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FIRM HETEROGENEITY AND INTERNATIONAL TRADE[†]

Endogenous Variety and the Gains from Trade

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There is a common perception that the gains from trade are larger than what quantitative general-equilibrium models of trade can explain. A recurring goal in the trade literature has been to find new channels through which such models can generate larger gains. A prominent example is Paul Romer (1994), where trade allows for the consumption of a wider variety of goods, and this generates additional benefits not included in standard calculations. We start in Section I by showing that the connection postulated by Romer between trade liberalization and increasing variety is present in the data by focusing on the experience of Costa Rica from 1986 to 1992. Romer performed a numerical exercise to show, in response to higher tariffs, that welfare losses operating through reduced variety may be an order of magnitude larger than losses in standard trade analysis (the Harberger Triangles). In Section II we use our Costa Rican data to evaluate this result by applying a method introduced by Robert C. Feenstra (1994) to compute the gains from increased imported variety for the 1986–1992 period. We find very small gains, and show that this is due to strong heterogeneity across imported goods. Upon trade liberalization, the new varieties are imported in small quantities, and hence contribute little to welfare. We refer to this effect as the effect of "curvature" in weakening the variety gains from trade. In Section III we relate this result to recent models of firm-level heterogeneity and derive a simple formula that shows the effect of curvature.

These results do not take into account the effect of trade liberalization on domestic variety. But it seems reasonable to think that an increase in import competition would cause a decline in domestic variety as domestic firms exit. In fact, the evidence does suggest that trade liberalization leads to exit by domestic firms (James Tybout 2003). Consistent with this, domestic variety is endogenous in most recent models and falls with a decline in trade costs.[1] In Section IV we present a model with firm-level increasing returns, differentiated goods, monopolistic competition, endogenous variety, and free entry to show that, as in Richard E. Baldwin and Rikard Forslid (2004), *total* variety (domestic plus imported) can either increase, decrease, or remain constant with trade liberalization. More importantly, the gains from trade do not depend on what happens to total variety. In fact, we find that the real wage is ultimately dependent on the ratio of imports to total expenditure with an elasticity that is the same across a range of models. We will argue that, conditional on the estimated elasticities of trade with respect to trade costs, the implications of models with increasing returns, endogenous variety, free or restricted entry, and heterogeneity (or not) across firms have exactly the same implications for welfare gains from trade liberalization as traditional models.[2] In our view,

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[1] See Marc J. Melitz (2003), Thomas Chaney (2007), Jonathan Eaton, Samuel Kortum, and Francis Kramarz (2007), and Arkolakis (2008).

[2] This assertion will be valid under the standard assumption that productivities are distributed Pareto, but may not be valid under alternative distributions.

the contribution of the new trade models is not to provide new channels for gains from trade, but rather to explain the levels and microfoundations of trade that we observe.

I. Variety and Tariffs in Costa Rica

Our dataset consists of Costa Rican imports of each of 1,338 products from up to 111 countries from 1986 to 1992. The product categories correspond to the NAUCA II classification used by Central American countries over this period (see Klenow and Rodríguez-Clare (1997) for an explanation of this classification system and our data sources). We have data on kilos and US dollars of imports (c.i.f.) for each product-country-year, as well as the tariff applying to each product-year.

We take country of origin as the demarcation of a variety (i.e., cars from the United States are a different variety than cars from Germany or Japan) and think of total variety for a good as the number of countries from which there were imports in a product category.[3] In our dataset, variety rose from an average of 8.2 in a category in 1986 to 11.5 in 1992 for the 369 consumer goods, and from 7.9 to 8.8 for the 969 intermediate and capital goods (hereafter just intermediate goods). Weighting each product category by total dollar imports, variety rose from 19.1 to 24 for consumer goods, and from 13.6 to 15.6 for intermediate goods. Over this period, average tariffs fell from 48.8 percent to 22.5 percent for consumer goods, and from 17.1 percent to 12.9 percent for intermediate goods.[4] Dollar-weighted tariffs fell from 43.3 percent to 20.3 percent for consumer goods, and from 11.2 percent to 10.0 percent for intermediate goods. Consumption goods imports rose from 5.4 percent of GDP in 1986 to 8.1 percent in 1992. The share of intermediate goods imports rose from 23.3 percent to 27.2 percent of GDP over the same period.

