Quantifying Variety Gains from Trade Liberalization

Peter J. Klenow and Andrés Rodríguez-Clare[1]
Graduate School of Business, University of Chicago

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Abstract

Standard estimates of the welfare losses from protection are on the order of only a few percent of GDP. Romer (1994) argues that a fall in the variety of goods available may raise the costs of protection by an order of magnitude. Consistent with Romer's hypothesis, we find that Costa Rica's 1986 to 1992 trade liberalization was accompanied by a surge in import variety. Using detailed data we find that a 1% larger market goes along with about .2% more variety of imported consumer and intermediate goods, and a 1% lower tariff goes along with an increase in variety of about .5%. We then calibrate a general equilibrium model in order to quantify the welfare gains from this variety expansion. The estimated welfare gains from trade liberalization are 50% larger when we take into account the impact of liberalization on variety. The effect of variety on welfare estimates is even more visible for the case of a 10% tariff. Under one of our scenarios we find that the welfare losses from a 10% tariff on both consumer and intermediate goods are 4 times larger when one takes into account the loss of variety.

1. Introduction

Traditional estimates of the welfare losses from protection are at most a few percentage points of GDP. For example, Tarr and Morkre (1984) estimate the total losses from protection to be around 0.26% of GDP in the United States. When protection levels are high and very uneven across sectors the implied welfare losses can be much higher, such as 9.5% of GDP in Brazil (for 1966) and 6.2% of GDP in Pakistan (for 1963) (see Balassa, 1971). But the point remains that the welfare losses from moderate, even protection are generally estimated to be small (see Lindert 1991 and Feenstra 1995).

Feenstra (1992) and Romer (1994) criticize this literature for assuming that the range of goods imported is not affected by the tariff. These authors suggest that a fall in the number of goods available could add substantially to the costs of protection. As Romer makes clear, when there are fixed costs of selling a good in a country (e.g., overhead related to dealing with an international supplier) the good will be imported only if profits cover these fixed costs. By reducing the market size for a good, a tariff reduces the profits that can be made from importing that good. A sufficiently high tariff may therefore imply not just lower imports, but no imports at all of a good. The result would be less variety in available consumer goods and less availability of specialized equipment and intermediate goods.

Romer performs a numerical exercise to show that the welfare losses arising from reduced variety may be an order of magnitude larger than those associated with the standard trade analysis (the Harberger Triangles). He finds that moving from free trade to a 10% tariff reduces welfare by 20% of GDP when the set of goods in use is allowed to fall, compared to only 1% of GDP when the set of inputs in use is fixed.

The purpose of this paper is twofold. First, we want to obtain evidence on whether market size and tariff rates affect the variety of goods imported. Second, we want to see how the quantitative welfare implications change once we take into account the effect tariffs have on variety. Our dataset consists of Costa Rican imports of 1,676 products from 115 countries over the seven years from 1986 to 1992. Our measure of variety is the number of countries from which a given product is imported. Costa Rican tariffs vary substantially across goods and years in our sample.

We find that the data is consistent with the view that higher tariffs and a smaller market limit variety. Based on these findings, we construct a general equilibrium model to quantify the impact of endogenous variety on the welfare gains from trade liberalization. We calibrate the model to the relevant features of our data for Costa Rica. A crucial parameter which we estimate for this calibration is the degree of substitutability between varieties; for a given change in variety, the welfare gain is smaller the greater the substitutability between new and existing varieties. We analyze the sensitivity of the results to variations in parameter values, and compare our findings to Romer's numerical exercise.

The rest of the paper proceeds as follows. In section 2 we describe the Costa Rican data and document the relationship between variety, market size, and tariffs. In section 3 we lay out the model. In section 4 we calibrate the model and quantify welfare gains. In section 5 we conclude with a discussion of the ways in which our estimates might understate the true welfare gains from trade liberalization.

2. Evidence

Our dataset consists of Costa Rican imports of each of 1,676 products from each of 115 countries over 1986 to 1992. The product categories correspond to the NAUCA II classification used by Central American countries over this period. This classification does not conform to the more widely used SITC. In terms of the number of categories the NAUCA II level of detail corresponds to 5 digit categories in the SITC. We have data on kilos and US dollars of imports (c.i.f.) for each product-country-year. Our source for this data is the Central Bank of Costa Rica, which applies a tariff (called *sobretasas*) to these imports, with the rate varying over time and across products. From the Costa Rican Finance Ministry we obtained data on Costa Rica's second tariff (called *tarifa*), which likewise varies across time and products. Our sample is bracketed by 1986 and 1992 since Costa Rica used different product classification systems before and after these years.

The product categories are sufficiently broad that a relatively stable 91% of all of the products were imported from at least one country in each year. We take country of origin as the demarcation of a variety. That is, we interpret cars from the US. as a different variety than cars from Germany or Japan. This measure is obviously not perfect. First, a given country might export more than one variety to Costa Rica, and this number may vary with the tariff and the size of the Costa Rican market for the product. In this event our estimates will miss a potential source of variety gains. Second, the same variety may be exported to Costa Rica from multiple countries. If this is typical then we should find that goods from different countries (within each of the 1,676 product categories) are close substitutes, so that greater variety contributes little to welfare.

Table 1 provides some summary statistics for the dataset. Defining variety as the number of countries from which there were imports in a product category, variety rose from 8.8 in 1986 to 11.4 in 1992 for the 469 consumer goods, and from 7.6 to 8.5 for the 1207 intermediate and capital goods (hereafter just intermediate goods). That is, the 469 consumer products were imported from an average of 8.8 countries each, and so on. Weighting each product category by total dollar imports, variety rose from 20.2 to 26.2 for consumer goods, and from 13.8 to 16.5 for intermediate goods. Over this period average tariffs fell from 46.1% to 24.2% for consumer goods, and from 15.6% to 12.7% for intermediate goods.[1] [2] Dollar-weighted tariffs fell from 48.5% to 22.1% for consumer goods, and from 11.8% to 10.3% for intermediate goods. Demand for imports were arguably elastic in that the tariff reduction was accompanied by a rise in import shares. Consumption goods imports rose from 5.4% of GDP in 1986 to 8.1% in 1992 (the share in consumption rose in tandem). The share of intermediate

[1]There is some ambiguity in constructing average tariffs for a year given that tariff rates change in mid-year, and some tariffs are applied differentially to more disaggregated product categories. The tabulations reported in the text used unweighted averages across subcategories and across time (using the day the tariff changed in each year). As an alternative we considered the minimum tariff across subcategories within the year. All of our results using tariffs are qualitatively unaffected by using this alternative measure of tariffs.

[2]The standard deviation of tariff rates also fell sharply, from 37% to 12% for consumer goods, and from 17% to 7% for intermediate goods. In most models the deadweight loss of tariffs rises with their variability as well as their average level. In a future draft we will investigate whether variability has implications for the deadweight losses that stem from reduced variety.

goods imports rose from 23.3% to 27.2% of GDP over the same period.

Of course, these aggregate numbers do not establish that tariff reduction, as opposed to some other factor (such as income and population growth), caused the increases observed in variety and import shares. Evidence suggesting that variety increased in those product-years where the tariff fell the most would be more compelling. Before examining the micro evidence on tariffs and variety, however, 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. That is, since lower tariffs are supposed to expand variety by expanding the size of the market, it is worth investigating the link between market size and variety directly.

