence the $\psi(z)$ weights are omitted in the denominator of (35). Global adding up $\sum_z E(z)^1 = Y$ in the

to solve the LR gravity system is the vector of $\hat{\beta}(i)$'s. These values are denoted with '$\hat{}$' because they come directly from the baseline solution of the SR gravity system in Step 1.

The solution to system (38)-(40) delivers estimates for the LR multilateral resistances as well as for the endogenous LR price indexes C(i,lr). In this case, the CES price index coincides with the inward multilateral resistance.

3. Construct percentage changes between real expenditure in the short run vs. long run for each country in our sample:

$$\frac{E(i,sr)/P(i,sr)}{E(i,lr)/P(i,lr)} \times 100 = \frac{1}{P(i,sr)} \frac{P(i,lr)}{C(i,lr)} \times 100$$

These are the indexes that appear in Table 4 of the main text.

counter-factual equilibrium implies that

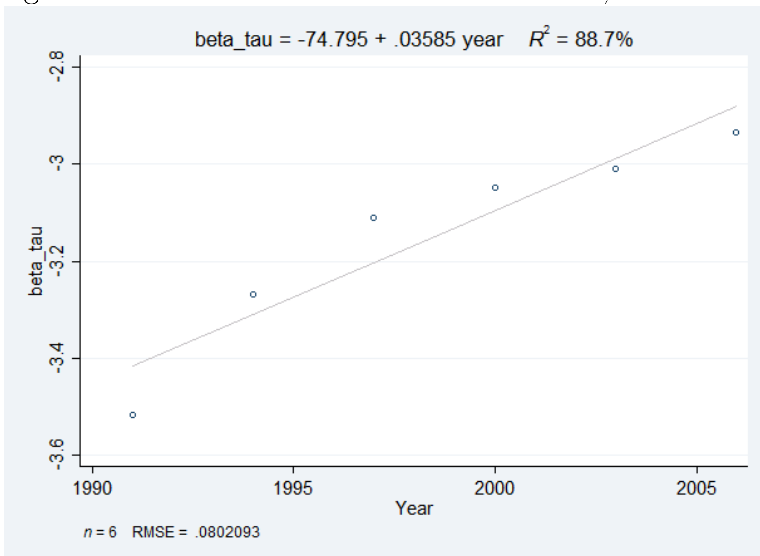
$$E(z)^1 = \frac{\psi(z)C(z)^1 R(z)}{\sum_z \psi(z)C(z)^1 R(z)} Y.$$

Table 5: SR Gravity & Efficiency, Size-adjusted Trade

	OLS Estimator				PPML Estimator			
	Standard	Efficiency	PairFEs	Efficiency2	Standard	Efficiency	PairFEs	Efficiency2
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
LN_DIST	-1.184	-1.185			-0.711	-0.723		
	$(0.049)^{**}$	$(0.049)^{**}$			$(0.066)^{**}$	$(0.067)^{**}$		
CNTG	-0.047	-0.048			0.559	0.554		
	(0.189)	(0.189)			$(0.150)^{**}$	$(0.151)^{**}$		
CLNY	0.460	0.459			0.060	0.055		
	$(0.159)^{**}$	$(0.159)^{**}$			(0.122)	(0.121)		
LANG	0.782	0.782			0.537	0.541		
	$(0.107)^{**}$	$(0.107)^{**}$			$(0.117)^{**}$	$(0.117)^{**}$		
FTA	0.413	0.406	0.165	0.147	0.122	0.043	0.321	0.108
	$(0.062)^{**}$	$(0.062)^{**}$	$(0.041)^{**}$	$(0.041)^{**}$	$(0.064)^{+}$	(0.070)	$(0.066)^{**}$	$(0.063)^{+}$
LN_TARIFF	-1.723	-1.704	-1.311	-1.283	-8.345	-7.981	-2.545	-1.420
	$(0.443)^{**}$	$(0.442)^{**}$	$(0.308)^{**}$	$(0.306)^{**}$	$(0.757)^{**}$	$(0.794)^{**}$	$(0.398)^{**}$	$(0.326)^{**}$
INTL_BRDR	-3.235	-3.733			-3.178	-3.501		
	$(0.299)^{**}$	$(0.324)^{**}$			$(0.179)^{**}$	$(0.174)^{**}$		
INTL_BRDR_1991		0.215		0.231		0.168		0.148
		$(0.091)^{*}$		$(0.092)^{*}$		$(0.027)^{**}$		$(0.018)^{**}$
INTL_BRDR_1994		0.462		0.511		0.358		0.316
		$(0.098)^{**}$		$(0.098)^{**}$		$(0.028)^{**}$		$(0.025)^{**}$
INTL_BRDR_1997		0.622		0.713		0.412		0.450
		$(0.122)^{**}$		$(0.121)^{**}$		$(0.048)^{**}$		$(0.032)^{**}$
INTL_BRDR_2000		0.685		0.812		0.472		0.528
		$(0.132)^{**}$		$(0.131)^{**}$		$(0.060)^{**}$		$(0.039)^{**}$
INTL_BRDR_2003		0.722		0.864		0.511		0.597
		$(0.149)^{**}$		$(0.144)^{**}$		$(0.064)^{**}$		$(0.041)^{**}$
INTL_BRDR_2006		0.799		0.965		0.440		0.663
		$(0.160)^{**}$		$(0.158)^{**}$		$(0.070)^{**}$		$(0.039)^{**}$
N	18345	18345	18344	18344	18928	18928	18928	18928
R^2	0.801	0.801	0.892	0.893	0.974	0.975		

