NBER WORKING PAPER SERIES

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THE ROLE OF INTERMEDIATE INPUT TRADE

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Working Paper 9020
http://www.nber.org/papers/w9020

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
June 2002

We wish to thank, without implication, Jack Barron, Tim Cason, Michael Ferrantino, John Ries, and seminar participants at Purdue University for helpful comments; Cathy Buffington and Arnold Rezneck at the Center for Economic Analysis for data assistance; and Purdue CIBER for financial support. The views expressed herein are those of the authors and not necessarily those of the National Bureau of Economic Research, the U.S. International Trade Commission or any of its individual Commissioners.

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June 2002
JEL No. F12, F15, R3

ABSTRACT

We show that "home bias" in trade patterns will arise endogenously due to the co-location decisions of intermediate and final goods producers. Our model identifies four implications of home bias arising out of specialized industrial demands. Regions absorb different bundles of goods. Buyers and sellers of intermediate goods co-locate. Intermediate input trade is highly localized. The effect of spatial frictions on trade are magnified. These implications are examined and confirmed using a unique data source that matches the detailed subnational geography of shipments to the characteristics of the shipping establishments. Our results broaden the measurement and interpretation of home bias, and provide new evidence on the role of intermediate inputs in concentrating production.

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I. Introduction

How does trade respond to geographic frictions? This question is distinct from, but related to, work showing how *much* trade responds to frictions. For example, several authors beginning with McCallum(1995) have demonstrated that nations trade far less than simple models predict. Wolf (1999) shows that home bias occurs even within national borders, as shipments within US states far exceed shipments across state boundaries.

What explains the large degree of apparent home bias in consumption? In answering this question, few papers step outside the simple gravity equation framework, or address any phenomena other than the level of trade.[1] Home bias itself is given exogenously, determined either by preferences or by some hard to measure costs of trade. This ignores the general equilibrium effect of frictions on firms' location choices, and in particular the geographic concentration of production.

In this paper we show how home bias might arise endogenously and derive observable implications for production and absorption patterns, and the level and composition of trade. We examine, and confirm, these hypotheses using data on establishment-level shipments drawn from the private sample 1997 U.S. Commodity Flow Survey (CFS) and the U.S. Census of Manufactures (CoM).

In our model, an extension of Krugman and Venables (1996), small trade costs lead to co-location between firms producing intermediate goods and the firms that intensively demand those intermediates. Consumers have identical preferences but industrial demands fall more heavily on goods that are locally available. And they are locally available because firms move to minimize trade costs. In this sense, demand becomes endogenously "home biased" – home (consumer plus industrial) demand is greatest for goods produced at home. This general equilibrium location response has three observable effects. First, absorption varies over space in a manner related to the structure of production. Second, frictions alter the composition of trade over space – intermediate goods are traded locally, while final goods are shipped long distances.

[1] Notable exceptions are Evans (2001) who augments the simple model with fixed costs of trade, and Haveman and Hummels (2001), who consider home bias when home and foreign varieties are not differentiated. These explanations provide, respectively, implications for the number of firms who export, and the number of sources from which importers buy.

Third, trade barriers can have a far larger effect on trade than that supposed by the simple models typically employed in the literature.

Our establishment-level data differ considerably from aggregate measures of cross-border trade commonly employed in the home bias literature. They provide tremendous detail on the commodity and geographic composition of shipments, and they allow us to link this detail to the characteristics of the firms doing the shipping. The tradeoff is that we cannot replicate certain exercises in the literature; in particular, we cannot address the "true" magnitude of US-Canada border costs. We are able, however, to examine joint hypotheses about production and trade within the United States that provide insights into why we see home bias in shipment patterns.

In addition to the literature on home bias, this paper is related, and contributes, to literatures on agglomeration economies and home market effects in trade. Of course, we are not the first to suggest the existence of industrial agglomeration. Our emphasis lies in showing how production concentration may help explain apparent home bias in consumption and trade patterns. Further, most studies of agglomeration focus on production location, while ignoring shipment implications. Our combined use of output and shipment data provides unique empirical insights into the role that intermediate inputs play in concentrating production.

Some of our insights are related to the literature on home market effects in trade, which addresses the responses of output to locally idiosyncratic demand for goods.[2] Unlike this literature, we endogenize demand variation, and provide related empirical implications.

Finally, our work most directly contributes to the literature on trade barriers and home bias. This literature typically addresses frictions through the lens of a gravity model. Nations produce (or, equivalently, are endowed with) final goods that are differentiated by origin. Trade barriers induce substitution between home and foreign varieties in proportion to the size of the barrier, and the elasticity of substitution between differentiated goods. Identifying these parameters has become a common focus of many papers in the literature. Several authors attempt to identify the trade barriers that make

[2] See Head and Ries (2001) and Davis and Weinstein (1999).

foreign goods, in a literal sense, much more expensive than domestic varieties.[3] Other authors provide econometric identification of substitution elasticities[4] or show that variation in substitutability helps to explain variation in measured border effects across goods.[5] By endogenizing production responses, we contribute to this literature in two ways. First, we provide observable implications for phenomena other than trade levels. Second, we show how typical estimation can overstate the magnitudes of barriers and substitution elasticities.

Section II sketches a model of trade in intermediate and final goods that yields predictions for the location of production and the shipment patterns that result. The model also provides useful implications for the level and composition of home bias. Section III describes our data. Section IV provides estimates. Section V concludes.

Section II. Theory

Our theoretical framework emphasizes the role of intermediate goods in production location and trade. It extends the model in Krugman and Venables (1996), which in turn nests the Krugman (1980) model of monopolistic competition and trade in final goods.[6] Since models of trade in final goods provide the theoretical baseline for most of the work on home bias, we focus on departures from that baseline associated with the presence of intermediate goods.

To briefly sketch model features, consumers have identical preferences that are Cobb-Douglas over commodities and Dixit-Stiglitz over differentiated varieties within a commodity group. Firms combine intermediate inputs, capital and labor to produce differentiated goods. Depending on the input-output structure these goods may be used as final goods, as intermediate inputs, or both. Capital and labor are mobile across sectors within a region, but immobile across regions. Firms move across regions in order

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[3] Foreign exchange volatility, language ties, immigration, colonial relationships, information about foreign markets, and shipping costs have all been suggested as potential explanations for barriers. See Anderson and van Wincoop (2001b), Helliwell (1996), Head and Ries (1998), Obstfeld and Rogoff (2000) Rauch(1999).

[4] Some examples include Clausing (2001), Head and Ries (2001), and Hummels (1999a).

[5] Evans (2000).

[6] The extension is to include two primary factors and to experiment with different forms of the input-output matrix. Including capital is useful because it allows us to explore gradations of specialization, as opposed to the complete concentration of production which tends to result from single factor models.

to maximize profits. We use this model to explore spatial variation in production, absorption, shipment levels, and shipment characteristics. We describe the most general model, and note restrictions that tie it to other models in the literature.

Throughout our discussion we suppress subscripts where possible. Subscripts i and j identify region of origin and destination, respectively. Superscripts k and s represent input and output commodities, respectively. For expositional purposes, we treat the elasticity of substitution among varieties (σ), and shipping costs (g) as common across sectors. We relax these restrictions in the estimating equations. We also assume the fixed input requirement, a, and the unit input requirement, b, are constant across sectors.

Manufacturers use fixed and marginal quantities of an input Z to produce their variety q.[7] Z is composed of capital, labor, and a vector of intermediate bundles.