Table 2 shows 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, variety being defined as the number of countries from which a product was imported in a year. The independent variable is the natural log of market size, market size being dollar imports of a product (gross of the tariffs) summed across all countries in a year. Year effects are included to deal with inflation in dollar imports. The results show that variety is greater in larger markets, both for consumer and intermediate goods. The relationship is statistically and economically significant: a 1% bigger market has .26% more variety on average. The R^2 indicates that most of the variation in variety across products is associated with market size. Figure 1 plots average variety against percentiles of market size (adjusted for inflation) for consumer goods to illustrate the relationship.

Suppose that product market size is exogenously determined by preferences and technologies (e.g. Cobb-Douglas with different shares for different products). Then the strong, positive correlation between product market size and variety demonstrated in Table 2 and Figure 1 is consistent with fixed costs of importing a given product from a given country (with the fixed cost being the same across products, or at least not varying in proportion to market size). When we construct a simple model in the next section, we will build in the feature that variety rises with – but not fully in proportion to – market size.

A simpler explanation for the positive correlation between market size and variety is that some product categories are arbitrarily broader than others. Exogenously larger categories would include more countries just because they are more aggregated. To see if the results owe entirely to cross-sectional variation in product size, we regressed variety on size and product dummies. The results are reported in the bottom half of Table 2. The size of the elasticity is roughly halved, but it remains economically and statistically strong.

We also stepped outside the Costa Rican data for a moment to look across countries to see if import variety is higher in countries with larger markets. Using U.N. data on 1980 bilateral trade flows at the 5 digit SITC level (1,074 categories), we measured a country's import variety as the average number of countries from which each 5 digit product was imported. Using the World Tables we measured market size as the level of GDP in 1980 in current dollars. For the 83 countries with available data we regressed the natural log of variety on the natural log of GDP and obtained a coefficient of .17 with a standard error of .01 (t-statistic of 14.1, and $\bar{R}^2 = .71$).[3] The relationship is depicted in Figure 2.

With some confidence that market size promotes variety, we now examine whether more varieties are imported of products with low or falling tariffs. Our identifying assumption is that product differences in tariff changes are exogenous. Table 3 presents the results from regressing the natural log of variety on the natural log of the gross tariff rate, with variety in a product-year defined as the number of countries exporting that product in that year to Costa Rica and

[3] We also regressed the log of the number of import partners (across all SITCS, rather than the average per SITC) on the log of GDP and found a coefficient of .12 (standard error .01, t-statistic 12.2 and $\bar{R}^2 = 0.63$).

the gross tariff defined as $1 + sobretasa + tarifa$. We include year and product dummies. We find an economically and statistically significant negative association between variety and tariffs, with a 1% higher tariff rate going along with .34% less intermediate good variety and .73% less consumer good variety. Figures 3 and 4 illustrate the relationships for consumer and intermediate goods, respectively, after year and product dummies have been removed from variety and the tariff.

3. The Model

We now construct a model with consumption and intermediate good varieties so that we can evaluate the welfare gains from trade liberalization. We consider a small open economy with a continuum of workers of mass L. There is a continuum of tradable consumption goods of mass M_c and a continuum of tradable intermediate goods of mass M_x. There is also a single nontradable consumption good which we take as the numeraire. For each tradable good there is a domestic variety and one variety for each foreign country. For example, there are cars produced domestically as well as German cars, Japanese cars, etc. There is only one variety for the nontradable consumption good. There is a continuum of countries with mass N.

The representative consumer has preferences given by:

$$u = \exp\left[\frac{\beta}{M_c}\int_0^{M_c} \ln C(j)dj + (1-\beta)\ln D\right]$$

where D is the nontradable consumption good and $C(j)$ is the composite tradable consumption good j which is produced from domestic and foreign varieties according to the CES function

$$C(j) = \left[\hat{c}(j)^{1-1/\sigma_c} + \int_0^N \left[\lambda_c(i)c(i,j)^{1-1/\sigma_c}di\right]^{1/(1-1/\sigma_c)}\right]$$

where $\hat{c}(j)$ is the quantity consumed of the domestic variety of consumption good j and $c(i,j)$ is the corresponding quantity for the country i variety. σ_c is the elasticity of substitution among varieties of a single tradable consumption good, and we assume that $\sigma_c > 1$. $\lambda_c(i)$ is a quality or preference parameter that can vary across countries.

The nontradable consumption good and the domestic varieties of all consumption and intermediate goods are produced with the same production function, which is given by:

$$y = \exp\left[\frac{\alpha}{M_x}\int_0^{M_c} \ln X(j)dj + (1-\beta)\ln L\right]$$

where $X(j)$ is the composite intermediate good j which is "produced" from domestic and foreign varieties according to the CES function

$$X(j) = \left[\hat{x}(j)^{1-1/\sigma_x} + \int_0^N \left[\lambda_x(i)x(i,j)^{1-1/\sigma_x} di\right]^{1/(1-1/\sigma_x)}\right]$$

where $\widehat{x}(j)$ is the quantity used of the domestic variety of intermediate good j and $x(i,j)$ is the corresponding quantity for the country i variety. σ_x is the elasticity of substitution among varieties of a single intermediate good, and we assume that $\sigma_x > 1$. Because D is the numeraire the price of all domestic varieties is one.

There is a fixed requirement of F_c (F_x) units of the numeraire good to run an importing firm for consumer (intermediate) goods, and we assume that each importing firm can import only one variety of one tradable good (i.e., there is an importing firm to import German cars, another to import Japanese cars, another to import Russian caviar, etc.). It is then natural to assume monopolistic competition in the importing market. We allow the fixed cost of importing to depend on the country of origin. This implies that F_c and F_x are functions of i. Without loss of generality we assume that $F_c(i)$ and $F_x(i)$ are increasing in i.[4]

Given the CES preferences and production function assumed above, importers charge a price equal to their marginal cost times a mark-up $1/(1-1/\sigma_c)$ for consumption goods and $1/(1-1/\sigma_x)$ for intermediate goods. We assume that the marginal cost of all importable goods is 1. The domestic price of consumer (intermediate) good imports is then $\tau_c/(1-1/\sigma_c)$ $(\tau_x/(1-1/\sigma_x))$, where $\tau_c - 1$ $(\tau_x - 1)$ is the tariff imposed by the government on all consumer (intermediate) good imports. (We assume that the revenue collected from this tariff is given back to consumers.)

We focus first on intermediate goods. Given a price of $\tau_x/(1-1/\sigma_x)$ for intermediate good imports and a price of 1 for the domestic variety of each intermediate good, the quantity of each imported variety of each intermediate good is

$$x(i,j) = \lambda_x(i)^{-1} h_x(i)^{-\sigma_x} {P_{X(j)}}^{\sigma_x} X(j) \tag{3.1a}$$

where $h_x(i) \equiv \frac{\tau_x/\lambda_x(i)}{1-1/\sigma_x}$ and where $P_{X(j)}$ is the implicit or shadow price of the

[4]It is not necessary to assume here that the ordering of countries from lowest to highest fixed import cost is the same for all goods.