Before considering the effect of tariff reductions on variety at the detailed product level, it is useful to examine the underlying premise that greater market size boosts variety, as implied by fixed costs of importing a given product from a given country.

Table 1—The Impact of Market Size on Variety

	Consumer		Intermediate	
Market size	0.264	0.121	0.257	0.121
	(0.005)	(0.008)	(0.003)	(0.004)
Year dummies	Yes	Yes	Yes	Yes
Product dummies	No	Yes	No	Yes
$\bar{R}^2$	0.479	0.883	0.465	0.882
No. of observations	2,583		6,783	

Table 1 presents the results from regressing variety on market size for consumer and intermediate goods, respectively. Each observation is a product-year, e.g., cars in 1990. The dependent variable is the natural log of variety, while the independent variable is the natural log of market size (imports of a product summed across all countries in a year). Year effects are included to deal with general inflation in dollar imports. The results show that variety is greater in larger markets, both for consumer and intermediate goods. Instead of larger markets pulling in more varieties due to fixed costs, however, exogenously larger categories could include more countries simply because they are more aggregated. To explore this possibility, we added product dummies to the regression. As shown in Table 1, the elasticity is roughly halved but it remains economically and statistically significant. The fact that the elasticity of variety with respect to market size is well below one, however, implies either that fixed costs are increasing in market size (albeit less than proportionately) or ever-less-important varieties are imported by bigger markets.[5]

With some confidence that market size affects variety, we examined whether products with falling tariffs see rising variety. Our identifying assumption is that product differences in tariff changes are exogenous. Table 2 presents the results from regressing the natural log of variety on the natural log of the gross tariff rate. Including year and product dummies, we find

[3] See Klenow and Rodríguez-Clare (1997) for a discussion of the limitations of this measure of variety.

[4] The standard deviation of tariff rates also fell sharply, from 37 percent to 12 percent for consumer goods, and from 17 percent to 7 percent for intermediate goods.

[5] Measuring market size as country GDP, David Hummels and Klenow (2002) similarly found a strong relationship between market size and import variety. And Eaton, Kortum, and Kramarz (2007) document that more French firms export to larger economies.

an economically and statistically significant negative association between variety and tariffs. Table 2 also shows that lower imports go along with higher tariffs for a product, consistent with the hypothesis that higher tariffs reduce variety by shrinking the market.

Table 2—The Impact of Tariffs on Variety and Market Size

	Consumer		Intermediate	
	Variety	Market size	Variety	Market size
Tariffs	−0.818	1.832	−0.289	−0.540
	(0.111)	(0.291)	(0.102)	(0.291)
$\bar{R}^2$	0.873	0.873	0.867	0.847
No. of observations	2,583		6,783	

II. Variety Gains in Costa Rica

Feenstra (1994) shows how to adjust the standard import price index for changing variety, including our case, where marginal varieties appear less important than inframarginal ones. We refer to this adjustment as the Feenstra Ratio and denote it by F, with

$$F = \left(\frac{\sum_{\Omega'} v_i' / \sum_{\Omega' \cap \Omega} v_i'}{\sum_{\Omega} v_i / \sum_{\Omega' \cap \Omega} v_i} \right)^{-1/(\sigma-1)}.$$

Table 3—Feenstra Ratios

[1992 Imports / 1986 Imports]	Consumer	Intermediate
All country-product pairs	2.869	1.904
Common country-product pairs	2.829	1.904
All / Common	1.014	1
Feenstra Ratio with $\sigma = 6$	0.997	1

Here, v_i are imports from country-product pair i in 1986 and Ω is the set of country-product pairs imported in 1986; the corresponding values with primes refer to 1992.