(1) $Z_i^s = \left(Cap_i^s\right)^{\mu_{Cap}^s} \left(L_i^s\right)^{\mu_L^s} \prod_s \left(M_i^{ks}\right)^{\mu_k^s}; \qquad \mu_{Cap}^s + \mu_L^s + \sum_k \mu_k^s = 1$

where *Cap* and *L* are the capital and labor employed in sector s, μ_{Cap}^s, μ_L^s and μ_k^s are the respective cost shares of capital, labor and sector k intermediates in the production of s, and M is an intermediate bundle of varieties of k used to produce s. M takes the form

(2) $M^{ks} = \left(\sum_n (m_n^k)^\theta\right)^{1/\theta} \quad ; \quad \theta = 1 - 1/\sigma$,

where m_n^k is the quantity of firm n's output from sector k that is used in sector s.

Cost minimization implies that the industry s expenditure on intermediate k can be written

(3) $\tilde{P}_i^k M_i^{ks} = \dfrac{\mu_k^s}{\mu_L^s + \mu_{cap}^s}(w_i L_i^s + r_i Cap_i^s)$,

where w is the wage, r is the return on capital, and $\tilde{P}^k$ is a price index. The sum of factor payments is value added in sector s; dividing through by the expenditure shares on capital and labor gives gross output, X.

$\tilde{P}_i^k M_i^{ks} = \mu_k^s X_i^s$

[7] For notational simplicity we define Z in terms of input usage by all firms in a particular region and sector. Since the firms are symmetric they will each employ an equal share of the total Z.

To get total expenditure on good k in region j, we sum over industrial demands originating from each sector s plus consumer demands

(4) $E_j^k = \eta^k Y_j + \sum_s \mu_k^s X_i^s$

Total absorption depends on the output mix (expressed in terms of sector s gross output), input-output arrangements (which define η and μ), and total household income Y. Given that the upper-tier of the production and utility functions are Cobb-Douglas, total absorption is invariant to prices.[8]

Prices do determine the distribution of purchases over potential suppliers. Region j's total intermediate demand for region i's output is the sum of each sector's intermediate demands:

(5) $m_{ij}^{k\,D} = \frac{\left(p_i^k g_{ij}\right)^{-\sigma}}{\left(\tilde{P}_j^k\right)^{1-\sigma}} \sum_s \mu_k^s X_i^s$

where p is the factory gate price. Similarly, consumer demand for each variety is

(6) $c_{ij}^k = \frac{\left(p_i^k g_{ij}\right)^{-\sigma}}{\left(\tilde{P}_j^k\right)^{1-\sigma}} \eta^k Y_j$,

where η^k is Cobb-Douglas expenditure share for industry k. Firms sell to both consumers and to downstream firms. Summing (5) and (6) produces a characterization of total demand in region j for the output of a firm in industry k, region i:

(7) $q_{ij}^{k\,D} = c_{nj}^k + m_{nj}^k = \frac{\left(p_i^k g_{ij}\right)^{-\sigma}}{\left(\tilde{P}_j^k\right)^{1-\sigma}} E_j^k$.

The f.o.b. value of commodity k shipments from region i to j represents the product of the number of industry k firms in region i (N), the region i price, and region j's demand per firm (7):

(8) $T_{ij}^k = N_i^k p_i^k q_i^k = \frac{N_i^k \left(p_i^k\right)^{1-\sigma} \left(g_{ij}\right)^{-\sigma} E_j^k}{\left(\tilde{P}_j^k\right)^{1-\sigma}}$.

[8] We employ this setup so that absorption variation arises only through changes in the composition of output. A more general upper level utility and production structure would allow expenditures to vary in response to prices.

Summing i's shipments over all destinations returns region i's gross output in each sector. Gross output can be represented $N_i^s p_i^s V$, where V is a function of exogenous parameters a,b, and σ. Labor (Capital) income is equal to the fraction μ_L^k (μ_{Cap}^s) of total sales. Thus, gross output can be related to value added as

$$(9)\ N_i^k p_i^k V = \frac{Y_i^k}{\mu_L^k + \mu_{Cap}^k}$$

where Y is industry k value added in region i. Substituting (9) and (4) into (8) we arrive at the following bilateral trade prediction:

$$(10)\ T_{ij}^k = V^{-1} \frac{\frac{Y_i^k}{\mu_L^k + \mu_{Cap}^k}\left(\eta^k Y_j + \sum_s \mu_k^s X_j^s\right)\left(p_i^k g_{ij}\right)^{-\sigma}}{\left(\tilde{P}_j^k\right)^{1-\sigma}} \quad .$$

Note that the level of shipment is sensitive to the intermediate content of industry k in region i, which may be related in equilibrium to trade frictions. This is assumed away in models without intermediate goods. In those models a region's shipments (a gross output measure) are assumed to add up to its gross domestic product (a value added measure).[9]

The model is written to allow for the most general depiction of the input-output structure. More familiar models are nested within this model. Much of the geography literature abstracts away from factor substitution ($\mu_{Cap}^k = 0$). Krugman and Venables (1993) assume industries demand only their own inputs ($\mu_k^k > 0, \mu_k^s = 0$ for $s \neq k$). More restrictive still is the multi-sector version of the Krugman (1980) model of monopolistic competition, which contains no role for intermediates ($\mu_k^s = 0, \forall s, k$). This final restriction is of particular interest.

Consider the implications of setting intermediate shares to zero. The bilateral trade prediction collapses to:

$$(11)\ T_{ij}^k = V^{-1} \frac{Y_i^k\left(\eta^k Y_j\right)\left(p_i^k g_{ij}\right)^{-\sigma}}{\left(\tilde{P}_j^k\right)^{1-\sigma}} \quad .$$

[9] Authors who attempt to square these measures typically gross up value added by a common economy-wide gross output/value added ratio. This is inappropriate when GO/VA varies over space, as we demonstrate below.

Equation (11) is the gravity equation, and motivates much of the empirical literature on bilateral trade patterns and home bias. Most typically it is implemented with an aggregate equation, dropping commodity superscripts, and setting $\eta = 1$. We focus on the empirical implications of the more general model in which intermediate goods play a role in production and trade.

The model is closed under the assumption that factor prices are equalized across sectors within a region. Given particular characterizations of geography (the number and size of regions, and shipping costs between them), endowments, preferences, and technology (input-output relationships, and elasticities of substitution), one can numerically solve for prices, the output and absorption mix, and the patterns of trade that result. For example, under assumptions of extreme symmetry (two identical regions and two equally-sized and identically parameterized sectors), Krugman and Venables (1993) show that industries tend to agglomerate completely.[10]

We explore the empirical implications of agglomeration, and the endogenous home bias it creates. Outcomes of interest include 1) the composition of regional demand, 2) the co-location of industry, 3) the characteristics of bilateral shipments, and 4) the size of interregional trade flows.

Implication 1: The composition of absorption varies across states due to industrial demands.

A well-known feature of U.S. manufacturing is production agglomeration, that is, the output mix varies over regions.[11] Since industries purchase different input bundles, regional variation in the output mix should also imply regional variation in industrial demands, with a corresponding effect on the composition of regional expenditures.