$X(j)$ composite good and is given by

$$P_{X(j)} = \left[1 + \int_0^{n_x(j)} h_x(i)^{1-\sigma_x} di\right]^{1/(1-\sigma_x)} \tag{3.2}$$

Here $n_x(j) \in [0, N]$ is the measure of countries from which intermediate good j is actually imported (i.e. for which $x(i,j) > 0$). From the production function above we know that

$$X(j) = \frac{\alpha Y}{M_x P_{X(j)}}$$

where Y represents total output.

The importer of intermediate good j from country i makes profits of

$$\pi_{ij}^x = x(i,j)\left(\frac{1}{1 - 1/\sigma_x} - 1\right) - F_x(i) = \frac{x(i,j)}{\sigma_x - 1} - F_x(i) \tag{3.3}$$

(Note that we are assuming here that the mark-up is imposed *before* the tariff is charged, so that the tariff is imposed on the price inclusive of the mark-up. The results would not change significantly if we assumed instead that the mark-up is imposed *after* the tariff charged.) Using the above equations to plug in for

$x(i,j)$ we obtain

$$\pi_{ij}^x = (\tau_x\sigma_x)^{-1} h_x(i)^{1-\sigma_x} P_{X(j)}^{\sigma_x-1}(\alpha Y/M_x) - F_x(i)$$

We assume that the variation in $\lambda(i)$ does not make $\pi_{ij}^x/F_x(i)$ increasing in i (recall that $F_x(i)$ is increasing in i), implying that, as implicitly assumed above, only varieties of intermediate good j in some interval $[0, n_x(j)]$ will be imported.

Symmetry across intermediate goods in the model implies that $P_{X(j)} = P_X$ for all j, implying that $X(j) = \alpha Y/(M_x P_x)$ for all j. Plugging this into the production function and rearranging yields

$$Y = \left(\frac{\alpha}{M_x P_X}\right)^{\alpha/(1-\alpha)} L$$

Plugging this in the profit function above and again using symmetry yields

$$\pi_{ij}^x(n_x) = f_x(i, n_x) \equiv (\alpha/M_x)^{1/(1-\alpha)} (\tau_x\sigma_x)^{-1} h_x(i)^{1-\sigma_x} P_x(n_x)^{\sigma_x - 1/(1-\alpha)} L - F_x(i)$$

where

$$P_X(n_x) = \left[1 + \int_0^{n_x} h_x(i)^{1-\sigma_x} di\right]^{1/(1-\sigma_x)}.$$

The curve $f_x(i, n_x^0)$ is decreasing in i because of the assumption of rising fixed import cost $F_x(i)$. The free entry condition implies that all varieties $i < \tilde{n}_x(n_x^0)$ will be imported, where $\tilde{n}_x(n_x^0)$ satisfies $f_x(\tilde{n}_x, n_x^0) = 0$. Thus, in equilibrium n_x must be such that $\tilde{n}_x(n_x) = n_x$. A sufficient condition for there to exist only one level of n_x that satisfies this condition is $df_x(n_x, n_x)/dn_x < 0$ for all n_x. This condition is not necessarily satisfied in the model, but our calibration will reveal that there is enough curvature that this condition is indeed satisfied for all n_x in the calibrated model, implying uniqueness of equilibria. Moreover, because (it can be shown that) $f_x(i, n_x)$ is decreasing in the tariff τ_x, an increase in the tariff on intermediate goods lowers the variety of intermediate goods imported. For future reference, note that the equilibrium variety (henceforth denoted by n_x^E) and imports of intermediate goods do not depend on what happens in the consumption side of the model.

The determination of equilibrium import variety for consumption goods follows a similar logic as for intermediate goods. The demand for consumer goods and the shadow price of consumer good $C(j)$, $P_{C(j)}$, are analogous to those for intermediate goods in equations 3.1a and 3.2. Profits for importers of consumer goods are analogous to those for intermediate good importers in equation 3.3. Total demand for the consumer good $C(j)$ is $C(j) = \beta I/(M_c P_{C(j)})$, where I

represents total income. Using symmetry in preferences and the tariff across consumer goods, demand for variety i of any (tradable) consumer good is then given by

$$c(i) = \lambda_c(i)^{-1} h_c(i)^{-\sigma_c} {P_C}^{\sigma_c - 1} \left(\frac{\beta I}{M_C}\right) \tag{3.4a}$$

Total income I is equal to total wages plus the tariff revenue.[5] Thus,

$$I = (1-\alpha)Y + \left(\frac{\tau_c - 1}{1 - 1/\sigma_c}\right) M_c \int_0^{n_c} c(i)di + \left(\frac{\tau_x - 1}{1 - 1/\sigma_x}\right) M_x \int_0^{n_x} x(i)di$$

Plugging in from 3.4a and rearranging we get

$$I(n_c) = \frac{(1-\alpha)Y^E + \left(\frac{\tau_x - 1}{1-1/\sigma_x}\right) M_x \int_0^{n_x^E} x^E(i)di}{1 - \beta\left(\frac{\tau_c - 1}{\tau_c}\right) {P_C}^{\sigma_c - 1} \int_0^{n_c} h_c(i)^{1-\sigma_c} di}$$

Using this we can then express profits for the importer of variety i of any con-

[5]We assume that importers are foreigners, so that their profits are not part of total income. If importers were nationals, then the mark-up charged on imports would lead to a wedge between the international and domestic price of imports, implying that free trade is not the first best policy. It is not clear that one would want this feature in the model. Indeed, if domestic varieties were also sold with a mark-up, which would be the case if there also were some fixed costs involved in their domestic distribution, then the distortions would cancel out, making free trade again the optimal policy. We conjecture that the results in this case would be very similar to the results we obtain under the assumption of foreign importers.

sumption good as a function of n_c:

$$\pi_{ij}^c(n_c) = f_c(i, n_c) \equiv (1/\tau_c\sigma_c)h_c(i)^{1-\sigma_c} P_C(n_c)^{\sigma_c - 1}(\beta I(n_c)/M_x) - F_c(i)$$

As in the case for intermediate goods, the equilibrium level of n_c is determined by the condition $f_c(n_c, n_c) = 0$. Note that with $\tau_c > 1$, an increase in n_c increases tariff revenue from consumer goods, making $I(n_c)$ increasing in n_c. This by itself would have a positive impact on demand for consumer goods, but $P_c(n_c)$ is decreasing, and it can easily be shown that $P_C(n_c)^{\sigma_c - 1} I(n_c)$ is decreasing. Thus, $\partial f_c(i, n_c)/\partial n_c < 0$, implying that, as long as $\lambda_c(i)$ is not too strongly increasing, $df_c(n_c, n_c)/dn_c < 0$ for all n_c. This implies that there is a unique level of n_c that satisfies $f_c(n_c, n_c) = 0$.

We can now consider the effect of protection on the equilibrium import variety of consumer goods. A tariff on intermediate good imports decreases total income $I(n_c)$, leading to a fall in profits for importers of consumer goods and a consequent fall in n_c. An increase in the tariff on consumption good imports may actually increase total income I because of the increase in tariff revenue, but the net effect on profits can be shown to be always negative, so it also leads to a fall n_c.