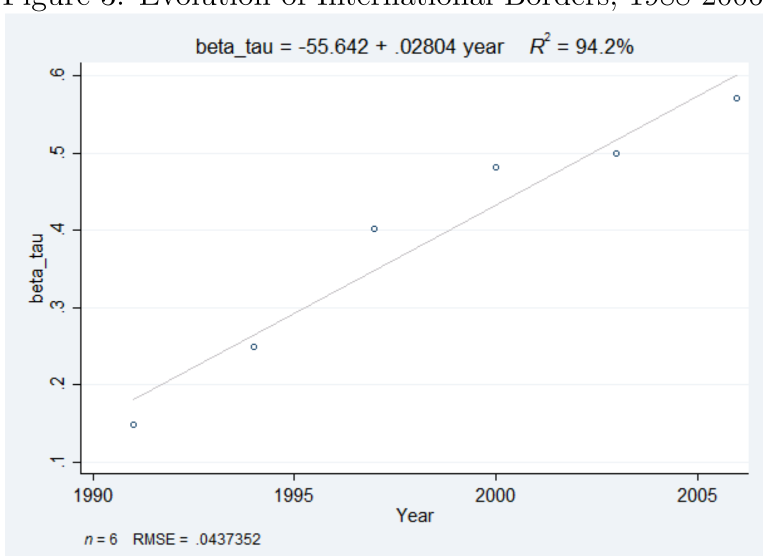
Notes: This table reproduces the main results from Table 1 with size-adjusted trade $X_{i,z,\tau}/Y_{i,\tau}$ as dependent variable. The estimates from columns (1)-(4) are obtained with the OLS estimator. Columns (1) and (2) reproduce the estimates with standard gravity variables from columns (1) and (2) of Table 1. Columns (3) and (4) reproduce the estimates with pair fixed effects from columns (4) and (5) of Table 1. Columns (5)-(8) of this table reproduce the estimates from columns (1)-(4) of the same table with the PPML estimator. All results are obtained with exporter-time and importer-time fixed effects, whose estimates are omitted for brevity. Standard errors are clustered by country pair and are reported in parentheses $^{+}$ $p < 0.10$, * $p < .05$, ** $p < .01$. See text for further details.

Figure 2: Evolution of International Borders, 1988-2006.



Note: This figure plots the evolution of the international border estimates from column (2) of Table 1, which are obtained with OLS and standard gravity variables, over time. The figure also reports the slope of the fitted line, which corresponds to the parameter b_τ from the main text.

Figure 3: Evolution of International Borders, 1988-2006.



Note: This figure plots the evolution of the international border estimates from column (5) of Table 2, which are obtained with the PPML estimator and pair fixed effects, over time. The figure also reports the slope of the fitted line, which corresponds to the parameter b_τ from the main text.

