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Variety Gains and the Extensive Margin of Trade[☆]

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Abstract

Findings from the literature suggest that previous estimates of the variety gains from trade are too small because of the imprecise measurement of the imported variety set under the Armington assumption. In this contribution, I use results from the literature on multi-product firms to obtain variety gain estimates that account for the entry and exit of firms as well as for product turnover within firms and find that welfare gains increase by a factor of 2.5 compared to the baseline Armington product-country variety differentiation case. I furthermore modify the lambda ratios presented in Feenstra (1994) by assuming that all import variations are due to extensive margin adjustments. Under this extreme assumption, variety gains increase by a factor of six but remain modest in magnitude.

Keywords: Margins of trade, welfare gains from trade, multi-product firm

JEL: F10, F12, F14

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1. Introduction

This paper contributes to the debate on the empirical quantification of what is commonly called the variety gains from trade. The notion that an enhanced set of differentiated varieties may contribute to economic welfare is not controversial as such—the theoretical analysis of it dates back to the seminal contributions by Krugman (1979, 1980, 1981). However, a debate has arisen on the size of these effects. The first structural estimate of the gains from variety (GFV) in the trade literature stems from Broda and Weinstein (2006). Applying the seminal methodology developed by Feenstra (1994), these authors find welfare gains of 2.6% of GDP in the United States from 1972 to 2001 owing to an expansion of the imported variety set.²

Several contributions in the literature suggest that Broda and Weinstein (2006) may underestimate the variety gains from trade, because changes in the variety set are imperfectly measured. Typically, trade data involve a two-way classification of varieties as in Armington (1969); first, by categories of goods and second, by countries of origin. Thus, the finest unit of observation on the import side is a certain product category stemming from a particular country. But the modern idea of product differentiation implies that besides the destination or origin of products, the number of active firms as well as the scope of available products within these firms are determinants of the extensive margin of trade as well.³ For example, Bernard et al. (2006a) show that U.S. firms adjust their product portfolio frequently, and that this has a substantial effect in determining the composition of aggregate industrial output. In an international

²In this paper, I focus on the identification of the *variety gains* from trade. A different objective is pursued by, for example, Arkolakis et al. (2009). These authors argue that total gains from trade can be inferred from two simple statistics, the import penetration rate and the elasticity of imports with respect to trade costs. These welfare gains then include any possible trade gains that may be identified by different micro models; e.g., variety gains, productivity gains through firm selection or scale economies. This paper uses the underlying theory to put an upper bound on the size of the GFV whatever the chosen variety definition.

³Evidence on the importance of the multi-product dimension of firms is, for example, found in Bernard et al. (2006b), Bernard et al. (2007), Bernard et al. (2009a), Bernard et al. (2009c) and Arkolakis and Muendler (2010).

context, Bernard et al. (2009b) find that changes in the extensive margin resulting from the entry and exit of firms, but also from product turnover within existing firms, are mainly responsible for import and export growth over longer time spans in the United States. As these additional extensive margins are unobserved in conventional trade data, the importance of the extensive margin of trade tends to be underestimated and thus also the variety gains from trade.⁴

The objective of this paper is to obtain estimates of the variety gains from trade in the United States under the presumption that products are not solely differentiated across countries of origin. It is related to other contributions such as Blonigen and Soderbery (2010). These authors use detailed market data on the U.S. automobile sector and estimate variety gains that are twice as large as compared to an estimation with conventional trade data. The analysis, however, is limited to a single manufacturing sector. Broda and Weinstein (2010) use bar code data on retail purchases surveyed from 55,000 households. Using this highly disaggregated dataset, the authors find that the majority of variety turnover occurs within the boundaries of the firm. This large turnover leads to substantial decreases in cost-of-living indices, implying high variety gains for retail store customers.⁵ These two contributions demonstrate that one way to

⁴Another aspect of the discussion on the magnitude of variety gains concerns the CES utility specification chosen by Broda and Weinstein (2006). Montagna (1999) argues that the standard Dixit-Stiglitz model incorporates a maximum love of variety. Feenstra and Shiells (1996) compare the CES framework to the translog case and conclude that new varieties have a larger impact using the former specification. Hummels and Lugovskyy (2005), based on Lancaster (1979), argue that the less than proportional increase in imported varieties with respect to market size can be explained by the falling marginal benefit of importing additional varieties. In their model, this is due to “crowding” in the variety space, an effect that is absent in the CES case. Taking a somewhat different approach, Ardelean (2009) argues that the standard Krugman (1980) model overstates the love of variety, since it assumes that larger countries export more only at the extensive margin, while models in the vein of Armington (1969) assume that countries’ exports grow only at the intensive margin. Nesting Krugman- and Armington-style models, she concludes that the love of variety is 44% lower than in Krugman’s CES model. These contributions imply that Broda and Weinstein (2006) may even overestimate the imported GFV. In my paper, however, I leave this issue aside and use to CES specification. I argue, however, that my results carry over to other modeling approaches, as for example the translog case.

⁵These two analyses are not restricted to imported variety. In my paper, I concentrate on imported variety. However, the concept presented below can, in principle, be applied to domestic production, for example by using the modeling approach of Ardelean and Lugovskyy (2010).

overcome restrictive variety definitions imposed by conventional trade data is, quite obviously, to use more detailed datasets. However, detailed data—such as multi-product firm-level data—covering all imports from all supplying countries are still not widely available for longer time spans.