Table 3 has the ingredients of the Feenstra Ratio as well as the ratio itself. The first row says that current dollar imports grew by a factor of 2.87 for consumer goods and 1.90 for intermediate goods from 1986 to 1992. But the next row indicates that imports grew almost as much for "common" country-product pairs (those with imports in both 1986 and 1992): by a factor of 2.83 for consumer goods and 1.90 for intermediate goods. The following row says that overall consumer imports grew 1.4 percent faster than for common country-product pairs, whereas overall intermediate imports grew at the same rate as for common pairs. For the Feenstra Ratios we use $\sigma = 6$ based on the estimates in Christian Broda and David E. Weinstein (2006) for higher and lower levels of aggregation than in the Costa Rican product categories. Using this value, the Feenstra Ratio is 0.997 for consumer goods and 1 for intermediates, suggesting a very modest downward adjustment of 0.3 percent to the price index for consumer imports, and none at all for intermediates.

How can we reconcile such modest adjustments with the surge in variety of about 25 percent for consumer goods (from 19.1 to 24) and 15 percent for intermediate goods (from 13.6 to 15.6)? The answer is that the new varieties must not be as important as incumbent ones.[6] For example, adding South Korea as a source of cars may not be as important as already having access to cars from Japan, the United States, and Germany.[7]

III. The Role of Curvature

Consider a continuum of foreign varieties indexed by s and ordered in terms of decreasing quality or increasing marginal cost. With CES preferences and an elasticity of substitution $\sigma > 1$, there will be some n such that all varieties $s \in [0, n]$ are imported. This n will be lower than

[6] Looking at trade liberalization episodes, Timothy J. Kehoe and Kim J. Ruhl (2003) found that varieties that were traded little or not at all before liberalization contributed a lot to new trade. Arkolakis (2008) similarly showed that the US tariff declines associated with NAFTA led to an increase in imported variety from Mexico, but that the new varieties were imported in relatively small quantities.

[7] Our results may seem at odds with those of Broda and Weinstein (2006). But the two exercises are quite different. Broda and Weinstein (2006) quantify the gains from the introduction of new varieties in the rest of the world that are eventually imported into the United States. This is very different from the effects of trade liberalization. Whereas greater import variety in response to trade liberalization entails consuming less desirable varieties (that is why they were not imported before), an expansion of import variety in time is more likely to be associated with the introduction of important (inframarginal) varieties abroad, which are more likely to contribute significantly to welfare.

total foreign variety if importing entails a fixed cost. Consider an increase in imported variety from n to n'. Taking the log derivative of the Feenstra ratio for this case with respect to n', we find

$$(1)\quad \frac{\partial \ln F}{\partial \ln n'} = -\frac{1}{\sigma - 1}\left(\frac{v(n')}{(1/n')\int_0^{n'} v(s)\, ds}\right).$$

The first term is the standard elasticity of welfare with respect to variety (love of variety) under CES preferences. The second is an adjustment for "curvature." A low value for this term implies that marginal varieties have either low quality (preference) parameters or high international prices, so the gains from increased variety are smaller.

A nice expression for this curvature adjustment can be obtained if we assume that the preference parameter, quality, or productivity is distributed Pareto. Under the productivity interpretation and with monopolistic competition, domestic prices of foreign varieties will be proportional to the inverse of productivity, ϕ, and $v(s)$ will be proportional to $\phi(s)^{\sigma-1}$, $v(s) = A\phi(s)^{\sigma-1}$ for some $A > 0$. Assume that there is a continuum of goods with exogenous measure M and $\Pr(\phi < \tilde{\phi}) = G(\tilde{\phi}) \equiv 1 - (b/\tilde{\phi})^{\theta}$, where $\tilde{\phi} \geq b > 0$ and $\theta > \sigma - 1$. Note for future reference that an increase in θ implies less dispersion in that more of the productivities are closer to the minimum b. If the fixed importing cost is the same across varieties, then profits will be increasing in productivity ϕ, and there will be a ϕ^* such that all inputs with $\phi > \phi^*$ are imported. Imported variety is then $n = M \times \Pr(\phi > \phi^*)$, and using (1) reveals that