In our model, this is formalized in equation (4), which describes state i expenditure on commodity k. Expenditures depend on intermediate demands, and intermediate demands depend on a state's output mix. If a state has a large auto sector, a greater share of that state's expenditure will go toward auto parts. Equation (4) nests the

[10] There is one equilibrium in which the two industries evenly divide between the two regions. However, this is a knife-edged solution that is not stable with respect to small perturbations.
[11] See Krugman (1991) and Ellison and Glaeser (1997)

case of no intermediate demands, or $\mu_s^k = 0 \quad \forall s,k$. In this case, expenditures arise only from consumer demands, and the expenditure share on k, η^k, is uniform across states.

Implication 2: Trade costs induce co-location between buyers and sellers of intermediates.

To demonstrate co-location we simulate a two-region, two-sector (autos, apparel), two factor (capital, labor) version of the model. The regions are of similar size and have very similar factor endowments, though region A is slightly more capital abundant. To analyze the role of intermediate goods in this model we assume the technology in Table 1

Table 1. A simple input-output matrix

	Demands		
	Industrial		Consumer
Inputs	Auto	Apparel	η_k
Auto	μ	0	.5
Apparel	0	0	.5
Labor	$0.5-0.5\mu$	0.7	0
Capital	$0.5-0.5\mu$	0.3	0

Consumer expenditure shares on the two goods are equal. Apparel uses no intermediate inputs and is relatively labor intensive. The auto industry expends μ on auto industry inputs (parts), with remaining gross output shares split evenly between labor and capital. We vary the importance of auto industry inputs over a range (0, 0.45) in order to examine how the strength of the agglomeration force depends on the intermediate shares.

We report four outcomes of the model: production concentration/uniformity, absorption uniformity, co-location, and home bias. First, write the industry k share of region i value-added as $y_i^k = Y_i^k / Y_i$, and the industry k share of region j absorption (expenditure) as $e_j^k = E_j^k / E_j$. For the 2x2x2 model employed here it is easy to describe the extent of agglomeration by reporting the share of autos in region A value-added. For models with higher dimensions (and the empirics that follow), we define more general measures of production and absorption uniformity for each commodity as

$$(12)\ PU_k = \sum_i \min\left(\frac{Y_i^k}{Y^k}, y_i\right) \qquad AU_k = \sum_j \min\left(\frac{E_{ik}}{E_k}, e_i\right)$$

where nation-wide value-added in industry k is $Y_k = \sum_j Y_{jk}$, region i's share in nation-wide value-added is y_i, and similarly for expenditures. These measures of uniformity are bounded (0,1]. If all regions produce a good in exact proportion to their share of national production, PU=1 for that good. A highly non-uniform distribution of production yields a measure close to zero.

We define co-location as the propensity of $e_j^k y_i^k$ to be large when trade costs between regions i and j are low. In the two-region model, this can be simply represented as a correlation between $e_j^k y_i^k$ and an indicator variable that takes value 1 for i=j. Finally, we measure home bias in terms of the share of total shipments that occur within a state.

Table 2 reports the effects of changes in μ on trade and location patterns. At $\mu = 0$ there is no force for agglomeration, and production shows a small degree of specialization according to comparative advantage. Region A, which is slightly more capital abundant than B, adds just over half of the value in auto production economywide. Absorption is completely uniform. Home bias is small, as trade costs induce some substitution by consumers toward local varieties.

As μ increases, the auto industry begins to agglomerate. A's initial endowment-based cost advantage in autos becomes more pronounced, as the greater local availability of auto parts lowers the cost of auto production in A. Note that our setup with two primary factors produces less extreme specialization than a single factor model. If we set capital shares to zero, as in Krugman and Venables (1996), auto production shifts entirely to region A for very small values of μ. In the two-factor model, endowment similarity between regions creates a tendency toward evenly distributed production. Agglomeration only occurs if intermediate goods shares, and the corresponding effect on auto prices, are sufficiently large.

As μ increases, absorption also becomes non-uniform, reflecting the rising importance of (regionally biased) industrial expenditures. However, absorption always remains more uniform than production, reflecting the fact that consumer expenditures remain perfectly uniform over space. The combination of production and absorption concentration is captured by our measure of co-location, which shows that auto expenditures and production are (causally) rising together in region A. These effects become very strong as the intermediate share approaches half of gross output in autos. Production is almost completely specialized, and shipments now exhibit a greater degree of home bias. The technology for shipping goods has remained constant throughout this exercise, but shipments are concentrated locally due to the agglomeration effect.

The co-location effect is related to a phenomenon described in the literature on home market effects. That literature predicts final goods output will respond more than proportionally to large local demand for final goods. However, Davis (1998) has shown that home market effects are very sensitive to the assumption of a costlessly traded numeraire sector. Our result, based on a model with symmetric trade costs in two increasing returns sectors, suggests that home market effects are quite robust. They simply require trade in intermediate goods.

Table 2. Co-location and the intermediate goods share

μ	Region A share of value-added in autos	Production Uniformity		Absorption Uniformity		Corr($e_j^k y_i^k$,Border)	Share of own region shipments in trade
		Autos	Apparel	Autos	Apparel		
0.00	0.56	0.94	0.95	1.00	1.00	0.00	0.55
0.05	0.57	0.93	0.95	1.00	1.00	-0.01	0.55
0.10	0.57	0.93	0.94	0.99	0.99	-0.01	0.55
0.15	0.58	0.92	0.93	0.99	0.99	-0.02	0.55
0.20	0.59	0.91	0.92	0.99	0.98	-0.02	0.55
0.25	0.61	0.89	0.91	0.98	0.97	-0.03	0.55
0.30	0.63	0.87	0.88	0.98	0.96	-0.04	0.55
0.35	0.67	0.83	0.83	0.97	0.94	-0.06	0.56
0.40	0.76	0.74	0.72	0.95	0.89	-0.09	0.59
0.45	0.90	0.60	0.50	0.93	0.80	-0.16	0.66

Parameterization: $L_A = 100$; $L_B = 100$; $K_A = 110$; $K_B = 100$; $g = 1.1$; $\sigma = 2$; $a = 1.1$; $b = 1.1$

Implication 3: Co-location affects the intermediate / final composition of shipments.

Co-location affects not only the level of shipments, but also the composition of shipments. Firms that produce intermediates locate proximate to concentrated industrial demands in order to minimize shipping costs. This pattern is clear in the preceding simulation. These results also imply that, in equilibrium, intermediate goods are shipped short distances while final goods travel long distances. Discerning this effect empirically is quite difficult, as many goods double as intermediate inputs and final consumer goods. Nevertheless, it is still possible to derive observable implications in terms of plant and shipment characteristics.

To demonstrate, we adapt our earlier simulation by splitting the auto sector into two parts – parts and assembly. We explore the implications of changes in the cost share of auto parts in assembly (μ_1^2) using the following input-output structure

Table 3. Input-output structure with multiple production stages

	Demands			
	Industrial			Consumer
Inputs	Auto parts	Auto assembly	Apparel	η_k
Auto parts	0.2	μ_1^2	0	.2
Auto assembly	0	0.2	0	.3
Apparel	0	0	0	.5
Labor	0.4	0.4-0.5 μ_1^2	0.6	0
Capital	0.4	0.4-0.5 μ_1^2	0.4	0

This setup illustrates several conceptual issues. Auto parts and assembly producers face both industrial and consumer demands. This is typical of input-output relationships, which makes it difficult to split goods on an intermediate/final basis from the industrial classification system alone. However, the input-output structure provides a useful measure of the degree to which the good is mostly intermediate or mostly final. Simply, sectors with a higher ratio of gross output to value added (factor payments) embody a higher value of intermediates and are closer to final good status.

