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Tradability, productivity, and international economic integration

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Abstract

This paper develops a model of endogenously tradable goods to study the implications of international integration for price dispersion and pricing to market. A distinctive feature of the model is heterogeneity in both trade costs and productivity. The model highlights the role of heterogeneity in shaping how new entrants at the extensive margin differ from incumbent traders, thereby giving extensive margin movements distinctive implications relative to the intensive margin. In particular, the model predicts that international integration mainly along the extensive margin should be associated with a more limited degree of price convergence. This prediction finds support in cross-sectional regressions on European data and offers insight into recent integration episodes.

Keywords: Extensive margin; Endogenous tradability; Price dispersion; Pricing to market; Trade costs

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1. Introduction

This paper studies the implications of international goods market integration for price dispersion by developing a theoretical model where goods are endogenously tradable and

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Table 1
Trade response to integration

Exporting country	Importing country or region	Least traded goods, as share of total exports		Total exports (mil$)		Increase in least traded goods exports/increase in total exports
		1990	2000	1990	2000	
Sweden	EU	0.10	0.17	40959	44862	2.02
Italy	EU	0.10	0.14	111485	124438	1.44
Portugal	EU	0.10	0.19	13607	17727	0.86
France	EU	0.10	0.13	116917	190043	0.35
UK	EU	0.10	0.14	88793	153943	0.34
Spain	EU	0.10	0.16	40629	71384	0.25
		1989	1999	1989	1999	
Canada	Mexico	0.10	0.42	525	953	0.99
Mexico	Canada	0.10	0.28	1578	5825	0.41
Mexico	US	0.10	0.17	27590	101842	0.25
US	Mexico	0.10	0.16	24969	80342	0.24

Increase in least traded goods exports relative to increase in total exports defined as col5 = [col2 * col4 − (col1) * (col3)]/[col4 − col3].

Data sources: Exports of least traded goods accounting for 10% or less of total trade in 1989 or 1990, from Kehoe and Ruhl (2002); total trade figures from *Direction of Trade* Yearbooks 1996, 2003; 1999 and 2000 figures deflated by US GDP goods deflator.

heterogeneous. Empirical studies of recent episodes of international goods market integration in Europe and North America have produced a richer picture of how market integration affects cross-border trade and price differences. This picture has pointed out limitations in existing open economy macro models.

One empirical finding relates to quantities, in particular, the fact that trade integration works in part through increases at the extensive margin of goods not previously traded. For example, consider the set of "least traded goods" prior to the North American Free Trade Agreement (NAFTA), defined as the set of 4-digit SITC industries ordered in terms of trade shares, from that with the lowest trade share up to the point that they collectively account for 10% of trade. During the 1990s, these least traded goods accounted for roughly 25% of increased Mexican exports to the United States, 40% of increased Mexican exports to Canada, and almost 100% of increased Canadian exports to Mexico (see Table 1, showing calculations based on data from Kehoe and Ruhl, 2002). In the case of the European Union's implementation of the Single Market Program in the early 1990s, least traded goods accounted for more than 100% of the increased trade of Sweden and Italy and almost 90% of that of Portugal with the rest of Europe.

A second empirical finding relates to the price effects of market integration. The top panel of Table 2 extends the analysis of Engel and Rogers (2004) with more recent Economist Intelligence Unit data on price dispersion across European countries. It shows that the implications of market integration for price convergence can vary widely: there was significant price convergence in the early 1990s with the Single Market Program, but little to no convergence after the European Monetary Union (EMU) was established in 1999. The bottom panel of Table 2 shows a similar result for North America: price dispersion declined considerably in the early 1990s but appeared to increase after 1994 at the time of the adoption of NAFTA.[2]

[2] This result is unaffected if the peso crisis years of 1994 and 1995 are excluded.

Table 2
Price dispersion response to integration

Country pairs or region	Change in price dispersion			
	1990–1994	1994–1998	1998–2004	
Euro zone, all country pairs	−8.70	−0.14	3.02	
Core–core pairs	−4.49	0.40	4.14	
Peripheral–core pairs	−11.11	−0.54	2.44	
Peripheral–peripheral pairs	−24.34	−1.70	−0.91	
	1990–1994	1994–2001	1990–1993	1996–2001
North America, all country pairs	−9.11	7.49	−9.38	7.69
Mexico–Canada	−31.95	21.78	−33.00	17.51
Mexico–US	−27.95	16.86	−27.71	8.08
US–Canada	−2.46	3.95	−2.79	6.76

Notes: Positive values imply price divergence; negative values imply price convergence. Peripheral countries in the Euro zone are Finland, Ireland, Portugal, and Spain; core countries are Austria, Belgium, France, Germany, Italy, Luxemburg, and The Netherlands. Calculations based on mean squared error of product price differences across cities. Since some countries are represented by more than one city, the reported dispersion figures for all country pairs differ from the average of figures for the subset pairs.
Data sources: Economist Intelligence Unit Citybase data and authors' calculations. See Engel and Rogers (2004) for the cities used and the product items included.

Standard open economy macro models are not well suited for studying such dynamics of economic integration since they tend to posit by assumption that a good is either tradable or nontradable by nature, and that a firm is either able to price to market or not by assumption. Recent advances have been made in modeling the costs of trade and how they determine the decision of firms to export and the export price that is set (see Melitz, 2003; Ghironi and Melitz, 2005; Kehoe and Ruhl, 2002; Ruhl, 2003). This paper builds upon this endogenous trade approach, being the first to apply it to the issues of price convergence and pricing to market. A distinctive feature of the model is that it considers multiple types of heterogeneity among goods, in terms of trade costs as well as productivities.[3] A general lesson of the model is that heterogeneity is important in that it shapes how new entrants at the extensive margin differ from incumbent traders; depending on heterogeneity, trade integration at the extensive margin can have very different implications for price convergence than at the intensive margin.

In addition to the productivity heterogeneity common in the trade literature, we also consider the possibility of heterogeneity in terms of trade costs. Hummels (1999, 2001) and Anderson and van Wincoop (2004) have emphasized that trade costs vary widely over different types of goods, depending on factors such as weight, distance, and the time sensitivity of demand. Further, models without trade cost heterogeneity have difficulty explaining recent findings regarding price deviations in Crucini et al. (2005): Firstly, international price wedges vary widely, and secondly higher price wedges are associated with less traded goods.[4] While trade cost heterogeneity is most

[3] The model of Chaney (2006) also allows for heterogeneity in trade costs, though this is at the sectoral level rather than the firm level where extensive margin movements take place.

[4] For example, the classic model of Dornbusch et al. (1977) ranks goods by their productivities, while the size of trade costs are assumed to be uniform. Those goods with the greatest comparative advantage in one country or the other are traded, while those goods with small gains from trading relative to the uniform trade costs remain nontraded. This implies that international price wedges are smallest for nontraded goods.

readily apparent at the goods level, it potentially may also operate at the firm level, due to variation in firm characteristics, such as their geographic location or size.[5]

This paper formulates a two-country two-good macro model where each country specializes in the production of a single good. Each good is available in a continuum of distinct varieties produced by monopolistically competitive firms, which must choose whether to sell in the domestic market alone or also export to the foreign market. This decision is affected by two types of real trade frictions: one in the form of per-unit iceberg trade costs which can vary by variety, and the other a fixed cost of international trade which does not depend upon the quantity traded and does not vary by variety. The first type of cost is motivated by tariffs and transportation costs; the second type reflects establishment costs or the cost of learning to deal with a foreign language or legal system.[6]

The model shows that the implications of market integration policies depend greatly on whether the policy works through reductions in tariffs or fixed costs of trade. A general implication is that when trade integration works more through the extensive margin entry of previously nontraded varieties, the degree of price convergence will be weakest. Part of the intuition is that reductions in the fixed costs of trade directly affect the profitability and entry decision of firms, but they do not directly affect the marginal costs and price setting behavior of monopolistically competitive firms. A second part of the intuition is that if the decision by firms to trade is endogenous, then new entrants will differ systematically from incumbent traders. Under productivity heterogeneity, new entrants will be less productive; under trade cost heterogeneity they will have higher trade costs. In either case, new entrants will charge higher prices than incumbent traders, which will tend to worsen the average international price wedge for a country's exports. Depending on the strength of these two effects, trade integration can have a wide range of implications for international price deviations.

The final section of the paper studies cross-sectional regressions for European data on price dispersion and extensive margins. These are found to support the prediction of the model. In particular, we find consistently across periods that a greater movement at the extensive margin has a negative effect on the degree of price convergence.

2. Model specification

The model consists of two countries, home and foreign, each of which produces a distinct country-specific good, labeled H and F, respectively. Each country's good is available in a continuum of differentiated varieties, produced by monopolistically competitive firms using labor as the sole input.

In principle, any good can be exported, but there are variable costs τ and fixed costs of exporting f_X for any good, which are borne by the exporting firm. Consequently, an endogenously determined fraction will be nontraded in equilibrium. Nontraded goods are labeled N and traded goods T. Home and foreign agents consume CES aggregates of their own domestic good and the other country's traded (export) good varieties. Quantities and prevailing prices for the goods varieties consumed in the foreign country are denoted by an asterisk (*). (Below we

[5] The possibility of trade cost heterogeneity at the firm level might be understood to reflect differences in the distribution of firms geographically, where firms with a shorter distance to travel to a border or port have lower transportation costs. This heterogeneity might also reflect a spillover from heterogeneity among firms in terms of size or productivity, if some portion of the distribution service needed for trade is produced within the firm.