$$(2)\quad \varepsilon \equiv -\frac{\partial \ln F}{\partial \ln n} = \frac{1}{\sigma - 1} - \frac{1}{\theta}.$$

Note that high curvature (low θ) decreases the impact of love of variety.[8]

As mentioned in Section II, in Costa Rica the mean (weighted) variety for consumer goods went from 19.1 in 1986 to 24 in 1992, an increase of 25.6 percent. Given the result in the previous section that the Feenstra Ratio for this period is 0.997 (a welfare gain of 0.3 percent thanks to increased variety for $\sigma = 6$), we have that $0.256\varepsilon = 0.003$. Using the expression in (2) for ε and $\sigma = 6$, we get $\theta = 5.3$. By comparison, Eaton, Kortum, and Kramarz (2007)—henceforth EKK—use data on exports and domestic sales by French firms to estimate that $\theta/(\sigma - 1) = 1.5$. If $\sigma = 6$, this means $\theta = 7.5$, just a bit lower than the central value for θ (i.e., $\theta = 8$) in Eaton and Kortum (2002). The Costa Rican experience suggests somewhat greater curvature than this. This difference matters for the welfare implications of the observed increase in variety in Costa Rica. If instead of $\theta = 5.3$ we used the lower curvature associated with $\theta = 7.5$, then $\varepsilon = 0.067$, and the variety gains would be 1.7 percent rather than our 0.3 percent. Of course, this difference could be due to the fact that in the Costa Rican data we are interpreting variety with country of origin, whereas in EKK variety is associated with the number of firms that serve a particular market.

IV. Endogenous Domestic Variety and Free Entry

The previous discussion has taken foreign variety to be exogenous and simply performed a comparative statics exercise with respect to variety. We also ignored any effects of trade liberalization on the variety of goods offered by domestic firms. What happens to total available variety (domestic plus foreign) following trade liberalization? Baldwin and Forslid (2004) address this question through a modified Melitz (2003) model with two asymmetric countries under exogenous wages. They show that if the fixed cost of supplying the home market is higher for foreign than for domestic firms, then total available variety *falls* with a decline in the costs of trade. They refer to this as the "anti-variety effect" of trade liberalization. Here, we present a model with endogenous wages and $N > 2$ countries to generalize the Baldwin and Forslid (2004) result. More important, we show that, conditional on the effect of trade liberalization

[8] This result does not depend on the implicit assumption that there is a unique fixed cost for all foreign varieties. In separate work we have established that if the fixed cost is distributed Pareto and is independent of ϕ, then this result remains valid.

on imports, all major quantitative models of trade deliver the same gains.[9]

As above, there is a continuum of goods, and preferences are CES with an elasticity of substitution $\sigma > 1$. We denote the exporting country by i and the importing country by j, where $i,j = 1,\ldots,N$. Given a measure L_j of identical consumers in country j, the demand for a firm with productivity ϕ from country i charging a price $p_{ij}(\phi)$ in country j is $x_{ij}(\phi) = p_{ij}(\phi)^{-\sigma} P_j^{\sigma-1} w_j L_j$, where w_j is the wage and P_j is the price index.[10] Each firm must pay a fixed cost (in terms of labor in the destination country) to enter a particular market that varies across country pairs, f_{ij}, and also incurs iceberg transportation costs $\tau_{ij} \geq 1$ with $\tau_{ii} = 1$. Firms from i with $\phi \geq \phi_{ij}^*$ will export to market j. The cut-off productivities ϕ_{ij}^* are determined by equating marginal profits to zero. This yields

$$(3)\qquad (\phi_{ij}^*)^{\sigma-1} = \frac{\sigma f_{ij}}{\left(\frac{\sigma}{\sigma-1}\tau_{ij} w_i\right)^{1-\sigma} L_j P_j^{\sigma-1}}.$$