Consider the implications of aggregating auto parts and assembly into one observable sector called autos. If we compare autos to apparel, autos will have a higher aggregate gross output/value added ratio (GO/VA). There will also be differences in establishments' GO/VA ratios within the auto sector - assembly has a higher GO/VA than parts. Co-location implies that intermediates will locate proximate to final demand to reduce payments of transport/border costs. By implication most cross-region (export) shipments will be in assembled autos. As the share of intermediate inputs in output rises, the share of exports in assembly will increase relative to the share of exports in parts.

We simulate the model over various parameterizations of μ_1^2. Table 4 shows the relationship between production staging and endogenous home bias. As μ_1^2 rises, the gross-output to value added ratio (GO/VA) for assembly increases relative to the GO/VA for parts. Changes in μ_1^2 have a similar effect on the internal share of shipments, which rises for both parts and assembly. Two effects are at work here. First, auto parts shipments become more local as a larger share of shipments go to an agglomerated assembly sector. Second, the degree of agglomeration within each sector rises as increases in μ_1^2 intensify small location advantages – both assembly and parts sectors shift even more production to region A. This geographic movement leads to increasing local intensity of own-sector intermediate trade. The net result of these two effects is that home bias rises in both sectors, but more quickly in the parts sector.

Table 4 also shows implications for the auto sector relative to the apparel sector. As the intensity of staging rises, the GOVA ratio of autos rises relative to apparel. The co-location of parts with assembly minimizes the need to export parts, and the own region share of trade in the aggregated auto good rises with μ_1^2. Since all demand for apparel is final, there is no endogenous home bias in apparel.[12]

The predictions developed here relate an establishment characteristic, plant-level GOVA ratio, to an establishment's propensity to export. One can also describe this prediction in terms of a shipment characteristic, unit prices measured as the shipment's ratio of value over weight. The weight of assembly sector output is, at a maximum, given by the combined weight of parts inputs. However, the value of the assembly sector

[12] The slight increases in domestic share of apparel shipments are due to relative factor price movements. By reducing factor demands in the capital intensive sector, we raise wages. Region B, which has a slight comparative advantage in labor-intensive apparel, receives a larger share of income, and is able to purchase a greater share of all final goods. Increased purchases of apparel by B is not home bias, as typically defined, it reflects only a change in relative regional incomes.

includes the value of parts plus the value of labor and capital services. The unit prices of assembled autos will then exceed unit prices of parts. Co-location implies that assemblers are more likely to export, so unit prices of exports should exceed unit prices of domestic shipments. The same logic applies in continuous space, unit prices should be rising in distance shipped. We show in an appendix that, given standard formulations of shipping costs, this result requires intermediate-final goods staging.

Table 4. Model Outcomes: Staging and Spatial Frictions

μ_1^2	$\frac{GO/VA_{assembly}}{GO/VA_{parts}}$	Share of own region shipments in		$\frac{GO/VA_{autos}}{GO/VA_{apparel}}$	Share of own region shipments in	
		parts	assembly		autos	Apparel
0.05	1.07	0.59	0.57	1.30	0.58	0.52
0.10	1.14	0.63	0.59	1.34	0.61	0.52
0.15	1.23	0.68	0.60	1.38	0.64	0.53
0.20	1.33	0.69	0.61	1.43	0.65	0.53
0.25	1.45	0.70	0.61	1.47	0.66	0.53
0.30	1.60	0.71	0.61	1.52	0.67	0.53
0.35	1.78	0.73	0.61	1.57	0.67	0.53
0.40	2.00	0.74	0.62	1.62	0.68	0.53
0.45	2.29	0.75	0.63	1.69	0.70	0.53

Parameterization: $L_A = 100; L_B = 100; K_A = 110; K_B = 100; g = 1.1; \sigma = 2$

Implication 4: Co-location magnifies the effect of trade frictions on trade volumes.

A commonly used baseline model for predicting trade flows is the gravity equation, which is frequently motivated by an appeal to the structural model in equation (11). In that model, the elasticity of trade volumes (T) with respect to trade frictions (g) is given by the elasticity of substitution between varieties (σ). However, the model in equation (11) assumes that production location is not responsive to costs. If production location is allowed to respond, the elasticity of trade with respect to frictions may be much larger than σ.

In the more general model, trade frictions will affect trade volumes through two channels as seen in equation *(10)*. The direct effect occurs as frictions (g) change relative prices, inducing substitution toward proximate varieties. This is the only effect captured by models that ignore production location. The indirect effect occurs through co-location. Firms linked closely in the input-output structure locate nearby so as to minimize trade costs. We previously defined co-location as a correlation between $e_j^k y_i^k$ and trade frictions and demonstrated it as an outcome of our theoretical model.

Note that the expenditure and value-added shares are arguments in the shipment equation *(10)*. If the composition of output and absorption, $e_j^k y_i^k$, is correlated with frictions and is omitted from estimates of the shipment equation, trade barrier variables will pick up direct and indirect effects of frictions. This magnification effect can be seen very clearly in the preceding simulations. As the use of intermediate goods rises, co-location occurs, and an increasing share of shipments stay local. True trade costs remain constant throughout the simulation, but their effect on trade flows is magnified by co-location.

In a sense, one can think of magnification in terms of omitted variables bias, as omitting production and absorption measures biases the coefficient on trade barriers away from their true values. It is not a spurious bias, in the sense that frictions ultimately cause both direct and indirect effects. But magnification, if incorrectly interpreted, may lead researchers to confuse big trade barrier coefficients for large price wedges between locations.

We propose co-location effects as possible answers to several puzzles in the gravity literature. National borders are only one of a serious of implicit barriers that seem to have unusually large impacts on the geography of bilateral trade. Unexpectedly large gravity model coefficients on currency unions (Rose and van Wincoop 2001) and regional trade agreements (Frankel, Stein and Wei 1996) might well be explained by estimation bias associated with the co-location of industry.

Co-location also serves as a potential explanation for a puzzle proposed by Head and Mayer (2000), who find that European flows exhibit less home bias than North American flows, even though trade frictions are thought to be higher in Europe. If high trade frictions in Europe prevent co-location, as Krugman and Venables (1993) suggest, our model would predict a smaller degree of home bias in European data, even though trade costs were larger.

Section III. Data

In order to examine our theoretical implications we require geographically detailed, commodity-level data on output, absorption, shipment levels, shipment characteristics, and plant characteristics. The primary data source we use is the raw data file from the 1997 U.S. Commodity Flow Survey. The CFS is collected every five years by the U.S. Census Bureau, which chooses a stratified sample of U.S. mining, manufacturing, and wholesale establishments. The sampled establishments report characteristics of a random sample of their shipments. Each shipment record contains the shipment's weight, value and commodity classification,[13] an establishment identifier, the shipper's (SIC) industrial classification, the zip code of the shipment's origin and destination and the actual shipping distance between them, a binary variable denoting shipments bound for export, and the country of export to which export shipments are bound, and the shipment's sampling weight.[14]

These are the best available data documenting sub-national shipments, and are substantially better for our purposes than the publicly available CFS data used by Wolf (2000) and Anderson and van Wincoop (2001a), or the Statistics Canada data employed by McCallum (1995) and subsequent authors. There are several advantages to using the CFS raw data file. First, the data are drawn from stratified random samples of actual shipments. This is in sharp contrast with the Statistics Canada data, which are imputed from at least ten distinct data sources.[15] Second, establishment identifiers in the CFS also allow us to match shipments data to establishments in the Census of Manufactures (CoM). We use this link to identify characteristics of the shipping establishments.