To determine the impact of protection on welfare, we need to derive the expenditure function for consumers. Since the price of the numeraire good is 1, the expenditure function is simply $E(u, n_c, \tau_c) = \phi P_C(n_c, \tau_c)^\beta u$, where $\phi = \beta^{-\beta}(1-\beta)^{\beta-1}$. Let the initial levels of the tariff, variety, utility, and income be τ_c^0, n_c^0, u^0, and I^0, respectively. Then we know that

$$u^0 = \frac{I^0}{\phi P_C(n_c, \tau_c)^\beta}$$

Now consider a change in the tariff to τ_c^1 that induces a change in consumer good variety to n_c^1. To maintain the initial utility level, income must now be

$$\phi P_C(n_c^1, \tau_c^1)^\beta u^0 = \left(\frac{P_C(n_c^1, \tau_c^1)}{P_C(n_c^0, \tau_c^0}\right)^\beta I^0$$

But what actually happens to income as a consequence of the tariffs? We can write total income as a function of the variety of consumption and intermediate goods and the respective tariffs, $I(n_c, \tau_c, n_x, \tau_x)$. Letting Δ be the proportional compensation necessary to keep consumers at their initial utility level given that (n_c, n_x) goes from (n_c^0, n_x^0) to (n_c^1, n_x^1) as (τ_c, τ_x) changes from (τ_c^0, τ_x^0) to (τ_c^1, τ_x^1), we have arrived at the expression necessary to determine the welfare effects of tariff changes:

$$\Delta = \left(\frac{P_C(n_c^1, \tau_c^1)}{P_C(n_c^0, \tau_c^0} \right)^{\beta} - \frac{I(n_c^1, \tau_c^1, n_x^1, \tau_x^1)}{I(n_c^0, \tau_c^0, n_x^0, \tau_x^0)}$$

In the next section we calibrate the model to quantify the welfare effects of Costa Rica's trade liberalization ($\tau_c^1 < \tau_c^0$ and $\tau_x^1 < \tau_x^0$) and a move from free trade to protection ($\tau_c^1 > \tau_c^0 = 0$ and $\tau_x^1 > \tau_x^0 = 0$). Our general equilibrium calculations incorporate the change in variety of consumer and intermediate goods induced by the new tariffs. To determine the impact of endogenous variety over and above the standard gains from trade, we also calculate the welfare effects when variety (n_c, n_x) is fixed. These fixed n calculations involve the restriction $n_c^0 = n_c^1$ and $n_x^0 = n_x^1$.

4. Calculation of Welfare Effects

Here we calibrate the model of the previous section to quantify the welfare gains from trade liberalization that arise from increased variety. We start by estimating the elasticity of substitution among varieties. We then calibrate the rest of the model's parameters to match the relevant features of the 1986-1992 data for Costa Rica.

4.1. Estimation of σ_c and σ_x

We start with the elasticity of substitution across varieties of intermediate goods, σ_x. We start with equation 3.1a but relaxing the assumption that the international price (before the mark-up) is one. We also allow the tariff to depend on the country of origin of imports, to capture the fact that during the period of study (86-92) Costa Rica participated in the Central American Common Market, which implied zero tariffs on almost all goods from the rest of Central America. Letting $p_x^*(i,j,t)$ denote the international price of good j from country i in year t and taking logs we get:

$$\begin{aligned}\ln x(i,j,t) &= -\sigma_x \ln \tau_x(i,j,t) + (\sigma_x - 1)\ln \lambda_x(i,j,t) - \sigma_x \ln p_x^*(i,j,t) \\ &\quad +\sigma_x \ln(1 - 1/\sigma_x) + \sigma_x \ln P_{X(j)} + \ln X(j)\end{aligned}$$

where $x(i,j,t)$ is the quantity of and $\tau_x(i,j,t)$ is the gross tariff on imports of intermediate good j from country i in year t. Note that we also allow the preference (or quality) parameter to vary across time and across goods. Based on this equation we could run a regression of $\ln x(i,j,t)$ on $\ln \tau_x(i,j,t)$ with $-\sigma_x \ln p_x^*(i,j,t) + (\sigma_x - 1)\ln \lambda_x(i,j,t)$ as the residual and using product-year dummies to capture the effect of $\sigma_x \ln(1 - 1/\sigma_x) + \sigma_x \ln {P_{X(j)}}^{\sigma_x} + \ln X(j)$. The problem is that, since the variation in the tariff is all between Central American countries and other countries, it is likely that the preference parameter $\lambda_x(i,j,t)$ is correlated with the regressor $\tau_x(i,j,t)$. For instance, Costa Rican consumers might prefer goods from outside of Central America if they are of higher quality. To avoid this problem we take first differences of the previous equation to get:

$$\Delta \ln x(i,j,t) = -\sigma_x \Delta \ln \tau_x(i,j,t) + \text{product-year dummies} + \varepsilon_x(i,j,t)$$

where $\varepsilon_x(i,j,t) = (\sigma_x - 1)\Delta \ln \lambda_x(i,j,t) - \sigma_x \Delta \ln p_x^*(i,j,t)$. As long as changes in the tariff to countries outside of Central America are exogenous with respect to changes in international prices and consumer preferences, we can consistently estimate σ_x by regressing percent changes in intermediate good import quantities on percent changes in intermediate good tariffs. We follow the same procedure to estimate σ_c. The resulting estimates are $\sigma_c = 4.8$ and $\sigma_x = 2.9$ (see Table 4). These estimates are in line with estimates of substitutability in the trade and industrial organization literatures (see Feenstra 1995 and Pindyck and Rubinfeld 1992).

4.2. Calibration and Welfare Estimates

We calibrate the remaining parameters of the model to the relevant features of the 1986-1992 data for Costa Rica. We need to allow for the preference parameter λ or the fixed cost F to vary across countries (i.e., we need to allow for "curvature") because otherwise the model cannot replicate all of the important features of the period. In particular, without curvature the implied partial elasticity of variety with respect to market size is higher in the model than in the data. Whether the curvature is in λ or in F matters for our results. In the next version of the paper we plan to explore ways to identify where the curvature actually exists, but for now we present the results for the two polar cases in which all curvature is in F and all curvature is in λ. For the calibration we assume that $F_s(i) = F_s(0)e^{\mu_s i}$ and $\lambda_s(i) = \lambda_s(0)e^{\eta_s i}$ where $\mu_s, -\eta_s > 0$ and where $s = c, x$.

To determine a value for the parameter α (the share of intermediate goods and capital in total output), note that the share of intermediate goods in total output in the US manufacturing sector is approximately 1/2, and the share of capital in total value added (GDP) is around 1/3. This suggests a value of 2/3 for α. We determine the remaining parameters as follows. Conditional on the values for σ_c and σ_x estimated above, we choose values for the parameters β

(the share of consumer tradables in total consumption), $\lambda_s(0)$, $F_s(0)$, μ_s and η_s for $s = c, x$ to satisfy the following conditions:

a) Given a dollar-weighted average tariff on consumer goods of 48% and on intermediate goods of 11.8%, the model's implied dollar-weighted variety and ratio of imports over GDP for consumer goods and intermediate goods match the actual 1986 values (see Table 1).

b) The model's implied partial elasticity of variety with respect to market size matches the one estimated from the data (see Table 2). There are several reasons why we choose to calibrate to the elasticity of variety with respect to size rather than the elasticity of variety with respect to the tariff (the one estimated in Table 3). First, it could be that quotas, for which we do not have any data, are correlated with tariffs, thereby introducing a bias in our estimate of the partial elasticity of variety with respect to the tariff. Second, the standard errors for our estimates of the partial elasticity of variety with respect to the tariff are significantly larger than they are for the elasticity with respect to size. Finally, calibrating to the tariff elasticity would actually imply *less* curvature and stronger results than we get by calibrating to the size elasticity.

c) The model's implied import share increase for consumer goods as the dollar-weighted average tariff on consumer goods falls from 48% to 22% matches the increase observed in the data (i.e., from 5.4% to 8.1%).