[6] The distribution services in the models of Corsetti and Dedola (2005) and Burstein et al. (2003) are related in spirit to our trade costs, in that they also generate international price wedges. However, they differ from trade costs by typically involving the use of a nontraded service produced in the destination country.

present consumption and price expressions for the home country only; corresponding foreign expressions are analogous.)[7]

2.1. Consumption and prices

The varieties in each country are indexed by i on the unit interval [0,1]. Let n denote the endogenous share of these varieties in the home country that are nontraded, where varieties are ordered such that $i \in [0, n]$ are nontraded and $i \in [n, 1]$ are traded. (Analogously, n^* represents the share of foreign nontraded.) The total mass of varieties of goods available for consumption in the home country is the sum of the mass of domestic varieties and of the good varieties exported by the foreign country, i.e., $1+(1-n^*)=2-n^*$.

Accordingly, aggregate consumption (C) is defined as a CES aggregate of consumption of the home country's own good (C_{H}) and imports of the foreign country's traded good varieties (C_{FT}):

$$C = \left((\theta[n^*])^{\frac{1}{\phi}} (C_{\mathrm{H}})^{\frac{\phi-1}{\phi}} + (1-\theta[n^*])^{\frac{1}{\phi}} (C_{\mathrm{FT}})^{\frac{\phi-1}{\phi}} \right)^{\frac{\phi}{\phi-1}}, \tag{1}$$

where $\phi > 1$ is the elasticity of substitution between home and foreign goods and $\theta[n^*]$ is the own-good bias coefficient that depends endogenously on the number of imported varieties (see Appendix A for the derivation):

$$\theta[n^*] \equiv \frac{1}{2-n^*}, \qquad 1-\theta[n^*] \equiv \frac{1-n^*}{2-n^*}, \qquad 0 \leq \theta[n^*] \leq 1.$$

As n^* rises and fewer varieties are imported by domestic residents, the relative weight in the consumption basket placed on the home good rises, i.e., $\theta' > 0$.

Consumption of the home country's own good is in turn defined as a CES consumption index of its nontraded (C_{HN}) and traded own varieties (C_{HT}):

$$(C_{\mathrm{H}})^{\frac{\phi-1}{\phi}} = \int_0^n (c_{\mathrm{H}i})^{\frac{\phi-1}{\phi}} + \int_n^1 (c_{\mathrm{H}i})^{\frac{\phi-1}{\phi}} di = n \left(\frac{C_{\mathrm{HN}}}{n} \right)^{\frac{\phi-1}{\phi}} + (1-n) \left(\frac{C_{\mathrm{HT}}}{1-n} \right)^{\frac{\phi-1}{\phi}}, \tag{2}$$

where

$$C_{\mathrm{HN}} \equiv \left[\left(\frac{1}{n} \right)^{\frac{1}{\phi}} \int_0^n (c_{\mathrm{H}i})^{\frac{\phi-1}{\phi}} di \right]^{\frac{\phi}{\phi-1}}, \qquad C_{\mathrm{HT}} \equiv \left[\left(\frac{1}{1-n} \right)^{\frac{1}{\phi}} \int_n^1 (c_{\mathrm{H}i})^{\frac{\phi-1}{\phi}} di \right]^{\frac{\phi}{\phi-1}} \tag{3,4}$$

and lower cases are used to denote consumption of individual varieties i of each differentiated good.[8] The elasticity of substitution among individual varieties of the home good and the foreign good is also assumed equal to ϕ.[9] At home, the HN varieties occupy $[0, n]$ and the HT varieties $[n, 1]$.

[7] Bergin et al. (2006) formulate a similar model without iceberg costs in order to investigate the effects of productivity growth on the real exchange rate and the range of goods traded.

[8] Our specification follows the tradition of standard open economy macro models by defining consumption aggregates as the sum of consumptions of individual varieties. This rules out the "love of variety" effect characteristic of Dixit–Stiglitz specifications which imply that utility rises nonlinearly with the number of varieties consumed. Benassy (1996) formulates a general specification of aggregate consumption with a parameter that nests "no love of variety" and "Dixit–Stiglitz love" as special cases; our specification corresponds to the case that exhibits no love of variety.

[9] In our specification with endogenous home bias weights, the elasticity between the home and foreign goods must be the same as that among individual varieties of home (and foreign) goods. With exogenous home bias weights, this constraint can be dropped and different elasticities can be posited.

Analogously, the consumption index of the foreign good varieties imported by domestic residents C_{FT} is defined as

$$C_{\mathrm{FT}} \equiv \left[\left(\frac{1}{1-n^*} \right)^{\frac{1}{\phi}} \int_{n^*}^{1} (c_{\mathrm{F}i})^{\frac{\phi-1}{\phi}} di \right]^{\frac{\phi}{\phi-1}}. \tag{5}$$

Price indexes are defined as usual for each range of varieties, in correspondence to the consumption indices above:

$$P = \left(\theta[n^*](P_{\mathrm{H}})^{1-\phi} + (1-\theta[n^*])(P_{\mathrm{FT}})^{1-\phi} \right)^{\frac{1}{1-\phi}}, \tag{6}$$

where

$$P_{\mathrm{H}}^{1-\phi} = \int_0^n (p_{\mathrm{H}i})^{1-\phi} di + \int_n^1 (p_{\mathrm{H}i})^{1-\phi} di = n(P_{\mathrm{HN}})^{1-\phi} + (1-n)(P_{\mathrm{HT}})^{1-\phi}, \tag{7}$$

$$P_{\mathrm{HN}} \equiv \left(\left(\frac{1}{n} \right) \int_0^n p_{\mathrm{H}i}^{1-\phi} di \right)^{\frac{1}{1-\phi}}, \qquad P_{\mathrm{HT}} \equiv \left(\left(\frac{1}{1-n} \right) \int_n^1 p_{\mathrm{H}i}^{1-\phi} di \right)^{\frac{1}{1-\phi}}, \tag{8,9}$$

$$P_{\mathrm{FT}} \equiv \left(\left(\frac{1}{1-n^*} \right) \int_{n^*}^1 p_{\mathrm{F}i}^{1-\phi} di \right)^{\frac{1}{1-\phi}}, \tag{10}$$

where P is the aggregate domestic country price level, P_{H} is the price index of the home good, P_{HN} is the price index of nontraded home varieties, P_{HT} is the price index of traded home varieties, and P_{FT} is the price (to domestic residents) of the imported foreign good.

These imply relative demand functions for domestic residents:[10]

$$C_{\mathrm{H}}/C = (\theta[n^*])(P_{\mathrm{H}}/P)^{-\phi}, \qquad C_{\mathrm{FT}}/C = (1-\theta[n^*])(P_{\mathrm{FT}}/P)^{-\phi}, \tag{11}$$

$$C_{\mathrm{HN}}/C_{\mathrm{H}} = n(P_{\mathrm{HN}}/P_{\mathrm{H}})^{-\phi}, \qquad C_{\mathrm{HT}}/C_{\mathrm{H}} = (1-n)(P_{\mathrm{HT}}/P_{\mathrm{H}})^{-\phi}. \tag{12}$$

2.2. Production and productivity

The production sector in each country consists of constant-returns-to-scale technologies for the output of each differentiated good:

$$y_{\mathrm{H}i} = A_i l_{\mathrm{H}i}, \tag{13}$$

where $y_{\mathrm{H}i}$ represents the level of home output, $l_{\mathrm{H}i}$ denotes workers employed in production, and A_i is the home productivity coefficient for each individual variety i. Labor is mobile across sectors within each economy, but immobile across countries.

Profit maximization under monopolistic competition implies pricing is determined by the standard cost markup rule. For domestic sales of all home varieties, either traded or nontraded:

$$p_{\mathrm{H}i} = \frac{\phi}{\phi-1} \frac{W}{A_i}, i \in [0,1], \tag{14}$$

[10] Also note that the CES specification implies for individual good variety i: $c_{Hi}/C_H = (p_{Hi}/P_H)^{-\phi}$, $c_{Hi}/C_{HT} = (1-n)^{-1} (p_{Hi}/P_{HT})^{-\phi}$, and $c_{Fi}/C_{FT} = (1-n^*)^{-1} (p_{Fi}/P_{FT})^{-\phi}$.

where W denotes the home wage rate, and $\phi/(1-\phi)$ is the markup. For export sales of traded varieties,

$$p^*_{\mathrm{H}i} = \frac{\phi}{\phi-1}\frac{W}{A_i}\frac{1}{1-\tau_i}, i\in[n,1], \qquad p_{\mathrm{F}i} = \frac{\phi}{\phi-1}\frac{W}{A_i}\frac{1}{1-\tau^*_i}, i\in[n^*,1], \tag{15,16}$$

where τ_i $(0<1-\tau_i<1)$ is the fraction of each variety i lost during shipment and it is assumed that consumers fully absorb these iceberg costs of shipping. Thus, for each traded varieties the foreign sales price exceeds the domestic price by the proportion $1/(1-\tau_i)>1$:

$$p^*_{\mathrm{H}i} = p_{\mathrm{H}i}\frac{1}{1-\tau_i}, \qquad p_{\mathrm{F}i} = p^*_{\mathrm{F}i}\frac{1}{1-\tau^*_i}.$$

Firms in the domestic country have a distribution of productivity levels given by $F[A_i]$. Among these firms, $n=1-F[A_n]$ are nontraders and $1-n=F[A_n]$ are exporters.