Third, the CFS data contain detail on the commodity shipped, geography of shipments, and the SIC of the shipper. Studies of home bias typically employ aggregate

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[13] In 1997, the Census Bureau used the Standard Classification of Transported Goods (SCTG) classification system, which can be concorded to 3-4 digit SIC. The SCTG system was developed by U.S. and Canadian statistical agencies for use in studies of transportation. In our sample with five-digit commodity detail, there are 504 commodity groups.

[14] The value and weight of shipments are calculated by multiplying reported estimates by the inverse of the sampling weight. Other reported information that goes unused in this study include a flag for shipments of hazardous materials, and the shipment mode used to transport the good.

[15] The Statistics Canada documentation of the imputation algorithm is 48 pages long.

data, which is inappropriate for examining the composition hypotheses that interest us.[16] Zip-code level geographic detail is unprecedented in studies of this type, which usually rely on province or state level data. This also allows a precise calculation of distance shipped, unlike previous studies that must impute distances, using, for example, the distance between states' largest cities. Establishment-level SIC data also allow us to distinguish wholesale shipments from producer shipments. This distinction is important because wholesale shipments have a substantially different economic function than shipments from manufacturers. As we show below, wholesale shipments exhibit quite different spatial characteristics. Failing to separate these activities can result in a misleading picture of trade costs.[17]

The U.S. Input-Output table (Bureau of Economic Analysis) is projected onto CoM state output figures to predict a state's intermediate demands. Combining the three data sets (CFS, CoM, and input-output tables) requires some aggregation because each data set uses a different classification system. In most cases, concorded data can be reported at the 4-digit SIC level. In some manufacturing categories, 3-digit SIC is the lowest level of aggregation that allows a reasonably consistent concordance. Mining and agricultural shipments are reported at the two-digit level of SIC. In total, there are 290 sectors that remain after the aggregation necessary to ensure consistent concordances.

The zip-code to zip-code distances reported in the Commodity Flow Survey provide excellent detail on internal shipment distances within the U.S. To estimate distances traveled by export shipments, we add Hummels' (1999b) estimates of the sea-lane distances between U.S. ports and ports in the country of destination to the CFS figures documenting the distance from zip-code of origin to the port of exit. Unfortunately, there is no information on internal distances within the importing country. These distances are assumed to be small, relative to internal U.S. distances plus U.S. to port of entry distances. This treatment is not appropriate for two countries, Canada and

[16] Our data are also considerably more disaggregated than used in the few previous studies that use moderately disaggregated data. See Helliwell (1998), Anderson and Smith (1999), and Hillberry (forthcoming).

[17] Wolf (2000) does not adjust public-use CFS data for the presence of wholesale shipments. Anderson and van Wincoop(2001a) propose to eliminate wholesale shipments by scaling all shipment values down uniformly so that total shipments equal manufacturers shipments. Because wholesale shipments are highly localized this adjustment results in overstating short shipments and understating long shipments.

Mexico, so shipments bound for Canada and Mexico are excluded for most of the analysis of international commodity movements.

Section IV. Econometric Specification and Results

The model in section II provides predictions in four broad areas: absorption, co-location, shipment levels, and shipment and plant level characteristics. We describe data exercises for each prediction below.

Absorption

We provide two exercises. First, we document the degree to which production and absorption are non-uniform over US states. Second, we attempt to explain absorption levels for each commodity and state using data on technology and output.

Define total *actual* absorption of a commodity k in state j using the sum of all CFS shipments (T) from all source states i, to absorbing state j (including i=j) in that commodity.

(13) $E_{jk}^{cfs} = \sum_{i=1}^{50} T_{ijk}^{cfs}$

Commodity k is defined as a 4 digit SIC category. We also define e_{jk}^{CFS} as the share of k in j's total absorption. *Predicted* absorption is taken from equation (4) of our model, and is the sum of personal consumption expenditures of commodity k, plus industrial demands for commodity k.

(14) $E_{jk}^{IO} = \eta^k Y_j + \sum_s \mu_k^s X_j^s$

This is implemented by taking state-level data on personal income and value-added by industry, and taking expenditures shares (η, μ) from the US input-output table. This assumes that technology is identical across states, and across firms within an industry. We define the degree of absorption and production uniformity for a given 4-digit SIC commodity using the indices in equation (12). If we assume away intermediate demands ($\mu_k^s = 0 \; \forall k, s$), production shares may vary over space, but absorption will be uniform (AU=1). In contrast, the model with industrial demands allows non-uniformity in both absorption and production, as related phenomena.

Figure 1 plots predicted absorption uniformity against actual absorption uniformity for goods measured at the 4-digit SIC level. Actual absorption is not uniform. Most of the observations lie below the forty-five degree line – actual absorption is less uniform than one would predict given industrial demands described by the 4-digit input output table. We interpret this as evidence that our input-output data are still too aggregated, and that there is substantial within-industry heterogeneity in intermediate input demands. This is consistent with recent work by Bernard and Jensen (1997) documenting within-industry heterogeneity in factor demands.

The table accompanying Figure 1 reports summary statistics for our uniformity measures. The results are intuitive. Neither production nor absorption are uniform, but production is less uniform than absorption. This is consistent with our model, which suggests that uniform personal consumption expenditures prevent absorption from becoming too idiosyncratic. All three uniformity measures are positively correlated. Commodities that we predict will be absorbed less uniformly are in fact absorbed less uniformly; commodities that are produced less uniformly are also absorbed less uniformly (using either measure).

Next, we regress the actual absorption of a (4-digit SIC) commodity k in state j, measured as a share of j's total absorption, on the predicted share of absorption (defined in (14) above).

(15) $e_{jk}^{CFS} = \beta_1 e_{jk}^{IO} + a_k + \varepsilon_{jk}$

The basic regression results are reported in the first column of Table 5. The second column excludes personal consumption expenditures from the predicted absorption equation, leaving only intermediate demands. The third and fourth columns repeat these estimates after excluding wholesale trade from the CFS data. All regressions pool over all commodities[18] and include a commodity fixed effect.[19]

[18] We also estimated equation (15) separately for each of 288 distinct 4 dig SIC sectors. Results are qualitatively similar, though in general the coefficients were larger and the regression fit was somewhat worse.

[19] The fixed effect soaks up variation due to concordance problems in mapping the SCTG categories in the CFS to the SIC categories used with the state output and IO table data.

Table 5. Predicting Commodity Absorption by State

Dep. Var	All shipments		Wholesale shipments excluded	
Indep. Var	All expenditures	Industrial expenditures	All expenditures	Industrial expenditures
β	0.554 (0.015)	0.329 (0.008)	0.684 (0.020)	0.412 (0.012)
Adj R^2	0.67	0.68	0.47	0.46
# of observations	16000	16000	16000	16000

Commodity-specific fixed effects employed for each the 4-digit SIC category. All coefficients significant at the 1% level.

Table 5 indicates that actual absorption shares closely match our predicted shares. This result is in marked contrast to the literature on international shipments. Harrigan (1995) finds no relationship between the commodity structure of a country's imports and the output mix of the country. We find that the production structure of US states, and their resulting industrial demands, are strongly related to idiosyncrasies in the absorption patterns of the states.