Firms have to pay a fixed entry cost, f_e, in order to enter the market and draw a productivity realization. New entrants draw their productivity from a Pareto distribution, as above.[11] If a firm gets a productivity draw below ϕ_{ii}^*, it exits immediately without operating. Because of free entry, in equilibrium, expected profits of a firm must be equal to entry costs. In other words, the product of the probability of getting a productivity draw above ϕ_{ii}^* and the average profits must equal the entry cost. The free entry condition, together with the labor market clearing condition, implies that the equilibrium number of firms producing in country i is

$$(4)\qquad N_i = \frac{(\sigma - 1) b_i^\theta / (\phi_{ii}^*)^\theta}{\theta \sigma f_e} L_i.$$

Notice that total export sales from country i to j are:

$$(5)\qquad T_{ij} = \underbrace{\left(\frac{\phi_{ii}^*}{\phi_{ij}^*}\right)^\theta N_i}_{\text{firms}} \quad \underbrace{w_j f_{ij} \frac{\sigma\theta}{\theta - \sigma + 1}}_{\text{average sales of operating firms}}.$$

Define the fraction of total income of country j spent on goods from country i by λ_{ij}. Using the definition of total sales from i to j and equation (4), we have:

$$(6)\qquad \lambda_{ij} = \frac{L_i b_i^\theta (\tau_{ij} w_i)^{-\theta} f_{ij}^{1-\theta/(\sigma-1)}}{\sum_\upsilon L_\upsilon b_\upsilon^\theta (\tau_{\upsilon j} w_\upsilon)^{-\theta} f_{\upsilon j}^{1-\theta/(\sigma-1)}}.$$

Remarkably, this expression is identical to that of Chaney (2007), who does not assume free entry, but rather a predetermined number of potential suppliers. Equation (6) is quite similar to the analogous equation in Eaton and Kortum (2002). In particular, market share changes in the same elasticity with respect to the cost factors, τ_{ij} and w_i.

Using equation (5) and the definition of λ_{ij} that implies $T_{ij} = \lambda_{ij} w_j L_j$, it follows that the measure of firms from country i selling to j, M_{ij}, can be written as:

$$M_{ij} = \lambda_{ij} \frac{L_j}{f_{ij} \frac{\sigma\theta}{\theta - \sigma + 1}}.$$

Thus, total varieties offered in country j are given by:

$$\sum_\upsilon M_{\upsilon j} = \frac{L_j}{f_{jj} \frac{\sigma\theta}{\theta - \sigma + 1}} + \frac{L_j}{\frac{\sigma\theta}{\theta - \sigma + 1}} \sum_{\upsilon \neq j} \lambda_{\upsilon j} \left(\frac{1}{f_{\upsilon j}} - \frac{1}{f_{jj}}\right).$$

This is a generalization of the Baldwin and Forslid (2004) result. In particular, increasing any $\lambda_{\upsilon j}$ (trade liberalization) has an anti-variety effect if and only if $f_{\upsilon j} > f_{jj}$, $\upsilon \neq j$. Intuitively, if $f_{\upsilon j} > f_{jj}$, then the marginal variety from country υ entails a lower price than the marginal domestic variety, so for each new foreign variety more than one domestic variety is displaced.

[9] One drawback of the model we present here is that we treat tariffs as transportation costs. This does not seem problematic for our purposes. See Demidova and Rodríguez-Clare (2007) for a full welfare analysis in a Melitz-type model for a small-economy.