Define special weighted productivity averages for home varieties $\tilde{A}$, nontraded home varieties $\tilde{A}_{\mathrm{N}}$, and traded home varieties $\tilde{A}_{\mathrm{T}}$:[11]

$$(\tilde{A})^{\phi-1} \equiv \int_0^1 A_i^{\phi-1}di, \qquad (\tilde{A}_{\mathrm{N}}[n])^{\phi-1} \equiv \frac{1}{n}\int_0^n A_i^{\phi-1}di, \quad (\tilde{A}_{\mathrm{T}}[n])^{\phi-1} \equiv \left(\frac{1}{1-n}\right)\int_n^1 A_i^{\phi-1}di. \tag{17–19}$$

If varieties are ordered with increasing productivity, then $\partial\tilde{A}_{\mathrm{T}}/\partial n>0$, $\partial\tilde{A}_{\mathrm{N}}/\partial n<0$, i.e., average productivity rises (falls) in the traded sector (nontraded) sector with increasing n. Intuitively, as the share of nontraded varieties in the economy rises, varieties at the low productivity end of the traded varieties sector become nontraded, and the average level of productivity of all remaining traded varieties rises.

Trade costs may also vary heterogeneously across varieties. Define the "effective" productivity of home good exports as $A_i(1-\tau_i)$, i.e., productivity adjusted by the trade costs of varieties exported abroad since higher τ effectively lowers the productivity of these varieties relative to the same varieties sold domestically.

Define the *average* effective productivity of home exports $\tilde{A}_{(1-\tau)\mathrm{T}}$ as

$$(\tilde{A}_{(1-\tau)\mathrm{T}}[n])^{\phi-1} \equiv \left(\frac{1}{1-n}\right)\int_n^1 ((1-\tau_i)A_i)^{\phi-1}di, \tag{20}$$

where the T in the subscript indicates that these averages are computed over the range of varieties that are traded. It is straightforward to express the price index for nontraded and traded home good varieties in terms of these productivity averages by using Eq. (14) to substitute for $p_{\mathrm{H}i}$ in Eqs. (8) and (9):

$$P_{\mathrm{HN}} = \frac{\phi}{\phi-1}\left(\frac{W}{\tilde{A}_{\mathrm{N}}[n]}\right), \qquad P_{\mathrm{HT}} = \frac{\phi}{\phi-1}\left(\frac{W}{\tilde{A}_{\mathrm{T}}[n]}\right), \tag{21,22}$$

with Eq. (7) implying

$$P_{\mathrm{H}} = \frac{\phi}{\phi-1}\frac{W}{\tilde{A}}. \tag{23}$$

[11] As pointed out by Melitz (2003), weighting by the elasticity parameter ϕ makes the weights proportional to the relative output shares of firms.

Correspondingly, the price of home varieties exported to foreign residents is

$$P^*_{\mathrm{HT}} = \frac{\phi}{\phi-1}\left(\frac{W}{\tilde{A}_{(1-\tau)\mathrm{T}}[n]}\right). \tag{24}$$

Observe that these prices are increasing in the wage rate and decreasing in average productivity.

2.3. Marginal trading condition

The additional profit to a home firm i of exporting to the foreign market may be written:

$$\pi^*_{\mathrm{H}i} = \left(p^*_{\mathrm{H}i} - \frac{W}{A_i}\frac{1}{1-\tau_i}\right)c^*_{\mathrm{H}i} - Wf_X, \tag{25a}$$

where the operating profits are defined as the export price minus marginal cost times the volume of sales to foreign residents. We follow Ghironi and Melitz (2005) in assuming that firms employ domestic workers to cover the fixed costs. With f_X measured in units of effective domestic labor and W as the wage rate of this labor, labor costs are expressed as Wf_X. If this additional profit is positive, the firm will choose to export; if negative, the firm will not. This provides the condition that pins down the index of the marginal trading firm and hence the share of nontraded goods. For firm index $i=n$, the profit from exporting is exactly zero, so

$$\left(p^*_{\mathrm{H}n} - \frac{W}{A_n}\frac{1}{1-\tau_n}\right)c^*_{\mathrm{H}n} = Wf_X. \tag{25b}$$

2.4. Closing and solving the model

Labor market equilibrium in each country requires that labor employed in production of nontraded and traded home varieties *plus* labor employed to cover the fixed costs of exporting equal the exogenous domestic labor supply L_{H}. The appendix shows that this condition implies the following relation for the home country:

$$WL_{\mathrm{H}} - (1-n)f_X W = \left(\frac{\phi-1}{\phi}\right)\left[P_{\mathrm{H}}C_{\mathrm{H}} + P^*_{\mathrm{HT}}C^*_{\mathrm{HT}}\right], \tag{26}$$

i.e., the domestic wage bill – net of wages paid for workers employed in covering fixed costs, $W(1-n)f_X$ – is proportional to the value of the home good consumed domestically or exported, with the proportionality constant equal to 1 minus the profit rate $1/\phi$.

Close the model with the balanced trade condition, equating the values of exports and imports

$$P^*_{\mathrm{HT}}C^*_{\mathrm{HT}} = P_{\mathrm{FT}}C_{\mathrm{FT}}, \tag{27}$$

and the normalization condition

$$P^* = 1. \tag{28}$$

Equilibrium determines the 24 variables C, C_{H}, C_{HN}, C_{HT}, C_{FT}, P, P_{H}, P_{HN}, P_{HT}, P_{FT}, W, and n and their foreign counterparts (denoted by *) by solving the system of 24 Eqs. (1)–(4), (11), (12), (21), (22), (24), (25b), and 26 plus their foreign counterparts, together with Eqs. (27) and (28).

3. Analytical results and discussion

3.1. Preliminaries: decomposition into homogenous and heterogeneous components

It will prove useful to decompose productivity and iceberg trade costs for varieties i into homogenous (α) and heterogeneous (β) components. We will address two polar cases: (i) heterogeneity in productivity only and (ii) heterogeneity in iceberg costs only. (We report only home country expressions; the foreign country counterparts are analogous.)

In the case of heterogeneity in productivity only, the distributions may be written as

$$A_i = \alpha_A \beta_A[i], \quad i \in [0,1], \quad 0 < \alpha_A, \beta_A \quad 1-\tau_i = \alpha_{1-\tau}, \quad i \in [0,1], \quad 0 \leq \alpha_{1-\tau} \leq 1,$$

implying effective productivity can be expressed as $A_i(1-\tau_i) = (\alpha_A \beta_A[i])\alpha_{1-\tau}$. Changes in α_A, $\alpha_{1-\tau}$ represent balanced changes in productivity and trade costs affecting all varieties equally. Note a rise in $\alpha_{1-\tau}$ implies a *decline* in iceberg costs. Home productivity averages can be expressed:

$$\tilde{A} = \alpha_A \left[\int_0^1 (\beta_A[i])^{\phi-1} di \right]^{\frac{1}{\phi-1}} \equiv \alpha_A \left(\tilde{\beta}_A \right), \tag{29a}$$

$$\tilde{A}_{\mathrm{T}}[n] = \alpha_A \left[\frac{1}{1-n} \int_n^1 (\beta_A[i])^{\phi-1} di \right]^{\frac{1}{\phi-1}} \equiv \alpha_A \left(\tilde{\beta}_{A\mathrm{T}}[n] \right), \tag{30a}$$

$$\tilde{A}_{(1-\tau)\mathrm{T}}[n] = \alpha_A \alpha_{1-\tau} \left[\frac{1}{1-n} \int_n^1 (\beta_A[i])^{\phi-1} di \right]^{\frac{1}{\phi-1}} \equiv \alpha_A \alpha_{1-\tau} \left(\tilde{\beta}_{A\mathrm{T}}[n] \right). \tag{31a}$$

Assuming that varieties are ordered with increasing productivity, average productivity in the traded sector rises as n increases and the traded good share declines.

In the alternative case of heterogeneity in trade costs only, we write the distributions

$$A_i = \alpha_A, \quad i \in [0,1], \quad 0 < \alpha_A \quad 1-\tau_i = \alpha_{1-\tau} \beta_{1-\tau}[i], \quad i \in [0,1], \quad 0 \leq \alpha_{1-\tau}, \beta_{1-\tau} \leq 1,$$

implying effective productivity is $A_i(1-\tau_i) = \alpha_A(\alpha_{1-\tau}\beta_{1-\tau}[i])$. The corresponding averages are

$$\tilde{A} = \alpha_A, \tag{29b}$$

$$\tilde{A}_{\mathrm{T}}[n] = \alpha_A, \tag{30b}$$

$$\tilde{A}_{(1-\tau)\mathrm{T}}[n] = \alpha_A \alpha_{1-\tau} \left[\frac{1}{1-n} \int_n^1 (\beta_{1-\tau}[i])^{\phi-1} di \right]^{\frac{1}{\phi-1}} \equiv \alpha_A \alpha_{1-\tau} \left(\tilde{\beta}_{(1-\tau)\mathrm{T}}[n] \right). \tag{31b}$$

Assuming that varieties are ordered with *decreasing* iceberg costs, i.e., $\partial \beta_{1-\tau}/\partial i > 0$, then $\partial \tilde{\beta}_{(1-\tau)\mathrm{T}}/\partial n > 0$, $\partial \tilde{A}_{(1-\tau)\mathrm{T}}/\partial n > 0$, i.e., average heterogeneity and transportability rise in the traded sector with increasing n.