Co-location

Our theoretical model predicts that buyers and sellers of intermediates will co-locate in order to minimize trade costs. To examine this, we test to see if production and absorption shares are matched for a given state pair. We estimate

$$(16)\quad \left(e_{jk}^{CFS} y_j^k\right) = \beta_1 \ln DIST_{ij} + \beta_2 OwnState_{ij} + \beta_3 ADJ_{ij} + a^k + \varepsilon_{ij}^k$$

The left hand side is constructed by taking all (ij) pairwise combinations of state j's actual absorption (from the CFS) and state i's production shares for a particular commodity k. If production and absorption are more likely to be matched for proximate states, this is evidence of co-location. We regress our measure on barrier proxies, including distance, and dummy variables for own-state (*OwnState*=1 when i=j), and bordering state (*ADJ* =1 for i adjacent to j). This formulation differs from the literature on home market effects, which takes demand variation as given exogenously, and estimates the effect of that variation on output. Our model suggests that output and absorption are determined endogenously, and we treat their product as the dependent variable.

We also estimate equation (16) using CFS absorption data that excludes wholesale shipments. Regressions pool over all 4-digit SIC commodities and include commodity fixed effects. Coefficients are reported in terms of elasticities, evaluated at the means of the left hand side variable.

Table 6 reveals that the closer are two states, the more closely matched is their production and absorption structure. However, this effect operates primarily at very short distances – distance is no longer statistically significant when own-state and adjacency variables are included in the regression. Results are quite similar whether including or excluding wholesale shipments from the absorption measure.

Table 6. Co-location over Space

	All shipments			Wholesale shipments excluded		
Distance	-0.085**	-0.054*	-0.012	-0.091**	-0.053	-0.017
Own State		0.277*	0.421**		0.332*	0.452**
Adjacent			0.161*			0.140
# observations	303086	303086	303086	271675	271675	271675
Adj R^2	0.21	0.21	0.21	0.22	0.22	0.22

* significant at 1%
**significant at 5%

Co-location Effects on Shipment and Plant Characteristics

Section II shows that co-location effects appear not just in the output/absorption mix and in shipment levels, but in the characteristics of the shipments themselves and the plants doing the shipping. The simulation results shown in Table 4 display a particular pattern of shipment characteristics. Because intermediate goods are demanded locally and final goods are demanded in all locations, shipments of intermediate goods should be more limited by distance. The model provides a useful guide for identifying how far an establishment is along the production process: establishment gross-output to value-added ratios, and shipment prices, will be rising in its stage of production.

We measure prices as the unit value-weight ratio for an individual shipment (s), and regress the price on the distance it is shipped, and whether the shipment crossed an international border.

$$(17)\ \ln p_{ij}^{s} = \beta_1 \ln Dist_{ij} + BORDER_{ij} + a_k + \varepsilon_{ij}^{k}$$

We include a vector of commodity specific fixed effects so that our identification comes entirely within a commodity classification. While this might miss some staging effects across categories, it is necessary given that the goods' prices might vary considerably over commodity groups for reasons unrelated to staging.

The base regression is reported in the first column of Table 7. We also provide several robustness checks. For international shipments we know to which country the good will be exported, but not where in the country it winds up. That is sufficient for distant countries, but it is problematic for Canada and Mexico. The length of a shipment from Seattle to Canada depends greatly on whether it is destined for Vancouver or Montreal. Accordingly, we drop Canada and Mexico for columns 2-4. The spatial characteristics of wholesale shipments differ from other goods, so we exclude these in column 3, and consider only wholesale shipments in column 4.

Table 7 tells us that the factory gate price is rising in the distance it is shipped. Prices are higher for export shipments than for domestic shipments. Our preferred specification is in column three, which excludes wholesale shipments and the noisier North American export destinations. A 10% increase in distance raises the unit value of shipments by 8%. The unit values of export shipments are 31% higher than domestic shipments. This is consistent with our staging story.

One alternative possibility for higher unit values is that long-distance shipments and exports are of higher quality than local domestic shipments. Hummels and Skiba (2001) show that the fas price of exports at the 10-digit commodity level is increasing in distance, and interpret this as evidence of quality differences that arise from Alchian-Allen effects. We are unable to reject this alternative explanation, but column 4 provides some suggestion that our multiple-staging story is important. Wholesale shipments are much less sensitive to distance and borders than are non-wholesale shipments. Since staging is more likely in non-wholesale shipments, and wholesalers are just as likely to exhibit Alchian Allen-type behaviors, we conclude that staging is at least partly responsible for f.o.b. unit values rising with distance and border variables.

Table 7. Shipment Characteristics and Spatial Frictions

	All shipments	Shipments to Canada/Mexico excluded	Wholesale shipments also excluded	Including only wholesale shipments
Constant	0.606 (0.002)	0.606 (0.002)	0.178 (0.002)	0.842 (0.002)
Distance	0.043 (0.0003)	0.043 (0.0003)	0.081 (0.0004)	0.053 (0.0004)
Border	0.253 (0.005)	0.348 (0.005)	0.311 (0.006)	0.075 (0.010)
Adj R^2	0.71	0.71	0.73	0.69
Observations	5221504	5211096	2869971	2341125

Fixed effects, 5-digit sctg code absorbed. All coefficients significant at the 1% level

The staging story can be seen more directly in plant characteristics. The further along in the value chain is a plant, the higher is the ratio of gross output to value added. We match our shipments data to the plants from which those shipments originated. We construct an average shipment distance for the shipments originating in each establishment *n*, and then regress average distance shipped on the gross-output to value added ratio of that establishment and a vector of commodity fixed effects.

$$(18)\ \ln DIST_n = \beta \ln\left(\frac{GO}{VA}\right)_n + a_k + \varepsilon_s$$

Similarly, we examine the effect of plant characteristics on the likelihood of exporting. We estimate the share of that plant's shipments that travel internationally given the GO/VA of the plant.

$$(19)\ \ln ExpShare_n = \beta \ln\left(\frac{GO}{VA}\right)_n + a_k + \varepsilon_n$$

We also use a probit to estimate the probability that a shipment crossed an international border given the GO/VA of the plant doing the shipping.

Table 8 tells us that, within an SIC, establishments with larger gross output to value added ratios ship longer distances, export a larger share of their output, and are more likely to be exporters. A 10% increase in an establishment's gross output to value added ratio raises the average distance it ships a given commodity by 0.9%. A 10% increase in the GOVA ratio raises the share of a commodity that an establishment exports by 0.04%. These results are consistent with our hypothesis that firms in earlier stages of production ship shorter distances and are less likely to export than later-stage firms.

Table 8. Establishment Characteristics and Spatial Frictions

Dependent variable	ln (Average shipment distance)	Share of shipments exported	Exporter dummy
Regression technique	OLS, 5-digit commodity fixed effects	OLS, 5-digit commodity fixed effects	Probit 2-digit commodity fixed effects
ln(go/va)	0.094 (0.012)	0.004 (0.001)	0.055 (0.010)
Adj R^2	0.16	0.04	0.04
Observations	77624	78175	78175

All coefficients significant at 1% level.

Shipment levels: commodity regressions

We wish to identify the size of geographic frictions that operate directly through changing the relative price of proximate v. distant goods, Table 6 identifies the indirect effect of frictions, operating through changes in the production/absorption mix in space. The remaining question is whether changing the production/absorption mix magnifies the total effect of geographic frictions on trade volumes. Put another way, by controlling for the production/absorption mix, we hope to separately identify the size of the direct effect. If it is smaller than in an uncontrolled regression, this is evidence for magnification.