[10] Here $P_j^{1-\sigma} = \sum_\upsilon \int_0^\infty p_{\upsilon j}(\phi)^{1-\sigma} M_{\upsilon j} \mu_{\upsilon j}(\phi)\, d\phi$, and $\mu_{\upsilon j}(\phi)$ is the density of productivities of firms from source country υ conditional on selling to country j, and $M_{\upsilon j}$ is the measure of firms from υ selling to j.

[11] We assume that the parameters of the model are such that $\phi_{ij}^* > \phi_{ii}^* > b_i, \forall i \neq j$.

Welfare for each consumer is given by $C_j = w_j/P_j$. Using (3) and (6) we can express real wages as

$$\frac{w_j}{P_j} = \lambda_{jj}^{-1/\theta} L_j^{1/(\sigma-1)} \times \left(\frac{b_j^{\theta} f_{jj}^{1-\theta/(\sigma-1)}}{f_e(\frac{\sigma}{\sigma-1})^{\theta}(\sigma)^{\theta/(\sigma-1)}} \frac{\sigma-1}{\theta-\sigma+1} \right)^{1/\theta}.$$

Consider, first, a closed economy, with $\lambda_{jj} = 1$. A larger population increases welfare with an elasticity of $1/(\sigma - 1)$. This is the standard result in models with love of variety and no heterogeneity, but differs from the results in Chaney (2007), EKK, and Arkolakis (2008), where this elasticity is $1/(\sigma - 1) - 1/\theta$. The reason why curvature does not affect the gains from size in our setup is that the number of goods (N_j) produced by an economy increases proportionately with L_j. Thus, contrary to models with no free entry, consumers in a country with larger populations are not forced to consume varieties produced with lower productivities. On the other hand, a decline in the fixed cost of operation, f_{jj}, increases welfare with elasticity $1/(\sigma - 1) - 1/\theta$. This shows how curvature decreases the variety gains associated with love of variety. A decline in the entry cost f_e, on the other hand, increases welfare with elasticity $1/\theta$. Here greater curvature entails a *higher* elasticity. The reason for this is that a lower f_e leads to more entry, while the number of operating firms remains the same. This entails more selection, the benefits of which are increasing with heterogeneity, or $1/\theta$.

Trade costs, τ_{ij}, and marketing costs, f_{ij}, affect real wages only indirectly through λ_{jj}. Thus, we can think of the welfare effects of trade liberalization as a reduction in λ_{jj}. In fact, in a proper calibration exercise, looking at the effects of trade liberalization involves matching λ_{jj} before and after the trade liberalization. In this model, λ_{jj} influences welfare with an elasticity of $-1/\theta$, exactly the same way as in Eaton and Kortum's (2002) model of pure Ricardian trade (with no variety), and also the same as in Chaney (2007) and Arkolakis (2008). In fact, it can also be shown that in Paul R. Krugman's (1980) model of trade, where varieties are homogenous and there is no variety effect, welfare is proportional to $\lambda_{jj}^{-1/(\sigma-1)}$. Noting that the relevant elasticity estimated in this model is $\sigma - 1$ rather than θ, the gains from trade are the same.

It is important to note that the result that trade liberalization affects welfare with an elasticity of $-1/\theta$ is valid, even if $f_{ij} \neq f_{jj}$, so that changes in λ_{jj} do affect total variety. To understand this, consider the case with $f_{ij} < f_{jj}$, so that an increase in λ_{ij} (with a corresponding decline in λ_{jj}) increases total variety. Given $f_{ij} < f_{jj}$, the varieties that enter from abroad have prices that are higher than the domestic ones that are displaced, and it turns out that this exactly offsets the gains associated with increased variety.

The broader implication of these results is that, given the estimated elasticities of trade flows with respect to trade costs, the volume of trade itself determines the associated gains. Contrary to what many have claimed, new trade models do not really offer new gains from trade, given observed trade levels.

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