Table 6: SR Gravity & Efficiency, All Years: 1988-2006

	OLS Estimator				PPML Estimator			
	Standard	Efficiency	PairFEs	Efficiency2	Standard	Efficiency	PairFEs	Efficiency2
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
LN_DIST	-1.186	-1.187			-0.643	-0.656		
	$(0.049)^{**}$	$(0.049)^{**}$			$(0.065)^{**}$	$(0.065)^{**}$		
CNTG	-0.036	-0.036			0.492	0.500		
	(0.189)	(0.189)			$(0.145)^{**}$	$(0.143)^{**}$		
CLNY	0.457	0.457			-0.056	-0.070		
	$(0.158)^{**}$	$(0.158)^{**}$			(0.110)	(0.110)		
LANG	0.773	0.773			0.346	0.362		
	$(0.105)^{**}$	$(0.106)^{**}$			$(0.137)^{*}$	$(0.136)^{**}$		
FTA	0.418	0.412	0.170	0.155	0.127	0.072	0.282	0.102
	$(0.062)^{**}$	$(0.062)^{**}$	$(0.037)^{**}$	$(0.036)^{**}$	(0.117)	(0.113)	$(0.073)^{**}$	(0.065)
LN_TARIFF	-1.513	-1.497	-1.114	-1.091	-7.444	-6.894	-4.391	-2.383
	$(0.378)^{**}$	$(0.377)^{**}$	$(0.259)^{**}$	$(0.257)^{**}$	$(1.092)^{**}$	$(1.157)^{**}$	$(0.631)^{**}$	$(0.539)^{**}$
INTL_BRDR	-3.229	-3.746			-2.652	-3.043		
	$(0.297)^{**}$	$(0.323)^{**}$			$(0.154)^{**}$	$(0.153)^{**}$		
INTL_BRDR_1990		0.183		0.195		0.180		0.137
		$(0.061)^{**}$		$(0.060)^{**}$		$(0.022)^{**}$		$(0.016)^{**}$
INTL_BRDR_1992		0.343		0.381		0.226		0.170
		$(0.088)^{**}$		$(0.091)^{**}$		$(0.023)^{**}$		$(0.018)^{**}$
INTL_BRDR_1994		0.463		0.515		0.324		0.250
		$(0.098)^{**}$		$(0.098)^{**}$		$(0.028)^{**}$		$(0.024)^{**}$
INTL_BRDR_1996		0.548		0.633		0.382		0.326
		$(0.115)^{**}$		$(0.116)^{**}$		$(0.039)^{**}$		$(0.032)^{**}$
INTL_BRDR_1998		0.657		0.769		0.479		0.459
		$(0.126)^{**}$		$(0.122)^{**}$		$(0.047)^{**}$		$(0.037)^{**}$
INTL_BRDR_2000		0.689		0.816		0.543		0.490
		$(0.132)^{**}$		$(0.130)^{**}$		$(0.055)^{**}$		$(0.042)^{**}$
INTL_BRDR_2002		0.653		0.789		0.455		0.459
		$(0.146)^{**}$		$(0.139)^{**}$		$(0.057)^{**}$		$(0.041)^{**}$
INTL_BRDR_2004		0.723		0.883		0.486		0.538
		$(0.152)^{**}$		$(0.148)^{**}$		$(0.062)^{**}$		$(0.042)^{**}$
INTL_BRDR_2006		0.807		0.975		0.509		0.585
		$(0.160)^{**}$		$(0.157)^{**}$		$(0.066)^{**}$		$(0.041)^{**}$
N	49916	49916	49916	49916	51376	51376	51376	51376
R^2	0.882	0.882	0.936	0.936				

Notes: This table reproduces the main results from Table 1 with data for all years. The estimates from columns (1)-(4) are obtained with the OLS estimator. Columns (1) and (2) reproduce the estimates with standard gravity variables from columns (1) and (2) of Table 1. Columns (3) and (4) reproduce the estimates with pair fixed effects from columns (4) and (5) of Table 1. Columns (5)-(8) of this table reproduce the estimates from columns (1)-(4) of the same table with the PPML estimator. All results are obtained with exporter-time and importer-time fixed effects, whose estimates are omitted for brevity. In addition, also for brevity, we have omitted the estimates on the bilateral border dummies for the odd years in the sample. The omitted estimates are available by request. Standard errors are clustered by country pair and are reported in parentheses $^{+}$ $p < 0.10$, * $p < .05$, ** $p < .01$. See text for further details.

Table 7: SR Gravity & Efficiency, All Years: 1988-2006

	(1) PuzzleOLS	(2) PuzzlePPML
LN_DIST	-1.184	-0.634
	(0.057)**	(0.074)**
LN_DIST_1990	-0.005	0.016
	(0.027)	(0.021)
LN_DIST_1992	-0.061	0.000
	(0.031)*	(0.023)
LN_DIST_1994	-0.027	0.012
	(0.040)	(0.023)
LN_DIST_1996	0.032	0.029
	(0.039)	(0.028)
LN_DIST_1998	0.008	-0.037
	(0.039)	(0.032)
LN_DIST_2000	0.006	-0.032
	(0.038)	(0.037)
LN_DIST_2002	0.013	-0.041
	(0.041)	(0.034)
LN_DIST_2004	0.004	-0.051
	(0.041)	(0.034)
LN_DIST_2006	0.033	-0.063
	(0.042)	(0.036)+
CNTG	-0.035	0.501
	(0.189)	(0.142)**
CLNY	0.458	-0.072
	(0.158)**	(0.110)
LANG	0.772	0.365
	(0.105)**	(0.136)**
FTA	0.425	0.072
	(0.065)**	(0.113)
LN_TARIFF	-1.509	-6.953
	(0.379)**	(1.167)**
INTL_BRDR	-3.754	-3.081
	(0.336)**	(0.164)**
INTL_BRDR_1990	0.200	0.152
	(0.097)*	(0.055)**
INTL_BRDR_1992	0.543	0.225
	(0.129)**	(0.056)**
INTL_BRDR_1994	0.549	0.300
	(0.159)**	(0.055)**
INTL_BRDR_1996	0.443	0.325
	(0.167)**	(0.076)**
INTL_BRDR_1998	0.628	0.546
	(0.170)**	(0.091)**
INTL_BRDR_2000	0.668	0.599
	(0.174)**	(0.108)**
INTL_BRDR_2002	0.608	0.528
	(0.192)**	(0.094)**
INTL_BRDR_2004	0.707	0.579
	(0.201)**	(0.089)**
INTL_BRDR_2006	0.693	0.624
	(0.209)**	(0.091)**
N	49916	51376
R^2	0.882	