To test these hypotheses, we estimate versions of equation (10) in three ways.

$$(20)\ \ln T_{ij}^k = a^k + \beta_1 \ln Y_i + \beta_2 \ln Y_j + \beta_3 \ln(Dist_{ij}) + \beta_4 OwnState_{ij} + \beta_5 ADJ_{ij} + \varepsilon_{ij}^k$$

$$(21)\ \ln T_{ij}^k = a^k + \beta_1 \ln\left(Y_i^k\right) + \beta_2 \ln\left(e_j^k\right) + \beta_3 \ln\left(Dist_{ij}\right) + \beta_4 OwnState_{ij} + \beta_5 ADJ_{ij} + \varepsilon_{ij}^k$$

$$(22)\ \ln T_{ij}^k = a^k + \beta_3 \ln(Dist_{ij}) + \beta_4 OwnState_{ij} + \beta_5 ADJ_{ij} + a_j + a_i + \varepsilon_{ij}^k$$

Each equation is estimated separately for each commodity on bilateral shipments between all state pairs. The first includes aggregate income and output for the importing and exporting state, along with trade barriers. This controls for state scale, but not composition, and omits relative prices. The second adds predicted absorption of commodity k for the importing state (defined in equation (14)), output of commodity k in the exporting state, and trade barriers. This controls for state scale and composition, but not relative prices. This equation is likely to suffer from simultaneity bias between production/absorption shares and bilateral shipments if, for example, our regressions do not include all the frictions that impede trade. For these reasons our preferred specification is equation (22), as it employs vectors of importing and exporting state fixed effects (a_i, a_j) to control for composition and prices. By controlling for relative prices in this way, we can accommodate the Anderson and van Wincoop (2001a) critique of the gravity literature in a parsimonious manner.

If magnification effects are important this should be evident in reduced trade barriers coefficients between the first and third specifications. In other words, once we control for composition and prices, the remaining barrier coefficients are more accurate measures of the direct effect of barriers on relative prices of proximate and distant varieties.

There are 160 commodity level regressions for each column in Table 9, which presents a problem for conveying results concisely.[20] We report the means and standard deviations of the 160 estimated coefficients in order to describe the distribution of trade barriers. We also report the number of coefficients from equations (21) and (22) that lie within the confidence interval from equation (20) that ignores composition effects. Several things are notable. First, there is a tremendous variation in estimated coefficients across commodities. For many commodities, there is no significant effect of the included barriers on shipment levels. This suggests that assuming common trade frictions across sectors, as done implicitly in aggregate gravity regressions, is highly inappropriate. Second, including composition effects improves the ability to explain shipment levels. Production and absorption shares are significant in all estimates of equation (21) and the

[20] Census disclosure rules also limit our ability to report results for specific commodities.

fit improves.[21] Third, own-state and adjacency effects are cut dramatically by the exclusion of wholesale shipments. This is a useful point to emphasize, as previous authors in the home bias literature have tried to address the presence of wholesale shipments in aggregate trade flows by uniformly reducing all trade flows by the wholesale share of total shipments. Our results show that wholesale shipments are highly localized, meaning that uniform reductions overstate the localized nature of remaining industrial shipments.

What we do not find is strong evidence for the magnification effect. In comparing estimates with and without fixed effects, the mean trade frictions are smaller for the own-state and adjacency variables, but larger for the distance variable. And most of the coefficients from the fixed effect regressions lie within the confidence intervals of the coefficients that ignore composition. This suggests that the elasticity of trade with respect to frictions is more or less the same whether or not we control for production and absorption composition.

There are two possible interpretations of this result. One, even though we found evidence for co-location it is not strong enough to create a noticeable magnification effect. Two, the co-location and magnification effects we are looking for occur at a highly disaggregated level. Heterogeneity below the level we can measure with this commodity classification system will escape our vectors of fixed effects.

[21] However, the potential for simultaneity bias gives us pause in interpreting these estimates.

Table 9. Commodity level shipments.

Sample	All shipments			Excluding wholesale shipments		
Control variables	Y_i, Y_j	Y_i^k, Y_j^k	Origin/destination fixed effects	Y_i, Y_j	Y_i^k, Y_j^k	Origin/destination fixed effects
$dist_{ij}$	-0.60 (0.45)	-0.63 (0.40) *110*	-0.90 (0.43) *71*	-0.53 (0.47)	-0.56 (0.38) *110*	-0.82 (0.41) *78*
Own-state	2.08 (1.20)	2.30 (0.95) *132*	1.83 (0.98) *125*	1.26 (1.34)	1.59 (1.13) *128*	1.16 (1.19) *124*
Adjacent	0.73 (0.55)	0.81 (0.53)	0.61 (0.37)	0.53 (0.55)	0.63 (0.49) *158*	0.42 (0.53) *156*
R^2	0.30 (0.14)	0.38 (0.13)	0.61 (0.09)	0.25 (0.15)	0.36 (0.14)	0.61 (0.09)

For each column 160 regressions are estimated. The table reports the mean and standard deviation of estimated coefficients, not the standard errors for any particular coefficients. Numbers in italics are the number of commodity-specific estimates that lie within the confidence interval of the estimates reported in the first column.

Section V. Conclusion

Apparent home bias in consumption is one of the great puzzles confronted by empirical trade research. We provide an explanation for home bias in trade levels that also yields observable implications in terms of the composition of trade and the characteristics of individual shipments and the firms' doing that shipping. We bring this theory to the data using detailed data on shipments and firms using the private sample 1997 U.S. Commodity Flow Survey and U.S. Census of Manufactures.

We have five major findings. One, absorption varies over space in strong relation to the location of final production and corresponding industrial demands for intermediate goods. Two, idiosyncratic production and absorption are matched in space, in the sense that absorption of a good is highest when production of that good is large locally (and vice versa). However, this phenomenon is highly local, operating within a state and in neighboring states, but not over longer distances.

Three, the characteristics of shipments *within* a narrow commodity classification vary markedly over space. Goods at the initial stages of the value chain travel very short distances while goods at the end stages of the value chain travel long distances. Late stage goods are also much more likely to be exported. This pattern is repeated in the characteristics of the firms doing the shipping. Within a narrow industrial classification, firms with a low ratio of gross output to value added (indicating they are early in the value chain) ship short distances, while firms with high ratios of gross output to value added (late in the value chain) ship long distances. Late stage firms are also much more likely to be exporters.

Four, barriers to trade vary considerably over goods, but loom very large for the median good. Five, we find no evidence that controlling for production location eliminates the magnification effect of trade barriers – the elasticity of trade with respect to barriers is unchanged whether or not we control for idiosyncratic production and absorption. A possible explanation for this is that our goods classification system is insufficiently granular, and intermediate-final linkages occur for very specific products. In other words, it is not so much that auto parts co-locate with auto assembly plants, but mufflers for Ford Explorer plants co-locate with the assembly of Ford Explorers.

In terms of future work, our results suggest that models intended to describe geographic frictions should be amended to incorporate a broader set of responses to those frictions. Incorporating intermediate goods into modeling appears especially important for matching facts about co-location effects and non-uniform absorption over space. Finally, research on home bias and trade frictions has focused almost entirely on trade levels. Our results suggest the story of frictions may be told more richly in terms of trade composition.