3.2. Tradability

One immediate conclusion is the equivalence between the two types of heterogeneity in terms of their effects on tradability. This may be seen by considering the trading condition for firm i Eq. (25a), substituting out all firm-specific endogenous variables and making some additional simplifying substitutions. Use the price setting Eqs. (15) and (24) to substitute for $p^*_{\mathrm{H}i}$ and P^*_{HT} and the relative demand condition $c^*_{\mathrm{H}i}/C^*_{\mathrm{HT}}=(1-n)^{-1}(p^*_{\mathrm{H}i}/P^*_{\mathrm{HT}})^{-\phi}$ for $c^*_{\mathrm{H}i}$ to find:

$$(A_i(1-\tau_i))^{\phi}\left(\frac{(\tilde{A}_{(1-\tau)\mathrm{T}}[n])^{-\phi}C^*_{\mathrm{HT}}}{(\phi-1)(1-n)}\right)=f_X.$$

In this equation, the variety-specific trade cost term and that for technology appear only as a product, $A_i(1-\tau_i)$, so it is only the net effect of the two terms that matters for the relative ranking of varieties in terms of their tradability. For example, even if a variety i is more costly to trade than a variety j, $\tau_i>\tau_j$, variety i nevertheless can be more tradable if it has a sufficiently high level of productivity so that $A_i(1-\tau_i)>A_j(1-\tau_j)$. Conversely, there also may be some highly productive varieties that nevertheless will probably never be traded because they have particularly high trade costs. Varieties can in principle be ranked in terms of tradability using this composite metric.

We next obtain some insight into the extensive margin of trade by considering the trading condition for the marginal variety Eq. (25b). Using the price setting Eq. (15) for $p^*_{\mathrm{H}n}$ and noting that the relative demand condition $c^*_{\mathrm{H}i}/C^*_{\mathrm{HT}}=(1-n)^{-1}\ (p^*_{\mathrm{H}i}/P^*_{\mathrm{HT}})^{-\phi}$ holds for all varieties i in $[n, 1]$:

$$\left\{\frac{1}{\phi-1}\left(\frac{1}{A_n(1-\tau_n)}\right)\right\}\left\{\left(\frac{p^*_{\mathrm{H}n}}{P^*_{\mathrm{HT}}}\right)^{-\phi}\frac{C^*_{\mathrm{HT}}}{1-n}\right\}=f_X. \tag{32}$$

In this form, we can infer that the nth firm's variable profits depend on two factors. The first is per-unit export profits, the term in the first set of curlicue brackets on the LHS, expressed as a proportion $1/(\phi-1)$ of marginal costs. The second factor is the quantity of exports sold, in the second set of curlicue brackets. This in turn can be decomposed into the relative price effect on demand for the nth firm's exports, $(p^*_{\mathrm{H}n}/P^*_{\mathrm{HT}})^{-\phi}$, and its share of the aggregate level of exports sold abroad, $C^*_{\mathrm{HT}}/(1-n)$.

When variable export profits exceed the fixed costs of exporting – either because per-unit profits or the volume of exports are high – varieties with effective productivity lower than that of the initial nth variety will become traded (since even though $A_i(1-\tau_i)<A_n(1-\tau_n)$ for these varieties, it has become profitable to export them). The resulting decline in n and rise in the share of tradable varieties $1-n$ raises the marginal cost and price of the marginally traded variety and reduces its share of aggregate exports. These effects cause both per-unit profits and the export volume to fall. In equilibrium profits are reduced to just cover the fixed costs of the nth firm entering the export market.

Eq. (32) can be used to understand the effects of trade policies on the pattern of trade. Consider first a balanced cut in per-unit (iceberg) costs, i.e., a rise in $\alpha_{1-\tau}$, $\alpha^*_{1-\tau}$. This policy will have offsetting effects on the components of the marginal firm's variable profits. Per-unit profits fall since monopolistically competitive firms pass on the decline in tariffs into lower sales price, multiplied by the markup. But export sales rise since the lower relative price of exports boosts foreign demand. Under elastic demand, the rise in sales will tend to dominate so that variable profits exceed fixed export costs for the nth firm and induce entry into trading.[12] Since this

[12] To see this, combine Eqs. (29), (30), (31), (32) with the foreign counterpart to Eq. (12) and assume for simplicity that productivity heterogeneity is described by the distribution $A_i=\alpha_A(1+i)^{\beta_A}$, $i\in[0,1]$, $0<\alpha_A$, β_A, implying $\frac{(1+n)^{\beta(\phi-1)}}{2-n}\left\{\frac{1}{\phi-1}\left(\frac{\phi}{\phi-1}\right)^{-\phi}(\alpha_A)^{\phi-1}\right\}\left\{W^{-\phi}P^{*\phi}C^*\right\}=f_X\left(\frac{1}{\alpha_{1-\tau}}\right)^{\phi-1}$. Provided that demand is elastic ($\phi>1$), it can be seen that a cut in per unit trade costs that raises $\alpha_{1-\tau}$ reduces the right-hand side of this expression, which should lead to extensive margin entry (fall in n). This abstracts from possible changes in aggregate wages, foreign prices, or foreign consumption, which are endogenous and prevent full analytical solution. But simulations in Section 4 confirm that endogenous movements in these aggregates do not overturn the prediction.

reduction in trade costs affects the pricing decisions of incumbent exporters as well as potential exporters, lowering their prices and raising their share of the foreign market, this policy will also have an effect on trade through the intensive margin.[13] So the intensive and extensive margins both will be operative. In contrast, a reduction in fixed costs (f_X, f_X^*) will have no impact on the prices of incumbent firms and hence no intensive margin effect. Yet it will have a direct effect of encouraging the entry of new firms, lowering n. Combining these observations, we conclude that the share of any rise in total exports due to the extensive margin is larger after a fixed cost reduction than after a per-unit cost reduction. A closed form solution verifying this claim is not possible in this model, but the claim is verified for a reasonable calibration of parameters in the numerical simulations presented in Section 4.

3.3. Law of one price and price divergence

Next examine the circumstances under which deviations from the law of one price may emerge. At the level of individual varieties i, Eqs. (14) and (15) make clear that the export price exceeds the domestic price of goods variety i by a wedge associated with trade costs:

$$\frac{p_{Hi}^*}{p_{Hi}} = \frac{1}{1-\tau_i} = \frac{1}{\alpha_{1-\tau}\beta_{1-\tau}[i]} > 1, \quad i \in [n, 1].$$

With homogeneous trade costs, the degree of price divergence is constant across varieties. However, if $\beta_{1-\tau}[i]$ and $1-\tau_i$ vary with i, the degree of price divergence varies with i as well. Thus, variations across varieties in the degree of law of one price (LOP) deviations depend on the presence of heterogeneous trade costs. Note that heterogeneous productivity will not have this effect.

One measure of price deviations familiar from past research is the “pricing to market” of home exporters. We follow the definition of pricing to market (PTM) from Bergin and Feenstra (2001), as the ratio of the average price of home tradable goods in the foreign market to that for the same set of goods in the home market. Eqs. (22) and (24) together with Eqs. (19) and (20) imply

$$\mathrm{PTM} \equiv \frac{P_{HT}^*}{P_{HT}} = \frac{\tilde{A}_T[n]}{\tilde{A}_{(1-\tau)T}[n]} > 1. \tag{33}$$

Since the presence of transport costs implies $\tilde{A}_T > \tilde{A}_{(1-\tau)T}$, the average price to foreign residents of exported home goods is higher than the average domestic price of the same goods at home.

We will emphasize a slightly different measure of price dispersion, more relevant for the data to be discussed later. Consider the ratio of the average price of the home good in the foreign country to the average price of the home good at home, where the average includes all varieties available to consumers in a given market. The distinction from pricing to market is that nontraded goods are included in the home market average price. Eqs. (22) and (24) together with Eqs. (17) and (19) imply for this measure

$$\mathrm{PDISP} \equiv \frac{P_{HT}^*}{P_H} = \frac{\tilde{A}}{\tilde{A}_{(1-\tau)T}[n]}. \tag{34}$$

[13] Chaney (2006) solves a similar model analytically to find that as the elasticity of substitution (ϕ) rises the intensive margin effect is amplified and the extensive margin effect dampened.

In the case of heterogeneity in terms of trade costs only, the PTM and PDISP measures are identical in our model, since Eqs. (29b) and (30b) indicated that $\tilde{A}_{\mathrm{T}}[n]=\tilde{A}=\alpha_A$. In other words, it does not matter whether nontraded varieties are included in the home market average price since all home varieties charge the same price at home ($P_{\mathrm{HT}}=P_{\mathrm{H}}$). It is only under productivity heterogeneity that the two measures might differ. Note also that whether the level of PDISP is greater than unity depends on the combination of the distribution and level of productivity and trade costs. In the cases studied below, we assume trade costs are sufficiently high to ensure that the price of the home good indeed is higher in the foreign country than at home. This condition is satisfied when we calibrate the model to available empirical evidence in simulations in Section 4.

How does economic integration affect these price deviations? The answer depends on two sets of distinctions. First, is trade policy reducing per-unit costs of trade or fixed costs? Second, are new entrants distinguished by heterogeneity in terms of trade costs or productivity? These two sets of distinctions imply a total of four cases, which will be studied in turn below.