Notes: This table reproduces the results from column (3) of Table 1, where we use our theory to resolve the 'distance puzzle' of trade, with data for all years. The estimates in column (1) of this table are obtained with the OLS estimator and the estimates in column (2) are obtained with the PPML estimator. In each case we allow for time-varying distance effects. All results are obtained with exporter-time and importer-time fixed effects, whose estimates are omitted for brevity. In addition, also for brevity, we have omitted the estimates on the time-varying distance variables and the estimates on the bilateral border dummies for the odd years in the sample for each group of countries. The omitted estimates are available by request. Standard errors are clustered by country pair and are reported in parentheses $^+ p < 0.10$, $^* p < .05$, $^{**} p < .01$. See text for further details.

Table 8: SR Gravity & Efficiency, All Years: 1988-2006

	(1) DvlpmntOLS	(2) DvlpmntPPML
FTA	0.148	0.171
	(0.036)**	(0.049)**
LN_TARIFF	-0.870	-1.826
	(0.227)**	(0.435)**
INTL_BRDR_HIGH_1990	0.329	0.341
	(0.109)**	(0.041)**
INTL_BRDR_HIGH_1992	0.572	0.636
	(0.163)**	(0.085)**
INTL_BRDR_HIGH_1994	0.603	0.774
	(0.185)**	(0.075)**
INTL_BRDR_HIGH_1996	0.759	0.882
	(0.253)**	(0.147)**
INTL_BRDR_HIGH_1998	0.998	1.068
	(0.250)**	(0.184)**
INTL_BRDR_HIGH_2000	1.023	1.019
	(0.258)**	(0.228)**
INTL_BRDR_HIGH_2002	0.904	0.937
	(0.283)**	(0.197)**
INTL_BRDR_HIGH_2004	1.023	1.044
	(0.289)**	(0.187)**
INTL_BRDR_HIGH_2006	1.300	1.168
	(0.304)**	(0.207)**
INTL_BRDR_LOW_1990	0.252	0.339
	(0.160)	(0.067)**
INTL_BRDR_LOW_1992	0.636	0.714
	(0.215)**	(0.098)**
INTL_BRDR_LOW_1994	0.946	1.166
	(0.212)**	(0.123)**
INTL_BRDR_LOW_1996	1.116	1.144
	(0.194)**	(0.132)**
INTL_BRDR_LOW_1998	1.132	1.488
	(0.257)**	(0.160)**
INTL_BRDR_LOW_2000	1.232	1.565
	(0.271)**	(0.172)**
INTL_BRDR_LOW_2002	1.323	1.710
	(0.296)**	(0.193)**
INTL_BRDR_LOW_2004	1.478	2.079
	(0.327)**	(0.189)**
INTL_BRDR_LOW_2006	1.528	2.133
	(0.347)**	(0.193)**
N	49914	51376
R^2	0.956	

Notes: This table reproduces the results from column (6) of Table 1, which distinguished between capacity improvement for the developed vs. developing countries in our sample, with data for all years. The estimates in column (1) of Table 8 are obtained with the OLS estimator and the estimates in column (2) of Table 8 are obtained with the PPML estimator. In each case we allow for different efficiency improvements depending on whether a country is developed or developing. All results are obtained with exporter-time and importer-time fixed effects, whose estimates are omitted for brevity. In addition, also for brevity, we have omitted the estimates on the bilateral border dummies for the odd years in the sample for each group of countries. The omitted estimates are available by request. Standard errors are clustered by country pair and are reported in parentheses $^{+}$ $p < 0.10$, * $p < .05$, ** $p < .01$. See text for further details.

Table 9: SR Gravity & Efficiency, Aggregate WIOD Data

	OLS Estimator				PPML Estimator			
	Standard	Efficiency	PairFEs	Efficiency2	Standard	Efficiency	PairFEs	Efficiency2
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
LN_DIST	-1.267	-1.268			-0.845	-0.846		
	(0.055)**	(0.055)**			(0.042)**	(0.042)**		
CNTG	0.343	0.342			0.317	0.317		
	(0.112)**	(0.112)**			(0.106)**	(0.106)**		
CLNY	0.524	0.524			0.244	0.247		
	(0.134)**	(0.134)**			(0.103)*	(0.103)*		
LANG	-0.034	-0.034			0.393	0.395		
	(0.122)	(0.122)			(0.104)**	(0.105)**		
RTA	0.406	0.402	0.172	0.156	0.180	0.180	0.121	0.023
	(0.081)**	(0.081)**	(0.062)**	(0.062)*	(0.065)**	(0.065)**	(0.043)**	(0.045)
INTL_BRDR	-3.553	-3.909			-3.568	-3.621		
	(0.247)**	(0.288)**			(0.107)**	(0.107)**		
INTL_BRDR_2002		0.075		0.081		-0.053		-0.033
		(0.038)*		(0.038)*		(0.011)**		(0.009)**
INTL_BRDR_2004		0.288		0.309		0.008		0.046
		(0.075)**		(0.077)**		(0.018)		(0.016)**
INTL_BRDR_2006		0.410		0.433		0.046		0.104
		(0.095)**		(0.097)**		(0.020)*		(0.018)**
INTL_BRDR_2008		0.503		0.526		0.065		0.147
		(0.103)**		(0.105)**		(0.024)**		(0.020)**
INTL_BRDR_2010		0.487		0.511		0.044		0.130
		(0.107)**		(0.110)**		(0.025)+		(0.022)**
INTL_BRDR_2012		0.577		0.609		0.096		0.185
		(0.120)**		(0.123)**		(0.024)**		(0.021)**
INTL_BRDR_2014		0.548		0.581		0.097		0.189
		(0.126)**		(0.127)**		(0.026)**		(0.021)**
N	14792	14792	14792	14792	14792	14792	14792	14792
R^2	0.890	0.891	0.978	0.978	1.000	1.000		