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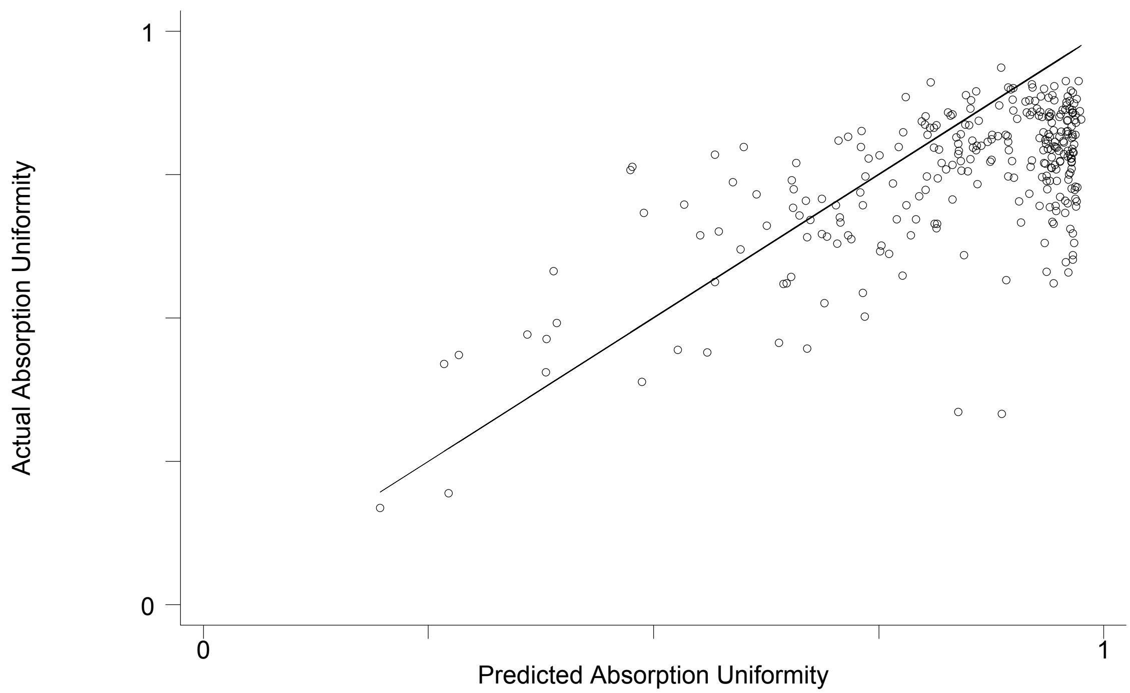
Figure 1. Predicted vs. Actual Absorption Uniformity



Summary of uniformity measures

	Median	Correlation		
		Production	Absorption (Actual)	Absorption (Predicted)
Production	0.71	1		
Absorption (Actual)	0.84	0.36	1	
Absorption (Predicted)	0.91	0.57	0.63	1

Appendix A: Price variation over space

In Section II we demonstrate a systematic relationship between trade frictions (how far a good is shipped) and the price of the good, which in our model measures its stage of production. In this appendix we demonstrate that, for the functional forms used universally in this literature, this is not an implication of a model with a single stage of production.

Our model nests a case where all goods are purchased solely for final consumption ($\mu_k^s = 0, \forall s, k$). Suppose that trade frictions are increasing in the distance shipped and in the ratio of a shipment's weight to value, reflecting the notion that heavier goods are more expensive to ship. Formally, let freight charges on a shipment of variety n from i to j (f_{nj}^k) be represented as

$$\text{A1)} \quad f_{nj}^k = \left(\frac{\omega_n^k}{p_n^k} \right)^{\varphi} F(Dist_{ij})$$

where ω is the unit weight, p is the f.o.b unit price, and *F(Dist_{ij})* is any increasing function of distance. The weight to value ratio captured here is of special interest as it is the inverse of the price measure we employ in the empirical section.

If all varieties within a category have the same per unit price and weight, freight charges affect each variety equally, and it is trivial to show that the composition of the traded bundle is independent of shipping costs. If instead varieties within a category differ in their weight-value ratio, freight charges will vary over varieties. Does this affect the average price (value/weight) of shipments over space?

The average price of shipments between regions i and j in commodity k is given by the total value over the total weight. The total value of ijk shipments is calculated by summing the value of shipments for each variety within ijk, and similarly for total weight. Note that the shipment value of a particular variety can be written as unit price times quantity, and the shipment weight can be written as unit weight times quantity.

$$\text{A2)} \qquad \left(\frac{T}{W} \right)_{ij}^k = \frac{\sum_n p_n^k q_{nj}^{kD}}{\sum_n \omega_n^k q_{nj}^{kD}} = \frac{\sum_n p_n^k \left(\eta^k Y_j \left(\frac{\omega_n}{p_n} \right)^{-\varphi\sigma} F(Dist_{ij})^{-\sigma} \right) / \left(\tilde{P}_j \right)^{1-\sigma}}{\sum_n \omega_n^k \left(\eta^k Y_j \left(\frac{\omega_n}{p_n} \right)^{-\varphi\sigma} F(Dist_{ij})^{-\sigma} \right) / \left(\tilde{P}_j \right)^{1-\sigma}}$$

Since $\eta^k Y_j$, $F\left(Dist_{ij}\right)^{-\sigma}$, and $\tilde{P}_j^k$ are common to all varieties, they factor out of both the numerator and denominator, and can be cancelled. The average per pound price of ijk shipments can then be expressed as

$$\text{A3)} \quad \left(\frac{T}{W} \right)_{ij}^k = \frac{\sum_n p_n^k \left(\frac{\omega_n}{p_n} \right)^{-\varphi\sigma}}{\sum_n \omega_n^k \left(\frac{\omega_n}{p_n} \right)^{-\varphi\sigma}},$$

Average prices are independent of trade frictions.

The intuition is straightforward. Heavier varieties face higher freight costs which reduce quantities sold. But quantity sold appears in both the numerator and denominator, so that the elasticity of total weight with respect to frictions is equal to the elasticity of total value with respect to frictions. In other words, the average price is constant across destinations and is given by a weighted average of f.o.b. prices divided by a weighted average of unit weights.

It should be noted that this implication does not go through for more general (non-iceberg) functional forms on trade frictions. The multiplicative property of the barriers is critical for factoring distance terms out of (A2). The appropriateness of this assumption is not within the scope of this paper, and we follow the functional form used universally in this literature.[22]

The intuition in (A3) and (A4) applies to our multi-stage model if the econometric procedure appropriately accounts for regional variations in expenditures, including industrial demands, E_j^k. E_j^k replaces $\eta^k Y_j$ in (A3), and it can be factored and cancelled in the same fashion. Thus, the Krugman and Venables model predicts that shipment characteristics are constant with respect to geographic frictions if the data are sufficiently disaggregated.

This is not the case if an industrial category in the data contains multiple stages of production. Suppose that earlier stages of production are likely to have higher weight/value ratios as successive stages of production add more value than weight.[23] We show in the implications section that earlier stages will have stronger incentives to co-locate. The response to trade costs is not simply a substitution away from heavy varieties – it includes an endogenous location response correlated with distance and borders. E_j^k will not factor out as in A3, and per pound prices will tend to rise with distance.

[22] For an exception, see Hummels and Skiba (2001).

[23] Imagine that one stage produces parts and the second stage assembles them. In that case the second stage adds only value and no weight.