First, consider a decline in iceberg costs ($\alpha_{1-\tau}$, $\alpha^*_{1-\tau}$ rise) under the assumption of productivity heterogeneity. In this case, Eqs. (30a) and (31a) imply that Eq. (34) reduces to

$$\mathrm{PDISP} \equiv \frac{P^*_{\mathrm{HT}}}{P_{\mathrm{H}}} = \left(\frac{1}{\alpha_{1-\tau}}\right)\left(\frac{\tilde{\beta}_A}{\tilde{\beta}_{A\mathrm{T}}[n]}\right), \tag{35a}$$

indicating that deviations from LOP at the aggregate level depend on the homogenous trade cost parameter $\alpha_{1-\tau}$, as well as overall productivity $\tilde{\beta}_A$ relative to the average productivity of traded varieties of the home $\tilde{\beta}_{A\mathrm{T}}$. An increase in $\alpha_{1-\tau}$, i.e., balanced decrease in trade costs, has the direct effect of lowering $P^*_{\mathrm{HT}}/P_{\mathrm{H}}$ and reducing the average deviation from LOP.[14] In addition, there is an indirect effect through the endogenous change in tradability on the heterogeneous component of productivity. Specifically, a decrease in n, implying an increase in the number of tradable varieties, implies that productivity is averaged over varieties with lower productivity, i.e., lower A_i. The resulting fall in $\tilde{\beta}_{A\mathrm{T}}[n]$ (since $\partial\tilde{\beta}_{A\mathrm{T}}[n]/\partial n>0$) raises $P^*_{\mathrm{HT}}/P_{\mathrm{H}}$. In this case, the indirect channel works to raise the degree of price divergence. The relative size of these two offsetting effects will be evaluated by numerical simulation in the following section.

The effects on pricing to market are much simpler. Eqs. (30a) and (31a) imply that Eq. (33) reduces to $\mathrm{PTM}=1/\alpha_{1-\tau}$. A reduction in the uniform trade costs leads to a direct and equal percentage fall in pricing to market.

Second, consider how the effect of a decline in iceberg costs changes under trade cost heterogeneity. In this case, Eq. (34) reduces to

$$\mathrm{PDISP} \equiv \frac{P^*_{\mathrm{HT}}}{P_{\mathrm{H}}} = \left(\frac{1}{\alpha_{1-\tau}}\right)\left(\frac{1}{\tilde{\beta}_{(1-\tau)}[n]}\right) > 1, \tag{35b}$$

and deviations from LOP at the aggregate level depend on the relative heterogeneity of trade costs ($\tilde{\beta}_{(1-\tau)\mathrm{T}}$) as well as on the homogeneous trade cost component ($\alpha_{1-\tau}$). Note that in the absence of any productivity heterogeneity, trade costs imply that the average price of the home good to foreigners always exceeds its average home price. The direct effect of a homogenous cut in costs (i.e., increase in $\alpha_{1-\tau}$) is to reduce price divergence. But there is also a potentially offsetting effect to consider through the endogenous changes in tradability on the heterogeneous component of

[14] The direct effects and indirect effects of lower transport costs are reversed if initially trade costs are low enough (i.e., $\alpha_{1-\tau}$ is high enough) so that P^*_{HT} is less than P_{H}. In this case the increase in $\alpha_{1-\tau}$ will lower the ratio $P^*_{\mathrm{HT}}/P_{\mathrm{H}}$ further below unity, implying greater price dispersion, while the decrease in $\tilde{\beta}_{A\mathrm{T}}[n]$ will raise the ratio, implying less price dispersion.

trade costs. Specifically, a decrease in n, implying an increase in the number of tradable varieties, implies that trade costs are averaged over varieties with higher costs, i.e., lower $1-\tau_i$. The resulting fall in $\tilde{\beta}_{(1-\tau)\mathrm{T}}[n]$ (since $\partial\tilde{\beta}_{(1-\tau)\mathrm{T}}[n]/\partial n>0$) raises the degree of price divergence. As noted above, the implications for pricing to market are identical here to those for PDISP.

Now consider the type of policy that cuts fixed costs (f_X, f_X^* fall). Fixed costs do not affect deviations from LOP at the individual firm level here, but they can affect deviations at the aggregate level to the extent they affect n. In the case of productivity heterogeneity, the relation Eq. (35a) applies, and the degree of price divergence depends on the heterogeneity of productivity ($\tilde{\beta}_{A\mathrm{T}}$) as well as homogeneous trade costs ($\alpha_{1-\tau}$). In this case, a decline in fixed costs that fosters decreased n and increased tradability reduces $\tilde{\beta}_{A\mathrm{T}}[n]$ and reduces the average export price of tradables to foreign residents. In words, if the source of heterogeneity is in terms of productivity, then the newly tradable varieties systematically will be those varieties with lower productivity. Given the lower fixed costs, it now becomes profitable to trade these varieties, despite the higher per-unit costs. Given that price setting responds to these costs, the newly traded varieties will tend to have a higher price in the foreign market. Assuming there initially is a positive price wedge between the foreign price of home tradables and the domestic country price of the home good, the size of the price wedge will increase, i.e., the average foreign price of traded varieties will rise relative to the overall home good price level. Implications for pricing to market again are simpler: since $\mathrm{PTM}=1/\alpha_{1-\tau}$ without heterogeneity in variable trade costs, a fixed cost cut has no impact.

Finally, in the presence of trade cost heterogeneity, Eq. (35b) holds and deviations from LOP then depend on the heterogeneity of trade costs ($\tilde{\beta}_{(1-\tau)\mathrm{T}}$). In this case, a decline in fixed costs that fosters decreased n and increased tradability reduces $\tilde{\beta}_{(1-\tau)\mathrm{T}}[n]$ and raises price disparity. If the source of heterogeneity is in terms of iceberg costs, then the newly tradable varieties systematically will be those varieties with higher per-unit costs. Given the lower fixed costs, it now becomes profitable to trade these varieties, despite the higher per-unit costs. Given that price setting responds to these costs, the newly traded varieties will tend to have a greater price wedge between national markets, so that average price dispersion of traded varieties will increase unambiguously.

To sum up, iceberg costs play an important role in the model in explaining market segmentation as measured in terms of price deviations because fixed costs have no impact on the pricing behavior of monopolistically competitive firms. Cuts in iceberg costs reduce price disparities across markets. Moreover, only heterogeneity in iceberg costs can explain heterogeneity of LOP deviations. In contrast, fixed trade cost reductions in the presence of either productivity or trade cost heterogeneity has the potential to explain why price divergence may actually increase when account is taken of endogenous changes in the tradability of varieties.[15]

Regarding trade volume, the policy experiments above have multiple offsetting effects which obscure analytical results. We present results for this variable in the numerical simulations below and refer the reader interested in the analytical discussion to the appendix.

4. Numerical results

4.1. Calibrations

In several of the cases discussed above, trade liberalization had ambiguous implications due to multiple offsetting effects. Numerical simulations are helpful to resolve these ambiguities.

[15] Implications for price may differ from the analysis above if strategic interactions between firms make price markups vary with extensive margin entry. See Bergin and Glick (2005) for some analysis of this case.

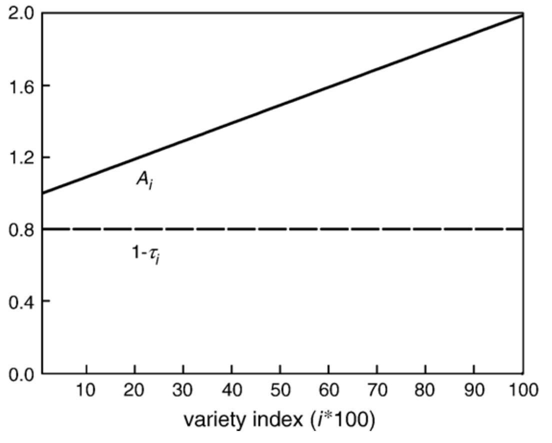

Fig. 1. Distributions in simulation with productivity heterogeneity only.

The elasticity of substitution between any two varieties, ϕ, is calibrated at the value 6. This implies a price markup of 20% over cost, which is a common value in the literature (Obstfeld and Rogoff, 2000).[16] Simulations require that particular distributions be specified for the heterogeneous elements. Productivity will follow the distribution:

$$A_i = \alpha_A (1+i)^{\beta_A}, \qquad i \in [0,1], \qquad 0 < \alpha_A,$$

and iceberg costs follow the distribution:

$$1 - \tau_i = \alpha_{1-\tau}(1+i)^{\beta_{1-\tau}}, i \in [0,1], \qquad 0 \leq \alpha_{1-\tau},$$

where α_A and $\alpha_{1-\tau}$ are scale parameters representing level effects common to all varieties, while β_A and $\beta_{1-\tau}$ are parameters indicating the degree of heterogeneity across firms along the continuum.

4.2. Per-unit cost reductions

The first simulation will consider the case where the source of heterogeneity is productivity, with distribution parameters set at $\alpha_A = 1$, $\beta_A = 1$ and $\alpha_{1-\tau} = 0.8$, $\beta_{1-\tau} = 0$. This implies a constant per-unit trade cost near 20% for all firms, similar to that assumed in Obstfeld and Rogoff (2000) and the level estimated in the empirical work of Anderson and van Wincoop (2004). Fig. 1 illustrates the distributions for technology and iceberg costs over the continuum of home good varieties. This calibration implies that the foreign price of tradables is greater than the domestic price of the home good in the initial steady state, implying that a rise (decline) in the ratio $P^*_{\mathrm{HT}}/P_{\mathrm{H}}$ corresponds to greater price dispersion (convergence). The experiment will consider a symmetric rise in $\alpha_{1-\tau}$ of 1% for both countries, which lifts the $1-\tau_i$ line for all varieties. This could be viewed as a 5% scaled reduction in the tariff rate. To ensure a share of nontraded varieties of 50%, the fixed cost f_X is calibrated at 0.0365. The foreign country is exactly symmetric.

[16] Note that this parameter also doubles as the elasticity between home and foreign goods. An alternative specification with two different elasticities will be considered at the end of this section.