In Table 5 we report the results of this calibration for three cases. The first two cases assume that all the curvature is in the fixed cost, whereas the third case assumes that all the curvature is in the preference parameter λ. The distinction between the first two cases arises from the fact that we have two estimates of the partial elasticity of variety with respect to size. As shown in Table 2, introducing product dummies lowers the estimate of this partial elasticity. We think this estimate may be too low because it does not take into account possible lags in the way variety reacts to changes in market size. In any case, we present our results for the high elasticity and low elasticity (with product dummies) reported in Table 2.

We report the results of the simulation for trade liberalization only for the model calibrated to the high size elasticity and with no lambda curvature. The results are presented in Table 6. Variety of intermediate goods does not increase significantly, a consequence of the fact that tariffs on intermediate goods did not fall very much. Consumer good variety increases almost 10% as a consequence of liberalization, but given the high elasticity of substitution estimated for consumer goods ($\sigma_c = 4.8$) this implies only small welfare gains. Taking into account the increase in variety caused by trade liberalization increases the estimated welfare gains by 50%.

Tables 7 through 9 present the results of the simulation comparing protection (10% tariffs on consumer and intermediate goods) to free trade under the different scenarios mentioned above, namely high and low elasticity with no lambda curvature and high elasticity with lambda curvature. These tables show that the main welfare losses from protection arise from the tariff on intermediate goods. The welfare results are summarized in Table 10. For the case of high size elasticity and no lambda curvature, the welfare losses from protection are 4 times higher than the standard estimate with fixed n. This number decreases to around 2.5 when we used the model calibrated to the low size elasticity, and to 1.5 when we use the high size elasticity but place all curvature on lambda.

4.3. Comparison to Romer's results

Romer (1994) finds that taking into account the variety effect of protection increases the welfare losses of a 10% tariff on intermediate goods from 1% of income to approximately 20%. Our results presented above lead to the same conclusion that reduced variety is an important cost of protection, but we find smaller variety losses relative to the standard losses. To understand the reasons for this discrepancy we start in Table 11 with the results for our calibrated model (with high size elasticity and no λ curvature) excluding consumer goods. A 10% tariff on intermediate goods leads to welfare losses that are four times larger when we allow variety to respond to the tariff (1.94% vs. 0.47% with fixed n). There are three reasons why the variety effect increases the welfare losses from protection by a factor of 20 in Romer's calculations but only by a factor of 4 in our calibrated model:

First, Romer assumed an elasticity of substitution among intermediate goods of 2, whereas our estimated elasticity is 2.9. In the second row of Table 11 we show the welfare losses arising from protection when we calibrate the model with an elasticity of substitution of 2. The variety effect now increases the welfare losses from protection by a factor of 7.

Second, Romer's calculations are based on a model that implies an import share of GDP of 100%, since the share of intermediate goods (all of which are imported) in gross output is assumed to be 50%. As we show in the third row of Table 11, the variety effect increases the welfare losses from protection by a factor of 9 in a model calibrated to a 100% import share and an elasticity of substitution of 2.

Finally, Romer's model has less curvature than our calibrated model. In particular, the partial elasticity of variety with respect to market size is 0.5 in

Romer's model, almost twice the partial size elasticity we estimate under no product dummies (our high estimate of the size elasticity). Row 4 of Table 11 shows that when we calibrate our model to an elasticity of substitution of 2, a 100% import share and a partial size elasticity of 0.5 the welfare losses from protection increase by a factor of 20 when one takes into account the effect of protection on variety. This finally matches Romer's result.

5. Conclusion

In standard models the welfare costs of protection are equivalent to at most a few percentage points of GDP. But as Romer (1994) demonstrated, the welfare losses can be an order of magnitude larger if tariffs diminish the range of goods available. The underlying premise is that there may be fixed costs to importing a variety, so that tariffs limit variety by shrinking the market for each good. Using a dataset on Costa Rican tariffs and imports, we have obtained some evidence on the importance of market size and tariff rates to the variety of goods actually imported. In this we have treated each country as exporting its own variety in a given product category. We found that a bigger market and lower tariffs substantially increase the number of varieties imported. A 1% larger market goes along with about .2% more variety of imported consumer and intermediate goods, and a 1% lower tariff goes along with about .4% more variety.

Using these estimates, we constructed and calibrated a general equilibrium model of consumer and intermediate good variety. For one of the cases we calibrated, we found that welfare losses from protection were 4 times larger than the standard estimates with fixed variety. Most of the welfare impact of variety comes from the effect of tariffs on intermediate good variety. Changes in the variety of intermediate goods lead to significant welfare effects because of the low estimated elasticity of substitution among these goods.

We hasten to add several caveats to our findings. First and most obviously, our results for Costa Rica may not be representative. Second, we took no account of varieties within a product-country category. A substantial benefit of lower tariffs on car imports into Costa Rica, for example, might be the availability of more US car models. [Casual empiricism suggests this has been the case for Argentina in their trade liberalization.] Our measure of variety (the number of countries exporting a product to Costa Rica) would miss this benefit.

Finally, the quality gains from trade liberalization could be bigger than the variety gains. In the case of Argentina's liberalization, the primary benefit may not have been access to more car models but rather access to higher quality car models. In other work one of us (Rodríguez-Clare 1996) calibrated a model of equipment quality upgrading and found that tariffs widen the distance between the quality of a country's equipment and the world technology frontier, with sizable output and welfare effects.

Table 1

Aggregate Summary Statistics

		Consumer		Intermediate	
		1986	1992	1986	1992
Unweighted	Mean Tariff	46.1	24.2	15.6	12.7
	Mean Variety	8.8	11.4	7.6	8.5
Weighted	Mean Tariff	48.5	22.1	11.8	10.3
	Mean Variety	20.2	26.2	13.8	16.5
	Import Share	5.4	8.1	23.3	27.2

Variety = # of countries from which Costa Rica imported a product.
Mean Variety = average across products in a given year.

Import Share = (consumer good imports / consumption) and
(intermediate and capital goods imports / GDP)

Table 2

Variety and Market Size

		Consumer Goods	Intermediate Goods
†	Coefficient	.267	.261
	Standard Error	(.005)	(.003)
	t-statistic	59.2	91.5
	$\bar{R}^2$	.541	.521
★	Coefficient	.149	.122
	Standard Error	(.006)	(.004)
	t-statistic	24.6	33.6
	$\bar{R}^2$	.892	.887
	# observations	2,992	7,718

Dependent Variable: ln(Variety[i, t])

Independent Variables: † ln(Market Size [i, t]), year dummies for the 1st set.
★ ln(Market Size [i, t]), year & product dummies for the 2nd.

Variety[i, t] = # of countries from which Costa Rica imported product i in year t.

Market Size [i, t] = Costa Rican dollar imports (gross of tariffs) of product i in year t.