Notes: This table reproduces the main results from Table 1 with the latest edition of the WIOD data, as described in the data section. The estimates from columns (1)-(4) are obtained with the OLS estimator. Columns (1) and (2) reproduce the estimates with standard gravity variables from columns (1) and (2) of Table 1. Columns (3) and (4) reproduce the estimates with pair fixed effects from columns (4) and (5) of Table 1. Columns (5)-(8) of this table reproduce the estimates from columns (1)-(4) of the same table with the PPML estimator. All results are obtained with exporter-time and importer-time fixed effects, whose estimates are omitted for brevity. Standard errors are clustered by country pair and are reported in parentheses $^{+}$ $p < 0.10$, * $p < .05$, ** $p < .01$. See text for further details.

Table 10: SR Gravity & Efficiency, Sectoral WIOD Data

	CropAnimal		ForestryLogging		FishingAquaculture		MiningQuarrying		Manufacturing		Services	
	PairFEs	SR_PairFEs	PairFEs	SR_PairFEs	PairFEs	SR_PairFEs	PairFEs	SR_PairFEs	PairFEs	SR_PairFEs	PairFEs	SR_PairFEs
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
RTA	0.130	0.112	0.202	0.186	0.301	0.283	0.136	0.116	0.159	0.141	0.181	0.164
	$(0.072)^{+}$	(0.071)	$(0.078)^{**}$	$(0.077)^{*}$	$(0.085)^{**}$	$(0.084)^{**}$	$(0.079)^{+}$	(0.077)	$(0.059)^{**}$	$(0.058)^{*}$	$(0.067)^{**}$	$(0.066)^{*}$
INTL_BRDR_2002		0.106		0.083		0.091		0.155		0.098		0.087
		$(0.046)^{*}$		$(0.048)^{+}$		$(0.044)^{*}$		$(0.047)^{**}$		$(0.040)^{*}$		$(0.038)^{*}$
INTL_BRDR_2004		0.309		0.331		0.293		0.400		0.322		0.324
		$(0.079)^{**}$		$(0.087)^{**}$		$(0.089)^{**}$		$(0.086)^{**}$		$(0.075)^{**}$		$(0.082)^{**}$
INTL_BRDR_2006		0.445		0.480		0.458		0.568		0.459		0.443
		$(0.098)^{**}$		$(0.115)^{**}$		$(0.113)^{**}$		$(0.107)^{**}$		$(0.098)^{**}$		$(0.101)^{**}$
INTL_BRDR_2008		0.562		0.544		0.586		0.671		0.550		0.552
		$(0.106)^{**}$		$(0.118)^{**}$		$(0.131)^{**}$		$(0.117)^{**}$		$(0.108)^{**}$		$(0.108)^{**}$
INTL_BRDR_2010		0.579		0.525		0.535		0.641		0.563		0.526
		$(0.123)^{**}$		$(0.145)^{**}$		$(0.140)^{**}$		$(0.120)^{**}$		$(0.113)^{**}$		$(0.112)^{**}$
INTL_BRDR_2012		0.680		0.613		0.605		0.746		0.651		0.618
		$(0.132)^{**}$		$(0.165)^{**}$		$(0.153)^{**}$		$(0.136)^{**}$		$(0.127)^{**}$		$(0.124)^{**}$
INTL_BRDR_2014		0.643		0.566		0.635		0.707		0.638		0.594
		$(0.135)^{**}$		$(0.181)^{**}$		$(0.149)^{**}$		$(0.141)^{**}$		$(0.133)^{**}$		$(0.127)^{**}$
N	14792	14792	14104	14104	14104	14104	14792	14792	14792	14792	14792	14792
R^2	0.970	0.970	0.969	0.969	0.966	0.966	0.972	0.972	0.979	0.979	0.976	0.976

Notes: This table reproduces the main results from Table 1 by capitalizing on the sectoral dimension of the latest edition of the WIOD data, as described in the data section. For brevity, for each sector we focus on reproducing the main specifications with pair fixed effects, which are reported in columns (4) and (5) of Table 1. All results are obtained with the OLS estimator and with exporter-time and importer-time fixed effects, whose estimates are omitted for brevity. Standard errors are clustered by country pair and are reported in parentheses $^{+}$ $p < 0.10$, * $p < .05$, ** $p < .01$. See text for further details.