Table 3a
Simulation results: cut in per-unit trade costs

	Steady state	% change (endogenous n)	% change (exogenous n)
Nontraded share (n)	0.50	−2.20	0.00
Export share [a]	0.21	4.75	4.00
Extensive share [b]	–	0.20	0.00
Price dispersion ratio (PDISP) [c]	1.13	−0.75	−1.00
Pricing to market (PTM) [d]			
Productivity heterogeneity case	1.25	−1.00	−1.00
Trade cost heterogeneity case	1.13	−0.75	−1.00

Calibration: $\beta_A=1$, $\alpha_A=1$, $\beta_{1-\tau}=0$, $\alpha_{1-\tau}=0.8$, $\phi=6$, $f_X=0.0365$.
[a] Export share: value of exports as ratio to GDP.
[b] Extensive share: fraction of new import value due to new entrants.
[c] Price dispersion ratio: $P^*_{\mathrm{HT}}/P_{\mathrm{H}}$.
[d] Pricing to market: $P^*_{\mathrm{HT}}/P_{\mathrm{HT}}$.

The results of this experiment are shown in Table 3a, where column 1 reports initial values before the tariff reduction. The export share of less than one half indicates some degree of home bias in consumption, arising from the presence of trade costs that make imported varieties more expensive than domestic goods. Column 2 reports the percentage change from steady state values after the tariff reduction. Recall that one ambiguity in the analytical solution of Section 3 is the degree of entry and increase in trade share. While the fall in export prices raises foreign demand for home exports, thereby increasing the profitability of paying the fixed cost of exporting, any new entrants will have systematically lower productivity and hence higher prices than the average among previous entrants. Line 1 of the table shows that there indeed is entry of new exporters, as the share of nontraded goods (n) falls. Line 2 shows that new entry amplifies the increase in trade volume, compared to the case where there is no entry, shown in the last column. But line 3 shows that the contribution of this extensive margin shift is modest, accounting for 20% of increased trade.

There was also an ambiguity in the analytical solution for price dispersion, PDISP, which depended on the relative size of a direct and indirect effect of a tariff reduction. The direct effect of a 1% increase in $\alpha_{1-\tau}$ is a 1% reduction in the international price dispersion ratio, which can be seen in column 3, which isolates the direct effect by holding fixed the extensive margin. But any entry of new firms with lower productivity will tend to raise the average price of the home good in the foreign market, raising it yet further above the price in the home market and worsening price dispersion. As can be seen in line 4 of the table, the fact that the extensive margin shifts only a modest amount in this case implies that the secondary effect of new entrants on price deviation is likewise small. So the direct effect dominates, and there is significant price convergence. Finally, the simulated impact on pricing to market (PTM) is as predicted in the analytical section: the 1% reduction in trade costs translates fully into a 1% reduction in pricing to market.

Next, we explore the effects of assuming heterogeneity in terms of per-unit trade costs instead of productivities. The distributions are parameterized by $\alpha_A=1$, $\beta_A=0$, $\alpha_{1-\tau}=0.5$, and $\beta_{1-\tau}=1$ and depicted in Fig. 2. The fixed cost is again calibrated at 0.0365. Again consider an experiment where $\alpha_{1-\tau}$ rises 1%, representing a tariff cut that raises the $1-\tau_i$ line for all varieties. For this calibration of trade cost heterogeneity, the experiment generates identical values as those shown

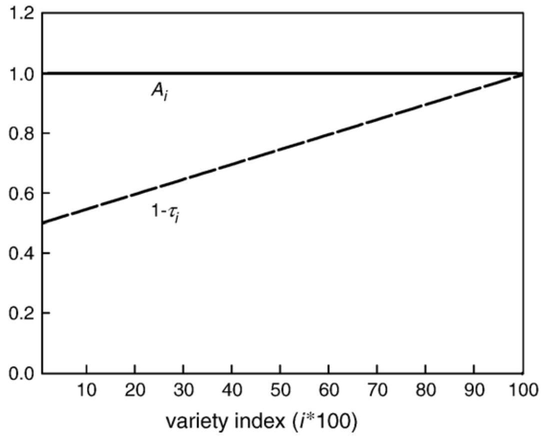

Fig. 2. Distributions in simulation with transport cost heterogeneity only.

in the first four lines of Table 3a for the case of productivity heterogeneity. (The only difference is the effect on the pricing to market measure (PTM), as explained in the analytical section.) Again there is a small secondary effect limiting price convergence somewhat, which arises from the extensive margin shift and entry of new firms. The reasoning is different, however, in that now the new entrants are distinguished from incumbent traders by having larger per-unit trade costs, which raises the average price wedge among varieties of the home good available in the foreign country. The isomorphism of the two types of heterogeneity arises from the fact that both distributions are calibrated to vary in the same way over varieties: $\beta_{1-\tau}=\beta_A$. If heterogeneity of one type is thought to vary more steeply over varieties, this case will tend to generate the weaker price convergence.

4.3. Fixed cost reduction

Consider next experiments that instead reduce the fixed cost of trade. The two cases will use the same pair of distributions graphed in the previous section, and this will imply that the starting

Table 3b
Simulation results: cut in fixed cost of trade

	Steady state	% change (endogenous n)	% change (exogenous n)
Nontraded share (n)	0.50	−6.00	0.00
Export share [a]	0.21	1.93	0.00
Extensive share [b]	–	1.51	0.00
Price dispersion ratio (PDISP) [c]	1.13	0.68	0.00
Pricing to market (PTM) [d]			
Productivity heterogeneity case	1.25	0.00	0.00
Trade cost heterogeneity case	1.13	0.68	0.00

Calibration: $\beta_A=1$, $\alpha_A=1$, $\beta_{1-\tau}=0$, $\alpha_{1-\tau}=0.8$, $\phi=6$, $f_X=0.0365$.

[a] Export share: value of exports as ratio to GDP.

[b] Extensive share: fraction of new import value due to new entrants.

[c] Price dispersion ratio: $P^*_{\mathrm{HT}}/P_{\mathrm{H}}$.

[d] Pricing to market: $P^*_{\mathrm{HT}}/P_{\mathrm{HT}}$.

equilibrium values for variables likewise will be the same as in the previous section. The experiment will be a symmetric reduction in the term f_X by 10% in both countries.

Table 3b reports the result for the case of productivity heterogeneity, which confirms the conjecture from the analytical section that there should be much more entry into exporting. However, despite this greater extensive margin growth, the overall export share in GDP rises less. This is because as new firms enter the market, firms previously trading experience an actual decline in their share of the export market. This implies the intensive margin growth is smaller, so that the share of new trade due to the extensive margin exceeds 100%. The large extensive margin shift also implies that the indirect effect on foreign prices will be large. The fourth line of the table shows that this indirect effect dominates the direct effect, and there is greater price dispersion on net. The final line shows that there is no impact on pricing to market, as predicted in the analytical section.

When this experiment is run for the case of trade cost heterogeneity, it generates values identical to those in Table 3b for the first four lines. (The only difference is pricing to market, where this again is identical to the measure of price dispersion PDISP.) So both types of heterogeneity can offer explanations for cases where trade integration appears to raise international price dispersion.[17]

5. Some empirical implications

A key testable implication of the theory above is that growth in trade along the extensive margin is positively related to price dispersion. We investigate the prediction with a regression of the change in European price dispersion on the change in the extensive trade margin across country pairs.

Our empirical measure of price dispersion is based on price level data drawn from the Economist Intelligence Unit (EIU) for the 101 traded as well as 38 nontraded goods, as used in Engel and Rogers (2004). These data cover 18 cities within the Euro zone for the period 1990–2004. The metric used for dispersion is the mean squared error of (the relative logs of) product item prices across cities in the Euro zone, averaged over goods categories. This measure of price dispersion is closely related to Eq. (34) for the relative price ratio derived in our theoretical analysis in Section 4. The EIU instructs its data collectors to obtain the price of a representative item in each city for each of its goods categories, where the item conforms to an international standard. A simple way to model this data collection process is as a random draw from the population of varieties available for sale in a given market. The expected value of this price draw then would equal the average price level over the range of varieties available, with weights equal to the volume of sales of each variety. Since nontraded domestic goods are in the population of possible price draws in the domestic market, the theoretical measure of price dispersion in the model labeled PDISP would be a better counterpart to this empirical measure than would the more

[17] We also simulated a version of the model where the elasticity of substitution between home and foreign goods was calibrated at 1.5, a value lower than the elasticity of 6 assumed between varieties of the same good. While such a case proved problematic for analytical solution because the home bias coefficient θ no longer can be viewed as endogenous, simulations showed that our results are robust. Calibrating the value of θ to 0.776 replicates the initial steady state of the simulations above. The only significant change in results is that trade volume and the extensive margin responded less to tariff reductions. Price convergence is stronger under tariff reductions, with a percent change in the price gap ratio of −0.98. Price divergence remains strong under a fixed cost reduction, with a percentage change in the price gap ratio of 0.56.

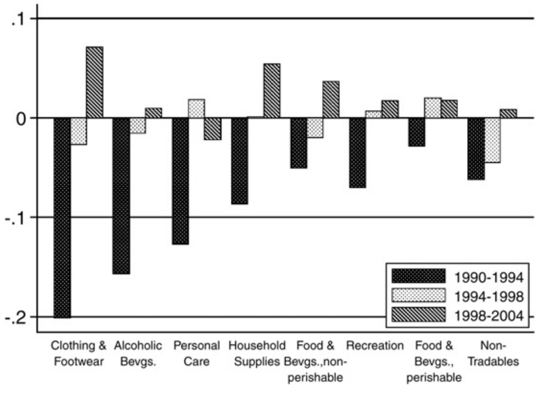

Fig. 3. Change in price dispersion in the euro-11. Source: Economist Intelligence Unit Citybase data and authors' calculations. See Engel and Rogers (2004) for the cities used and the product items included in each goods category. Note: positive values imply price divergence; negative values imply price convergence over the period.

familiar pricing to market measure, PTM.[18] As with the CES price indexes in our model, changes in the set of varieties available in the market will affect this market average. In fact, the EIU notes in its literature that its price measures could be affected by such shifts in the extensive margin: "As governments welcome foreign investment and open up their markets to international companies, so the variety and availability of imported products improves."