$i \in \{1, ..., 469\}$ for consumer goods
$i \in \{1, ..., 1207\}$ for intermediate goods.
$t \in \{1986, ..., 1992\}$

Table 3

Variety and Tariffs

	Consumer Goods	Intermediate Goods
Coefficient	−.732	−.345
Standard Error	(.118)	(.091)
t-statistic	6.2	3.8
$\bar{R}^2$	.868	.867
# observations	2,992	7,718

Dependent Variable: ln(Variety[i, t])

Independent Variables: ln(1 + *sobretasa*[i, t] + *tarifa*[i, t]), year & product dummies

Variety[i, t] = # of countries from which Costa Rica imported product i in year t.

sobretasa[i, t] = Central Bank tariff rate on product i in year t.
tarifa[i, t] = Finance Ministry tariff rate on product i in year t.

See Table 2 for subscript ranges.

Table 4

Substitutability of Varieties

$$\Delta \ln z = -\sigma \Delta \ln \tau + [(\sigma - 1)\Delta \ln \lambda - \sigma \Delta \ln p^*]$$

	Consumer Goods	Intermediate Goods
σ	4.78	2.92
Standard Error	(0.15)	(0.24)
t-statistic	32.3	12.3
$\bar{R}^2$	.035	.003
# observations	20,269	42,456

Dependent Variable = Δln(kilos of imports)
Independent Variable = Δln(1 + tariff rate)
Samples are unbalanced panels of country-product-years.
Product-year means are removed from both variables.

Table 5
Estimated and calibrated parameters used in simulation

	High Elasticity	Low Elasticity	High Elasticity, Lambda curvature
β	0.125	0.125	0.125
α	0.67	0.67	0.67
σ_c	4.8	4.8	4.8
σ_x	2.9	2.9	2.9
L	3,000,000	3,000,000	3,000,000
η_c	0	0	-.05
η_x	0	0	-.11
$\lambda_c(0)$	0.99	0.99	1.41
$\lambda_x(0)$	0.16	0.16	0.30
μ_c	0.13	0.26	0
μ_x	0.24	0.53	0
$F_c(0)$	$0.33*10^{-7}$	$0.25*10^{-8}$	$0.42*10^{-7}$
$H_x(0)$	$0.64*10^{-7}$	$0.12*10^{-8}$	$0.13*10^{-6}$

Table 6
Variety and Welfare Effects of Trade Liberalization

	Pre-Liberalization	Post-Liberalization
τ_c	48.5	22.1
τ_x	11.8	10.3
n_c	20.2	22.6
n_x	13.8	14
Welfare, fixed n	---	1.0%
Welfare, flexible n	---	1.5%

Table 7
Variety and Welfare Effects of Protection

	Variety Effect		Welfare Effect		
	n_c	n_x	Fixed n	Flex. n_x	Flex. $n_{c,}$, n_x
10% tariff on C	24.43 -> 23.67		0.07%	0.07%	0.16%
10% tariff on X	24.43 -> 24.32	15.14 -> 13.99	0.40%	1.79%	1.81%
10% tariff on C and X	24.43 -> 23.56	15.14 -> 13.99	0.47%	1.88%	1.99%

Table 8
Variety and Welfare Effects of Protection, Low Elasticity

	Variety Effect		**Welfare Effect**		
	n_c	n_x	Fixed n	Flex. n_x	Flex. $n_{c,}$, n_x
10% tariff on C	22.57 -> 22.13		0.07%	0.07%	0.13%
10% tariff on X	22.57 -> 22.53	14.41 -> 13.89	0.39%	1.02%	1.03%
10% tariff on C and X	22.57 -> 22.1	14.41 -> 13.89	0.46%	1.10%	1.16%

Table 9
Variety and Welfare Effects of Protection, High Elasticity and Lambda Curvature

	Variety Effect		**Welfare Effect**		
	n_c	n_x	Fixed n	Flex. n_x	Flex. $n_{c,}$, n_x
10% tariff on C	23.99 -> 23.27		0.068 %	0.068%	0.073%
10% tariff on X	23.99 -> 23.96	14.98 -> 13.97	0.38%	0.55%	0.55%
10% tariff on C and X	23.99 -> 23.24	14.98 -> 13.97	0.45%	0.62%	0.63%

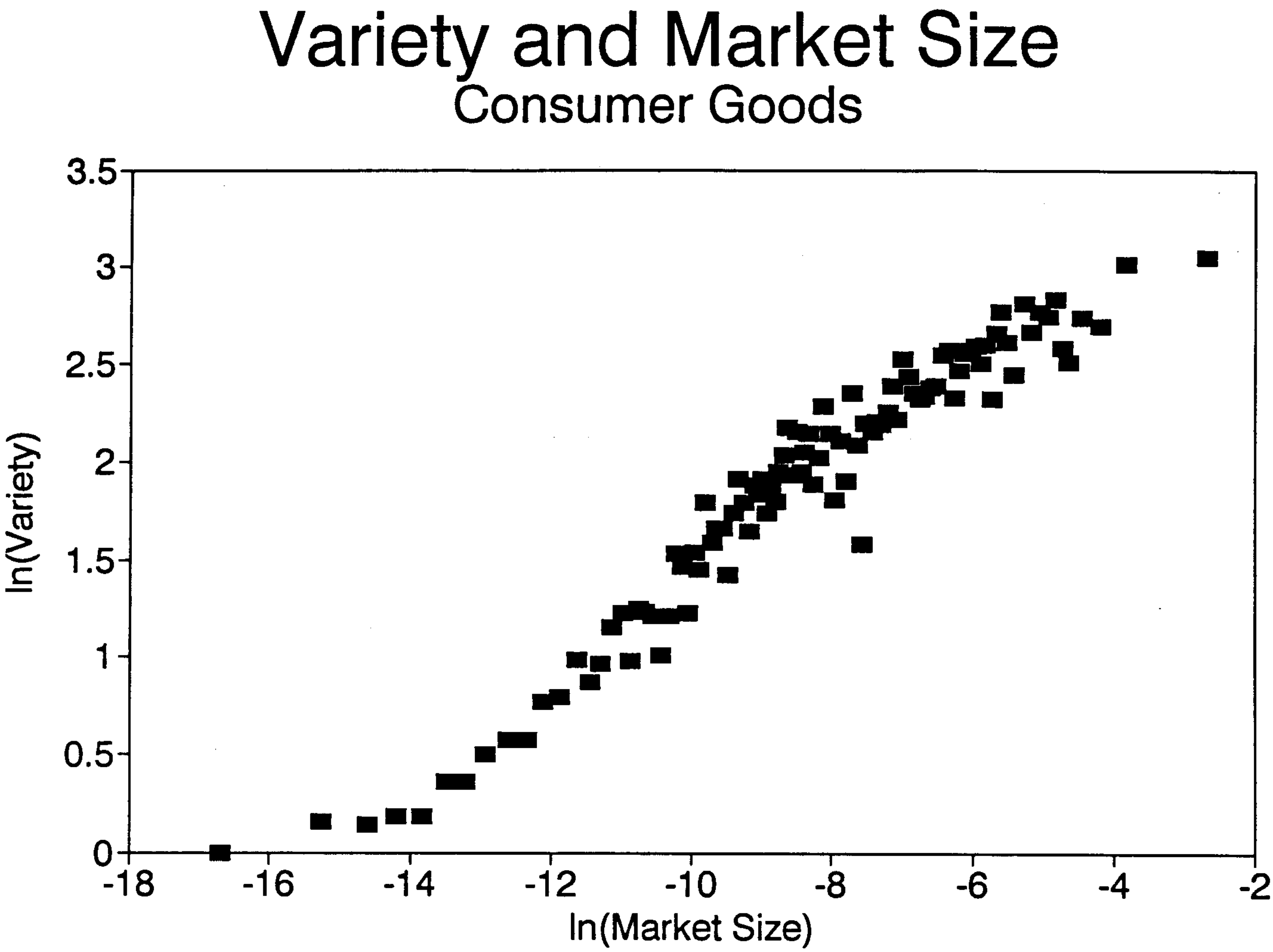
Table 10
Welfare Effects of Protection under Different Scenarios