Table 11: SR Gravity & Efficiency, 3-year Intervals

	(1) Standard	(2) LagTrade	(3) LSDV	(4) LSDV_IV
LN_DIST	-1.184	-0.404		
	(0.049)**	(0.026)**		
CNTG	-0.047	0.019		
	(0.189)	(0.066)		
CLNY	0.460	0.146		
	(0.159)**	(0.058)*		
LANG	0.782	0.238		
	(0.107)**	(0.036)**		
FTA	0.413	0.200	0.111	0.077
	(0.062)**	(0.025)**	(0.033)**	(0.054)
LN_TARIFF	-1.723	-0.802	-0.868	-1.195
	(0.443)**	(0.286)**	(0.260)**	(0.433)**
INTL_BRDR	-3.235	-0.992		
	(0.299)**	(0.105)**		
L.ln_trade		0.651	0.397	0.630
		(0.014)**	(0.017)**	(0.276)*
N	18345	15551	15549	10122
R^2	0.880	0.940	0.953	0.955
$\hat{\rho}$		0.250	0.534	0.273
		(0.015)**	(0.020)**	(0.304)
UnderId χ^2				7.092
p-val				(0.069)
Weak Id χ^2				2.345
p-val				(0.071)
Over Id χ^2				4.056
p-val				(0.131)

Notes: This table uses 3-year interval data to reproduce the results from Table 3 of the main text. All results are obtained with exporter-time and importer-time fixed effects, whose estimates are omitted for brevity. The dependent variable in each specification is the log of nominal bilateral trade. Column (1) reports standard (long run) gravity estimates. The estimates from column (2) are obtained with lagged trade added as a covariate. Columns (3) reproduces the results from column (2) but with pair fixed effects, thus implementing the LSDV estimator. Column (4) implements an IV LSDV estimation. Robust standard errors are reported in parentheses $^{+}$ $p < 0.10$, * $p < .05$, ** $p < .01$. See text for further details.

Table 12: SR Gravity & Efficiency, Size-adjusted Trade

	(1) Standard	(2) LagTrade	(3) LSDV	(4) LSDV_IV
LN_DIST	-1.186	-0.248		
	(0.049)**	(0.016)**		
CNTG	-0.036	0.005		
	(0.189)	(0.039)		
CLNY	0.457	0.092		
	(0.158)**	(0.034)**		
LANG	0.773	0.147		
	(0.105)**	(0.022)**		
FTA	0.418	0.108	0.070	0.029
	(0.062)**	(0.013)**	(0.016)**	(0.017)+
LN_TARIFF	-1.513	-0.348	-0.446	-0.579
	(0.378)**	(0.100)**	(0.118)**	(0.141)**
INTL_BRDR	-3.229	-0.635		
	(0.297)**	(0.064)**		
L.ln_trade_y		0.788	0.614	0.747
		(0.009)**	(0.011)**	(0.107)**
N	49916	46868	46868	35411
R^2	0.802	0.932	0.939	0.940
$\hat{\rho}$		0.202	0.371	0.241
		(0.008)**	(0.011)**	(0.104)*
UnderId χ^2				15.863
p-val				(0.003)
Weak Id χ^2				4.135
p-val				(0.003)
Over Id χ^2				0.921
p-val				(0.820)

Notes: This table uses size-adjusted trade as dependent variable to reproduce the results from Table 3 of the main text. All results are obtained with exporter-time and importer-time fixed effects, whose estimates are omitted for brevity. The dependent variable in each specification is the log of nominal bilateral trade. Column (1) reports standard (long run) gravity estimates. The estimates from column (2) are obtained with lagged trade added as a covariate. Column (3) reproduces the results from column (2) but with pair fixed effects, thus implementing the LSDV estimator. Column (4) implements an IV LSDV estimation. Robust standard errors are reported in parentheses $^{+}$ $p < 0.10$, * $p < .05$, ** $p < .01$. See text for further details.