Fig. 3 shows the changes in price dispersion for different subperiods and eight different product groups. It indicates that for all eight groups of goods there was a fall in price dispersion in the early 1990s, and this was followed by a period of stasis or even worsening price dispersion after 1998. The top line of Table 2 confirms the observation for the average over all goods, that there were periods with strikingly different degrees of price convergence.[19] Other recent papers support this general conclusion (see the European Commission, 2002; Baye et al., 2002; Lutz, 2002).[20]

[18] Other assumptions must be made to draw a correspondence between the two country model and our multicountry data set. The model assumes that each country produces a country-specific home good, implying each good is exported by one country and imported by the other. Our data set includes more than two goods, of course. We assume each good can be categorized as being either an H or F good based on whether the home country is a net exporter or importer and construct our empirical price dispersion measure as an average of the price wedges across all of these goods. Further, more than one country is likely to be an exporter of some varieties of each good in the data set. We note that the direction of our model's theoretical prediction would still hold in the absence of complete specialization, provided there is some degree of specialization, where one country produces more varieties of a good than does the other country. Another subtle difference is the fact that our empirical measure of price dispersion is constructed from price deviations that are squared to prevent positive deviations for some goods from canceling negative deviations for other goods. The model-based measure of price dispersion does not need to square deviations because the country specialization structure of the model implies all home good exports are more expensive in the importing country than at home. Thus, there is a monotonic relationship between the two measures. Note that our price indexes by definition are free of love of variety effects, which certainly would not be present in the EIU price data.

[19] The fact that this finding continues to hold in our extended data set through 2004 suggests that it is likely not just a temporary byproduct of transition to new currency units at the onset of the monetary union.

[20] This result is consistent with the findings of the European Union's "Internal Market Scoreboard" (available at http://europa.eu.int/comm/internalmarket/score/index) that price differences persist across Europe for general grocery and household items. However, some microlevel studies do find convergence to the law of one price in particular industries for narrowly defined goods, such as particular brands of autos and televisions (see Imbs et al., 2004; Goldberg and Verboven, 2005). Our finding of greater price dispersion in recent years is a distinct issue from the evident lack of convergence in European national inflation rates: for example, divergent inflation rates may still be associated with convergence in price levels if the higher rates of change are in countries that initially had low price levels.

Table 4
OLS estimates: change in bilateral price dispersion in euro area

	1992–1998 period		1998–2002 period	
	(1)	(2)	(3)	(4)
ExtMargin	0.514***(0.154)	0.697*** (0.213)	0.130(0.065)*	0.448*** (0.101)
ExtMargin * Dum_CP		−0.081 (0.146)		−0.271*** (0.090)
ExtMargin * Dum_PP		−0.211 (0.180)		−0.418*** (0.103)
Distance	−77.3*** (22.1)	−64.0** (27.7)	21.9 (18.4)	19.1 (19.5)
Constant	−0.050* (0.026)	−0.075** (0.034)	0.012 (0.016)	−0.039* (0.019)
R^2	0.290	0.317	0 091	0.358
No. of country pairs	45	45	45	45

Notes: OLS estimation, where the dependent variable is the change in bilateral price dispersion over each period across (45) individual country pairs in the Euro zone. ExtMargin, the extensive margin variable for each country pair, is defined as the share of total bilateral trade in 1998 or 2002 of the ("least traded") goods that accounted for 10% of this trade in 1992 or 1993, depending on data availability. Dum_CP and Dum_PP are dummies for core–peripheral or peripheral–peripheral country pairs, respectively; see notes to Table 2. Standard errors in parentheses. Variables significant at 10%, 5%, and 1% indicated by *, **, and ***, respectively.

Data sources: price dispersion figures based on EIU Citybase data. Extensive margin figures based on bilateral trade data from OECD International Trade by Commodity Statistics, SITC rev. 3, disaggregated to the 4-digit level.

The extensive trade margin is measured using the metric of Kehoe and Ruhl (2002), as the share of trade represented at the end of the period by the set of least traded goods that initially represented 10% of trade in the base year of 1992 (or in 1993 in some cases depending on data availability). We construct these measures from OECD data on International Trade by Commodity Statistics (ITCS), disaggregated at the 4-digit SITC product level. The regressions also include geographic distance between countries as a control variable, as is common in gravity regressions.

We consider two time periods: first 1992–1998, corresponding to the period of implementation of the Single Market Program in the early 1990s but prior to monetary union, and second 1998–2002, corresponding to the period after formation of the European Monetary Union. The first period begins in 1992 and the second period ends in 2002 because of the absence of bilateral product-disaggregated trade data for most countries before and after these years.[21]

Results are reported in Table 4, where columns 1 and 2 pertain to the early time period and columns 3 and 4 pertain to the later period. Recall from Table 2 that the early period was characterized by significant price convergence on average, whereas the second period was characterized by price divergence on average. Nonetheless, in each of the periods, the estimate for the effect of the extensive margin is significantly positive, with a p-value less than 1% in the early sample and 5.2% in the latter sample. This indicates that our model's prediction regarding the relationship between the two variables finds empirical support throughout the sample, robust to the fact that the outcomes for price convergence were different between the two periods.

If prices nonetheless converged during the pre-EMU period, it must be that something different was happening during this period. We get some clue regarding this issue since the coefficient on distance is negative and highly significant in the first period, but it is insignificant (and with a positive point estimate) in the later period. Distance is often included in gravity regressions to reflect iceberg transport costs, which are isomorphic in our model to the per-unit costs τ_i. The negative coefficient

[21] The EIU price data are not available before 1990.

could indicate a reduction in trade costs due to improved shipping technology or the reduction in some other trade cost related to distance. This result itself is new to the literature.[22]

An additional finding in the regressions is that the result for the extensive margin above works mainly through a particular subset of countries. Columns 2 and 4 of the table introduce dummies to distinguish "core" and "periphery" countries in the bilateral observations, where Finland, Ireland, Portugal, and Spain as peripheral countries, and Austria, Belgium, France, Germany, Italy, Luxemburg, and the Netherlands as the core countries. This distinction makes sense based on both geography and the extent to which lowered trade barriers have had time to foster stronger cross-country trade links. The former countries are located in the outer areas of Europe. Moreover, Ireland joined in 1973, Portugal and Spain in 1986, and Finland in 1995, well after the core members formed the European Union in 1957.[23] Table 2 shows that price divergence during the latter period was greatest among the core countries. In fact, for these countries the increase in price dispersion since 1998 has almost fully offset the decline in price dispersion experienced in the early 1990s. In contrast, the peripheral countries experienced a much greater decline in price dispersion in the early 1990s and a much weaker increase in dispersion with core countries since adoption of the euro. Further, the regressions in Table 4 show that the extensive margin effect on price dispersion is significant only for the case of core countries trading with other core countries. The degree of significance of this relationship is very high for both time periods.

6. Conclusion

Empirical evidence arising from recent experiences in Europe and North America suggest that international price convergence and trade volume expansion, two common measures for the integration of goods markets across countries, need not coincide. This paper proposes a model of economic integration which can explain a range of varied relationships between price and quantities. Firstly, the model highlights the distinction between trade policies that focus on reducing fixed costs of trade and those that focus on per-unit costs of trade like tariffs. Secondly, as an alternative to heterogeneity in productivity, the model allows for heterogeneity in terms of iceberg trade costs, where the reason some goods are not traded is that these goods tend to have higher per unit costs of trade. The main prediction of the theoretical model is that cases where trade integration works more heavily through the extensive margin of goods not previously traded are the cases where price convergence is likely to be weakest. Empirical work supports this theoretical relationship and indicates this way of thinking about integration could be useful in understanding the recent experiences of integration in Europe and elsewhere.

Our theoretical research also raises a basic question regarding the appropriate metric for gauging international integration policies, analogous to that discussed in Feenstra (1994) for computing import price indexes. Past research has tended to prefer price-based measures since quantity-based alternatives are affected by factor endowments and opportunities for scale economies. But our model indicates that standard price metrics might also be problematic, if integration takes place at the extensive margin and if new goods are different from those previously traded.

[22] The European Commission (1996a) estimates that the elimination of border controls and reduced transit times in the transition towards a Single European Market significantly reduced the freight costs of cross-border transit. The European Commission (1996b) finds that air transportation costs also fell with liberalization, allowing greater access to foreign carriers and new startups.

[23] Austria did not join the European Union until 1995 but is treated as a core country because of its long-standing trade links with Germany and its central geographic position within Europe.