	Welfare Effect of 10% tariff on C and X	
	Fixed n	Flexible n
High Elasticity, curvature on fixed cost	0.47	1.99
Low Elasticity, curvature on fixed cost	0.46	1.16
High Elasticity, curvature on lambda	0.45	0.63

Table 11
Reconciling our results with Romer's (only intermediates)

	Welfare Effect of 10% tariff on X	
	Fixed n	Flexible n
σ=2.9	0.47	1.94
Romer's σ=2	0.33	2.32
Romer's σ, Romer's share (100%)	1.06	9.52
Romer's σ, Romer's share, Romer's size elasticity	0.98	19.2

Figure 1

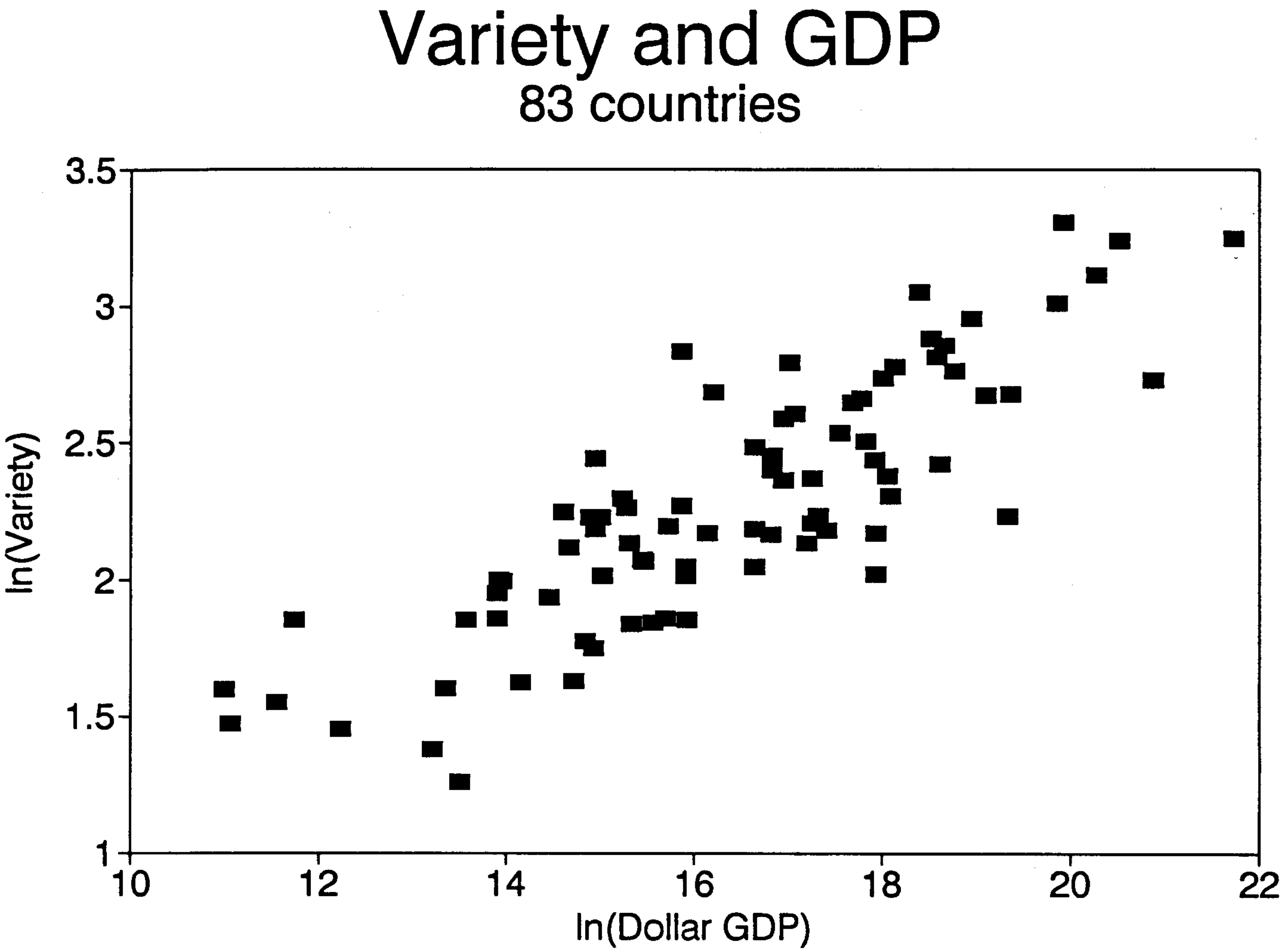


Variety = # of countries from which Costa Rica imported in a product-year.

Market Size = 1987-dollar imports (gross of tariffs) in a product-year.

Underlying the 100 data points shown are 2,992 product-year observations. ln(Market Size) is in percentiles, so each square is the average of roughly 30 dollar imports in that percentile of dollar imports. ln(Variety) represents the average of the varieties for each product-year in that dollar import percentile.