Table 13: SR Gravity & Efficiency, International Trade Data Only

	(1) Standard	(2) LagTrade	(3) LSDV	(4) LSDV_IV
LN_DIST	-1.210	-0.272		
	(0.040)**	(0.014)**		
CNTG	-0.082	-0.006		
	(0.192)	(0.042)		
CLNY	0.452	0.098		
	(0.163)**	(0.037)**		
LANG	0.761	0.155		
	(0.104)**	(0.023)**		
FTA	0.420	0.116	0.067	0.023
	(0.063)**	(0.014)**	(0.017)**	(0.018)
LN_TARIFF	-1.204	-0.304	-0.439	-0.458
	(0.336)**	(0.098)**	(0.118)**	(0.162)**
L.ln_trade		0.772	0.613	0.889
		(0.008)**	(0.011)**	(0.174)**
N	48928	45932	45932	34697
R^2	0.879	0.955	0.960	0.957
$\hat{\rho}$		0.217	0.373	0.105
		(0.000)**	(0.011)**	(0.165)
UnderId χ^2				10.190
p-val				(0.070)
Weak Id χ^2				1.720
p-val				(0.143)
Over Id χ^2				6.875
p-val				(0.143)

Notes: This table uses international trade only as the dependent variable to reproduce the results from Table 3 of the main text. All results are obtained with exporter-time and importer-time fixed effects, whose estimates are omitted for brevity. The dependent variable in each specification is the log of nominal bilateral trade. Column (1) reports standard (long run) gravity estimates. The estimates from column (2) are obtained with lagged trade added as a covariate. Column (3) reproduces the results from column (2) but with pair fixed effects, thus implementing the LSDV estimator. Column (4) implements an IV LSDV estimation. Robust standard errors are reported in parentheses $^{+}$ $p < 0.10$, * $p < .05$, ** $p < .01$. See text for further details.

Table 14: SR Gravity & Efficiency, Arellano-Bond

	(1) All Years	(2) 3-Year Intervals
LN_DIST	-0.856	-0.460
	(0.064)**	(0.194)*
CNTG	0.020	0.024
	(0.117)	(0.101)
CLNY	0.324	0.162
	(0.100)**	(0.111)
LANG	0.544	0.277
	(0.077)**	(0.141)*
FTA	0.248	0.184
	(0.038)**	(0.047)**
LN_TARIFF	-0.927	-0.694
	(0.228)**	(0.340)*
INTL_BRDR	-2.352	-1.140
	(0.268)**	(0.578)*
L.LN_TRADE	0.254	0.603
	(0.045)**	(0.161)**
N	46868	15551
Over Id χ^2	168.99	17.530
p-val	(0.025)	(0.041)
AR(1)	-10.268	-4.514
χ^2 p-val	(0.000)	(0.000)
AR(2)	1.302	2.293
χ^2 p-val	(0.193)	(0.022)
AR(3)		-0.476
χ^2 p-val		(0.634)

Notes: This table reports results from the structural investment approach to test SR gravity theory with the Arellano-Bond estimator. All estimates are obtained with exporter-time and importer-time fixed effects, whose estimates are omitted for brevity. The dependent variable in each specification is the log of nominal bilateral trade. Column (1) implements the Arellano-Bond estimator with data for all years. Column (2) uses 3-year interval data. Robust standard errors are reported in parentheses $^{+}$ $p < 0.10$, * $p < .05$, ** $p < .01$. See text for further details.

Table 15: SR Gravity & Efficiency, PPML Estimations

	3-year Interval Data			Data All Years		
	Standard	SRG	SRG_LSDV	Standard	SRG	SRG_LSDV
	(1)	(2)	(3)	(4)	(5)	(6)
LN_DIST	-0.647	-0.073		-0.643	-0.028	
	(0.065)**	(0.008)**		(0.065)**	(0.002)**	
CNTG	0.489	0.021		0.491	0.008	
	(0.148)**	(0.018)		(0.145)**	(0.007)	
CLNY	-0.049	-0.018		-0.056	-0.007	
	(0.109)	(0.021)		(0.110)	(0.007)	
LANG	0.325	0.006		0.346	0.005	
	(0.139)*	(0.016)		(0.137)*	(0.006)	
FTA	0.142	0.060	0.059	0.126	0.015	0.010
	(0.123)	(0.013)**	(0.024)*	(0.117)	(0.004)**	(0.008)
LN_TARIFF	-7.440	0.524	-0.539	-7.441	0.166	-0.209
	(1.167)**	(0.150)**	(0.138)**	(1.091)**	(0.055)**	(0.057)**
INTL_BRDR	-2.636	-0.124		-2.651	-0.048	
	(0.154)**	(0.025)**		(0.154)**	(0.008)**	
L_trade		0.913	0.691		0.967	0.869
		(0.007)**	(0.014)**		(0.002)**	(0.006)**
N	18928	15665	15657	51376	47236	47231
$\hat{\rho}$		-0.033	0.205		0.031	0.124
		(0.007)**	(0.015)**		(0.002)**	(0.006)**

Notes: This table uses the PPML estimator to reproduce some of the results from Table 3 of the main text. All results are obtained with exporter-time and importer-time fixed effects, whose estimates are omitted for brevity. The dependent variable in each specification is nominal bilateral trade. The estimates from columns (1)-(3) are obtained with 3-year interval data and the estimates from columns (4)-(6) use data for all years. Column (1) reports standard (long run) gravity estimates. The estimates from column (2) are obtained with lagged trade added as a covariate. Column (3) reproduces the results from column (2) but with pair fixed effects, thus implementing the LSDV estimator. Columns (4)-(6) reproduce the results from columns (1)-(3). Robust standard errors are reported in parentheses $^{+}$ $p < 0.10$, * $p < .05$, ** $p < .01$. See text for further details.