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Appendix

A.1. Derivation of consumption aggregate Eq. (1) with endogenous bias weights

To derive Eq. (1), define consumption by domestic residents of the home good and foreign traded good as c_{Hi}, $i \in [0,1]$ and C_{FTi}, $i \in [0, 1-n^*]$, respectively. We index all varieties available for consumption in the domestic country by j on the interval $[0, 2-n^*]$, and order consumption as $c_j = c_{Hi}$, for $j = i \in [0, 1]$ and $c_j = c_{Fi}$ for $j = i+1$, $j \in [1, 2-n^*]$, $i \in [0, 1-n^*]$. Accordingly, assuming the elasticity of substitution between all varieties, domestic or foreign, is the constant ϕ, we define aggregate consumption as

$$
\begin{aligned}
\mathrm{C}^{\frac{\phi-1}{\phi}} &= \left(\frac{1}{2-n^*}\right)^{\frac{1}{\phi}}\left[\int_0^1 (c_i)^{\frac{\phi-1}{\phi}}di + \int_1^{2-n^*}(c_i)^{\frac{\phi-1}{\phi}}di\right] \\
&= \left(\frac{1}{2-n^*}\right)^{\frac{1}{\phi}}\left(\frac{1}{1}\right)^{\frac{1}{\phi}}\int_0^1 (c_i)^{\frac{\phi-1}{\phi}}di + \left(\frac{1-n^*}{2-n^*}\right)^{\frac{1}{\phi}}\left(\frac{1}{1-n^*}\right)^{\frac{1}{\phi}}\int_1^{2-n^*}(c_i)^{\frac{\phi-1}{\phi}}di \\
&= \left(\frac{1}{2-n^*}\right)^{\frac{1}{\phi}}(C_{\mathrm{H}})^{\frac{\phi-1}{\phi}} + \left(\frac{1-n^*}{2-n^*}\right)^{\frac{1}{\phi}}(C_{\mathrm{FT}})^{\frac{\phi-1}{\phi}} \\
&= (\theta[n^*])^{\frac{1}{\phi}}(C_{\mathrm{H}})^{\frac{\phi-1}{\phi}} + (1-\theta[n^*])^{\frac{1}{\phi}}(C_{\mathrm{FT}})^{\frac{\phi-1}{\phi}},
\end{aligned}
$$

where $\theta[n^*] \equiv \frac{1}{2-n^*}$, $1-\theta[n^*] \equiv \frac{1-n^*}{2-n^*}$, $0 \le \theta[n^*] \le 1$.

A.2. Derivation of labor market equilibrium condition Eq. (26)

Labor market equilibrium in the domestic country requires that labor employed in production of nontraded and traded home varieties *plus* labor employed to cover the fixed costs of exporting equal the (exogenous) domestic labor supply L_{H}:[24]

$$\int_0^n l_{\mathrm{H}i}di + \int_n^1 l_{\mathrm{H}i}di + (1-n)f_X = L_{\mathrm{H}}$$

[24] When all home goods are nontraded, i.e., $n = 1$, then no labor is employed to cover fixed costs of exporting.

Substituting for l_{Hi} with the production function Eq. (13):

$$\int_0^n \frac{y_{Hi}}{A_i} di + \int_n^1 \frac{y_{Hi}}{A_i} di + (1-n) f_X = L_H \text{ or}$$

$$\int_0^n \frac{c_{Hi}}{A_i} di + \int_n^1 \frac{c_{Hi} + \frac{c^*_{Hi}}{1-\tau_i}}{A_i} di + (1-n) f_X = L_H$$

since $y_{Hi} = c_{Hi}$ for $i \in [0, n], y_{Hi} = c_{Hi} + \frac{c^*_{Hi}}{1-\tau_i}$ for $i \in [n, 1]$. Substituting with $c_{Hi}/C_H = (p_{Hi}/P_H)^{-\phi}$ and $c^*_{Hi}/C^*_{HT} = (1-n)^{-1} (p^*_{Hi}/P^*_{HT})^{-\phi}$ gives

$$\int_0^n \frac{C_H}{A_i}\left(\frac{p_{Hi}}{P_H}\right)^{-\phi} di + \int_n^1 \left(\frac{1}{A_i}\right)\left[C_H\left(\frac{p_{Hi}}{P_H}\right)^{-\phi} + \frac{1}{1-\tau_i}\left(\frac{1}{1-n}\right) C^*_{HT}\left(\frac{p^*_{Hi}}{P^*_{HT}}\right)^{-\phi}\right] di + (1-n) f_X = L_H.$$

Using Eqs. (14) and (15) in turn to substitute for p_{Hi}, p^*_{Hi} and Eqs. (17) and (20) to substitute for the definitions of $\tilde{A}, \tilde{A}_{(1-\tau)T}[n]$ gives

$$W = \left(L_H - (1-n) f_X\right)^{-1/\phi}\left(\frac{\phi-1}{\phi}\right)\left[\left(\frac{P_H C_H}{(P_H)^{1-\phi}}\right)(\tilde{A})^{\phi-1} + \left(\frac{P^*_{HT} C^*_{HT}}{(P^*_{HT})^{1-\phi}}\right)(\tilde{A}_{(1-\tau)T}[n])^{\phi-1}\right]^{\frac{1}{\phi}}.$$

Substituting for P_H, P^*_{HT} with Eq. (23), Eq. (24), and canceling terms gives

$$W = (L_H - (1-n) f_X)^{-1/\phi}\left(\frac{\phi-1}{\phi}\right)\left[\left(\frac{P_H C_H}{\left(\frac{\phi}{\phi-1}\frac{W}{\tilde{A}}\right)^{1-\phi}}\right)(\tilde{A})^{\phi-1} + \left(\frac{P^*_{HT} C^*_{HT}}{\left(\frac{\phi}{\phi-1}\frac{W}{\tilde{A}_{(1-\tau)T}[n]}\right)^{1-\phi}}\right)(\tilde{A}_{(1-\tau)T}[n])^{\phi-1}\right]^{\frac{1}{\phi}},$$

which reduces to Eq. (26).

A.3. Model implications for trade volume

Balanced trade (see Eq. (27)) implies that exports and imports as ratios of total aggregate consumption are equal:

$$\frac{P^*_{HT} C^*_{HT}}{PC} = \frac{P_{FT} C_{FT}}{PC}.$$

Relative demand conditions imply:

$$\frac{P^*_{HT} C^*_{HT}}{PC} = (1-\theta^*[n])\left(\frac{P^*_{HT}}{P^*}\right)^{1-\phi}, \frac{P_{FT} C_{FT}}{PC} = (1-\theta[n^*])\left(\frac{P_{FT}}{P}\right)^{1-\phi},$$

implying that exports relative to consumption – which equals GDP in our single period model – depend on two factors: (i) the relative import price for foreign residents, P^*_{HT}/P^*, and (ii) the foreign bias coefficient for imported home varieties, $1-\theta^*[n]$. A decrease in the relative price of imports and/or an increase in the foreign bias towards imports raise the home country's exports.

How does trade liberalization affect exports? We proceed by considering first a reduction in iceberg costs and then a reduction in fixed costs. We assume a symmetric steady state which because the foreign aggregate price level is normalized to unity, implies $P=P^*=1$. We also assume that changes are symmetric across countries and lead to equal declines in n, n^* and hence increases in the number of tradable varieties. Because of the symmetric nature of the experiment, relative aggregate prices remain constant and equal to unity as well. Hence, we may infer the change in relative prices solely from the change in P^*_{HT} given by Eq. (24):

$$P^*_{\mathrm{HT}} = \frac{\phi}{\phi-1}\left(\frac{W}{\tilde{A}_{(1-\tau)\mathrm{T}}[n]}\right).$$

For reference, we express this price in terms of the relevant productivity averages when productivity is heterogeneous

$$P^*_{\mathrm{HT}} = \frac{\phi}{\phi-1}\left(\frac{W}{\alpha_{1-\tau}\,\alpha_A\tilde{\beta}_{A\mathrm{T}}[n]}\right),$$

and when transport costs are heterogeneous

$$P^*_{\mathrm{HT}} = \frac{\phi}{\phi-1}\left(\frac{W}{\alpha_{1-\tau}\alpha_A\tilde{\beta}_{(1-\tau)\mathrm{T}}[n]}\right).$$

A fall in iceberg costs (increase in $\alpha_{1-\tau}$) directly reduces the price of goods exported to foreign residents, increases demand, and raises the home country's level of exports. But there is an opposing effect, as falling n and increased trade at the extensive margin imply varieties with either lower effective productivity or higher transport costs become traded, raising the average price of imported varieties.[25] Wages W rise as well because of increased demand for labor to produce the greater export volume. The effect on θ^* tends also to raise exports: as more varieties become traded, the weight placed on the imported good in the foreign price index increases, and the relative demand by foreign residents for the imported good in their consumption basket rises.[26]

With a fixed cost reduction, there is no direct effect on the relative price of exports to foreigners. But the decline in n also implies varieties with lower effective productivity or higher transport costs become traded, raising the average price of the exported good.[27] In addition, W falls in this case since less labor is needed to cover the fixed costs of exporting. The effect on θ^* works in the direction of raising home exports, as the increase in imported varieties raises the demand by foreigners for home country exports.

The theoretical ambiguities of the effects of trade liberalization on trade volume shares are resolved in the simulation analysis reported in Section 4.

[25] Mathematically, since $\partial\tilde{\beta}_{A\mathrm{T}}/\partial n>0$, $\partial\tilde{\beta}_{(1-\tau)\mathrm{T}}/\partial n>0$, the fall in n implies that $\tilde{\beta}_{A\mathrm{T}}[n]$, $\tilde{\beta}_{(1-\tau)\mathrm{T}}[n]$ both decline.

[26] Since $\partial\theta^*/\partial n>0$ (recall $\theta^*[n]=1/(2-n)$), a decrease in n, i.e., an increase in tradables varieties, decreases θ^* and raises $1-\theta^*$.

[27] Mathematically, since $\partial\tilde{\beta}_{A\mathrm{T}}/\partial n>0$, $\partial\tilde{\beta}^*_{(1-\tau)\mathrm{T}}/\partial n>0$, the fall in n implies the terms in the denominator, $\tilde{\beta}_{A\mathrm{T}}[n]$, $\tilde{\beta}_{(1-\tau)\mathrm{T}}[n]$, decline.

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