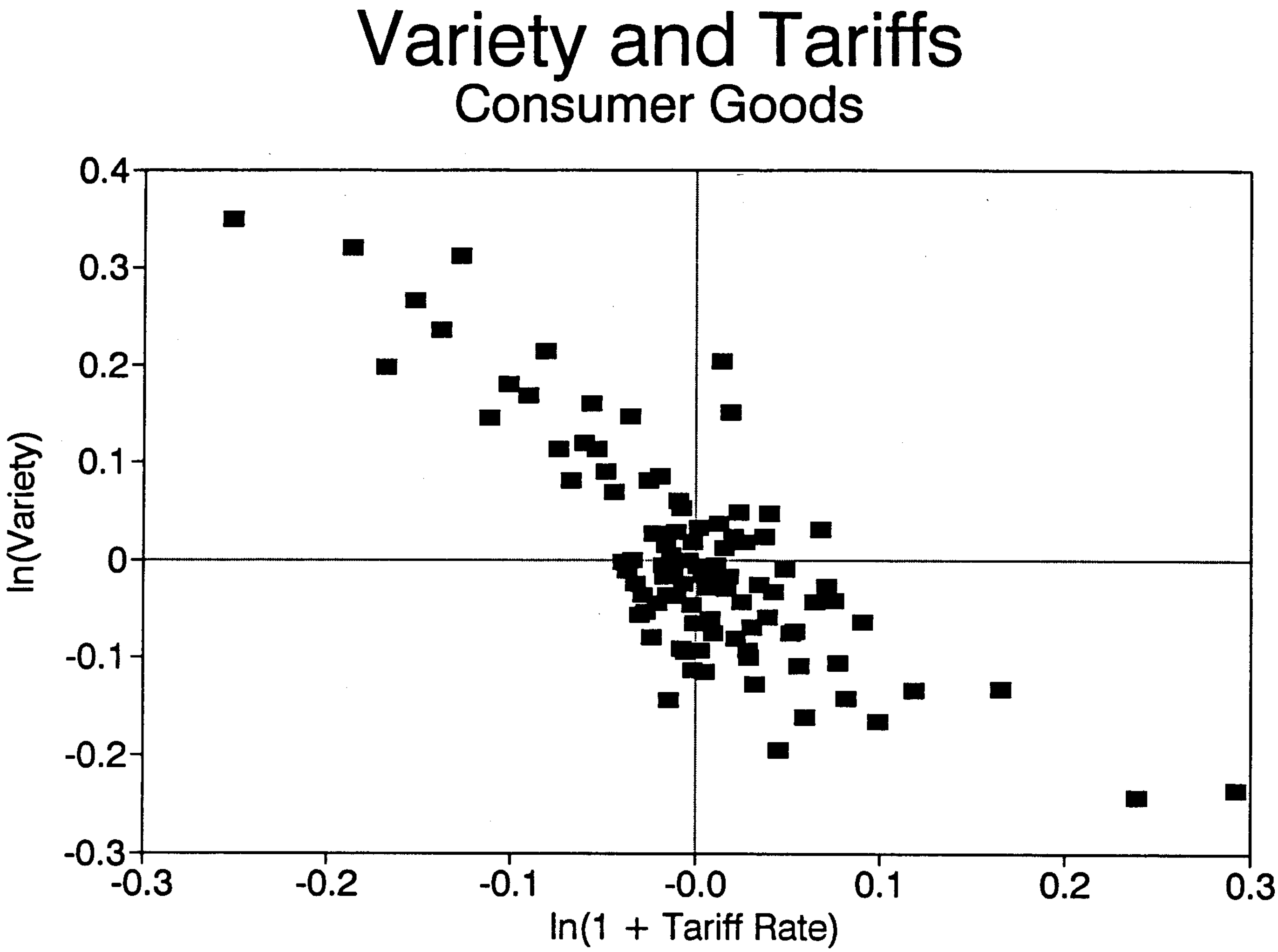
Figure 2



Variety = Average # of country import partners at the 5 digit SITC level (U.N. data).

GDP = 1980 GDP in current U.S. dollars (World Tables data).

Figure 3

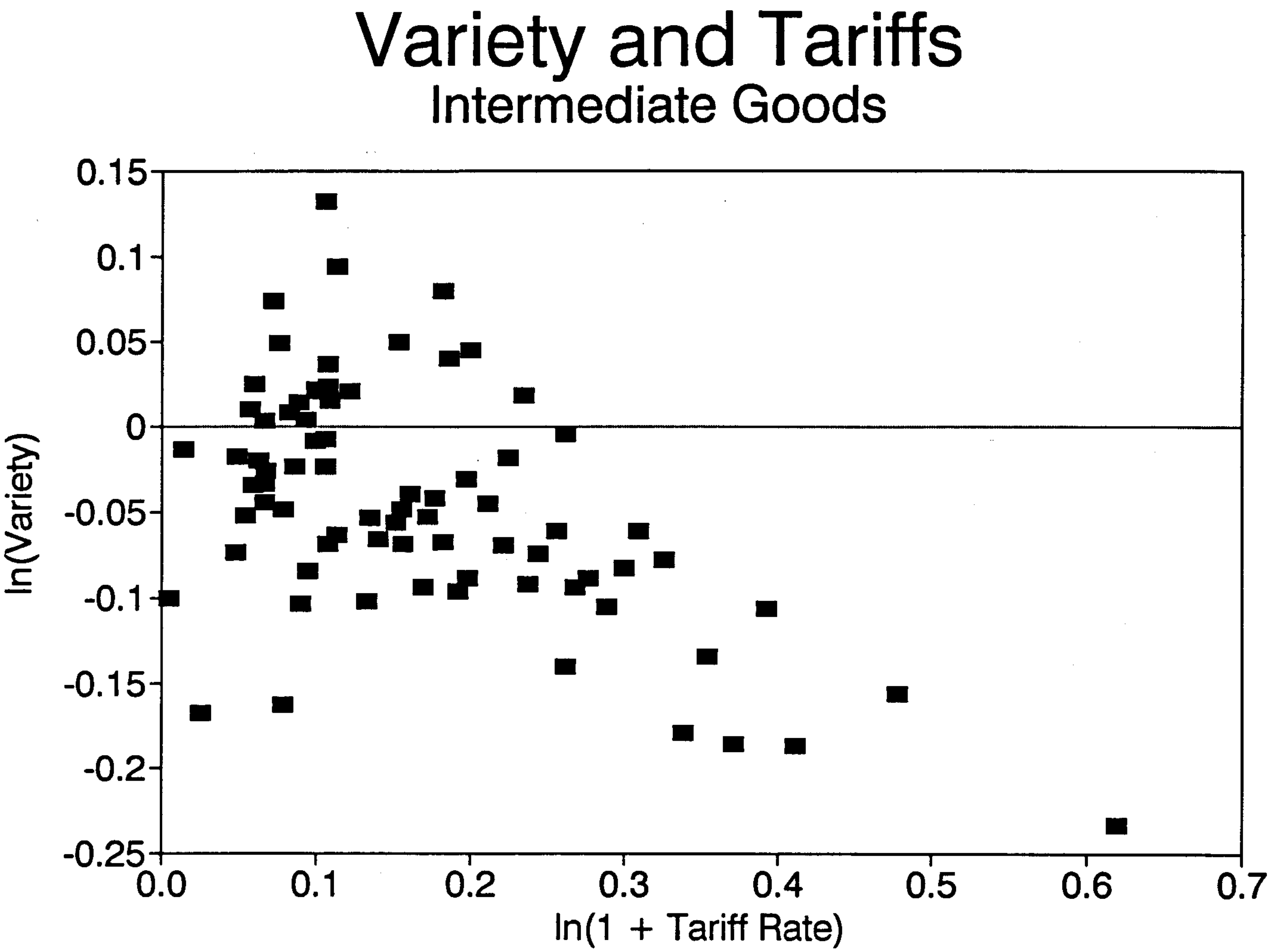


Variety = # of countries from which Costa Rica imported in a product-year.

Tariff = 1 + *sobretasa* + *tarifa*

Underlying the 100 data points shown are 2,992 product-year observations. ln(tariff) is in percentiles, so each square is the average of roughly 30 tariff rates. ln(Variety) represents the average of the varieties for each product-year in that tariff percentile.

Figure 4



Variety = # of countries from which Costa Rica imported in a product-year.

Tariff = 1 + *sobretasa* + *tarifa*

Underlying the 100 data points shown are 2,992 product-year observations. ln(tariff) is in percentiles, so each square is the average of roughly 30 tariff rates. ln(Variety) represents the average of the varieties for each product-year in that tariff percentile.

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