Table 16: SR Gravity & Efficiency, Aggregate WIOD Data

	(1) Standard	(2) SRG_OLS	(3) LSDV	(4) SRG_LSDV
LN_DIST	-1.267	-0.144		
	(0.055)**	(0.014)**		
CNTG	0.343	0.039		
	(0.112)**	(0.017)*		
CLNY	0.524	0.066		
	(0.134)**	(0.025)**		
LANG	-0.034	-0.009		
	(0.122)	(0.023)		
RTA	0.406	0.110	0.172	0.112
	(0.081)**	(0.016)**	(0.062)**	(0.051)*
INTL_BRDR	-3.553	-0.470		
	(0.247)**	(0.045)**		
L.ln_trade		0.870		0.363
		(0.009)**		(0.022)**
N	14792	12943	14792	12943
R^2	0.890	0.973	0.978	0.982
$\hat{\rho}$		0.070		0.598
		(0.009)**		(0.024)**

Notes: This table uses the latest edition of the WIOD data and reproduces the results from Table 3 of the main text. All results are obtained with exporter-time and importer-time fixed effects, whose estimates are omitted for brevity. The dependent variable in each specification is the log of nominal bilateral trade. Column (1) reports standard (long run) gravity estimates. The estimates from column (2) are obtained with lagged trade added as a covariate. Columns (3) and (4) reproduce the results from columns (1) and (2) but with pair fixed effects, thus implementing the LSDV estimator. Robust standard errors are reported in parentheses $^{+}$ $p < 0.10$, * $p < .05$, ** $p < .01$. See text for further details.

Table 17: SR Gravity & Efficiency, Sectoral WIOD Data

	CropAnimal		ForestryLogging		FishingAquaculture		MiningQuarrying		Manufacturing		Services	
	SR_OLS	SR_LSDV	SR_OLS	SR_LSDV	SR_OLS	SR_LSDV	SR_OLS	SR_LSDV	SR_OLS	SR_LSDV	SR_OLS	SR_LSDV
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
L.ln_trade	0.827	0.288	0.841	0.327	0.819	0.303	0.844	0.318	0.850	0.327	0.870	0.374
	(0.010)**	(0.021)**	(0.008)**	(0.021)**	(0.010)**	(0.019)**	(0.011)**	(0.024)**	(0.009)**	(0.021)**	(0.008)**	(0.020)**
LN_DIST	-0.227		-0.223		-0.227		-0.194		-0.180		-0.140	
	(0.019)**		(0.019)**		(0.019)**		(0.019)**		(0.015)**		(0.014)**	
CNTG	0.098		0.121		0.120		0.047		0.046		0.031	
	(0.023)**		(0.029)**		(0.029)**		(0.024)*		(0.018)*		(0.017)$^{+}$	
CLNY	0.069		0.112		0.110		0.098		0.070		0.064	
	(0.028)*		(0.038)**		(0.034)**		(0.033)**		(0.026)**		(0.025)**	
LANG	-0.013		-0.068		-0.054		-0.028		-0.002		-0.011	
	(0.027)		(0.033)*		(0.032)$^{+}$		(0.029)		(0.024)		(0.024)	
RTA	0.110	0.122	0.110	0.142	0.123	0.183	0.098	0.118	0.107	0.112	0.106	0.111
	(0.022)**	(0.066)$^{+}$	(0.026)**	(0.076)$^{+}$	(0.026)**	(0.074)*	(0.021)**	(0.067)$^{+}$	(0.017)**	(0.051)*	(0.017)**	(0.053)*
INTL_BRDR	-0.597		-0.580		-0.658		-0.512		-0.438		-0.519	
	(0.060)**		(0.068)**		(0.070)**		(0.059)**		(0.047)**		(0.046)**	
N	12943	12943	12341	12341	12341	12341	12943	12943	12943	12943	12943	12943
R^2	0.961	0.974	0.961	0.974	0.956	0.971	0.965	0.976	0.974	0.983	0.972	0.981
$\hat{\rho}$	0.113	0.679	0.099	0.637	0.121	0.663	0.095	0.647	0.090	0.637	0.069	0.586
	(0.010)**	(0.022)$^{+}$	(0.008)**	(0.022)$^{+}$	(0.010)**	(0.020)*	(0.011)**	(0.026)$^{+}$	(0.009)**	(0.022)*	(0.008)**	(0.022)*

Notes: This table reproduces the main results from Table 3 by capitalizing on the sectoral dimension of the latest edition of the WIOD data, as described in the data section. For brevity, for each sector we focus on reproducing the main specifications with lagged trade and standard gravity variables and with lagged trade and pair fixed effects. All results are obtained with the OLS estimator and with exporter-time and importer-time fixed effects, whose estimates are omitted for brevity. Robust standard errors are reported in parentheses $^{+}$ $p < 0.10$, * $p < .05$, ** $p < .01$. See text for further details.