In this paper, this issue is first approached in a different, more conceptually oriented way, by following Feenstra (1994) and by using a specific interpretation of the lambda ratios. In particular, it is assumed that all variation in import values occurs at the *extensive* margin of trade. Doing this, a hypothetical measure of the maximum variety gains given the realized import flows in the United States is obtained. This measure does not require any particularly detailed data. In a second step, I use aggregate empirical evidence from the existing literature on multi-product firm-level trade data to estimate the variety gains from imports, considering within entry and exit of firms, as well as within firm-level variation. Using these approaches, I obtain realistic magnitudes of imported variety gains in the United States.

The empirical analysis covers all U.S. merchandise imports of the period from 1990 to 2006. I estimate a baseline specification, akin to Broda and Weinstein (2006), where varieties are defined as product-country pairs, hence using the Armington (1969) variety definition. In this case, the GFV amount to 0.54% of GDP. These welfare gains are similar in magnitude to those found in Broda and Weinstein (2006) for the period from 1990 to 2001. In comparison, attributing all variation in U.S. import flows to changes in the extensive margin raises these gains substantially. This measure of maximum variety gains leads to a variety-induced welfare increase of 3.32% of GDP. While this is a substantial, sixfold increase compared to the baseline specification, I argue that this upper-bound measure of variety gains is still useful due to its modest magnitude. In a further step using empirical results from Bernard et al. (2009b), I explicitly include firm entry and exit as well as product turnover within existing firms into the analysis. This yields variety gains of 1.34% of GDP. While these gains are still almost three times

larger than under the baseline specification, the stark increase matches with findings from other empirical studies that recognize the importance of the firms' important contribution to the extensive margin.

The remainder of this paper is structured as follows: Section 2 reviews the methodology used to determine the GFV, mainly referring to Feenstra (1994) and Broda and Weinstein (2006). In Section 3, I follow the idea of Feenstra (1994) and interpret the lambda ratios in a way suitable for taking unobserved variety changes into account. In Section 4, the variety gains in the United States for the period from 1990 to 2006 are estimated and discussed. Also, the robustness of these results is evaluated. Section 5 concludes.

2. A Brief Review of the Standard Model

In this section, the methodology used to estimate the GFV as developed by Feenstra (1994) and Broda and Weinstein (2006) is reviewed. Utility M_{gt} of good g is composed of varieties c in the following way:

$$M_{gt} = \left(\sum_{c \in C} d_{gct}^{1/\sigma_g} m_{gct}^{(\sigma_g-1)/\sigma_g} \right)^{\sigma_g/(\sigma_g-1)} ; \quad \sigma_g > 1 \quad \forall g \in G, \quad (1)$$

where σ_g is the elasticity of substitution between the varieties of good g . m_{gct} is the quantity consumed of variety c . G is the set of goods and C is the set of all potential varieties. d_{gct} is a taste or quality parameter. Using the results of Diewert (1976), Sato (1976) and Vartia (1976) and assuming a constant variety set I_g , the price index for the unit-cost function of the above utility can be written as

$$P_g^M(I_g) = \prod_{c \in I_g} \left(\frac{p_{gct}}{p_{gct-1}} \right)^{w_{gct}}, \quad \text{where} \quad (2)$$

$$w_{gct}(I_g) = \frac{(s_{gct} - s_{gct-1})/(\ln s_{gct} - \ln s_{gct-1})}{\sum_{c \in I_g} ((s_{gct} - s_{gct-1})/(\ln s_{gct} - \ln s_{gct-1}))},$$

$$s_{gct}(I_g) = \frac{p_{gct}x_{gct}}{\sum_{c \in I_g} p_{gct}x_{gct}}.$$

Hence, the price index is the geometric mean of all price changes where the weights depend on the expenditure shares s_{gct} . It is due to Feenstra (1994) that the price index for a time-varying set of varieties, I_{gt} , is known:

$$\pi_g^M(I_{gt}, I_{gt-1}) = P_g^M(I_g) \left(\frac{\lambda_{gt}}{\lambda_{gt-1}} \right)^{1/(\sigma_g-1)}, \text{ where} \quad (3)$$

$$\lambda_{gt} = \frac{\sum_{c \in I_g} p_{gct}x_{gct}}{\sum_{c \in I_{gt}} p_{gct}x_{gct}}, \quad (4)$$

$$\lambda_{gt-1} = \frac{\sum_{c \in I_g} p_{gct-1}x_{gct-1}}{\sum_{c \in I_{gt-1}} p_{gct-1}x_{gct-1}}. \quad (5)$$

π_g^M is a *corrected* price index that accounts for changes in the variety set. It is obtained by multiplying the conventional price index P_g^M by a correction term. This term consists of a fraction, called the lambda ratio, which is weighted by a term negatively related to the elasticity of substitution. The numerators of λ_{gt} and λ_{gt-1} comprise the expenditure on varieties available at both time t and $t - 1$. The set containing these varieties, I_g , is referred to as the common set. The denominators of λ_{gt} and λ_{gt-1} consist of expenditures on varieties belonging to the sets I_{gt} and I_{gt-1} , respectively. In the first set, common and new varieties are included, while in the second set, common and disappearing varieties are included. Hence, high expenditures on new varieties lower the lambda ratio, while high expenditures on disappearing varieties increase it. Furthermore, note that the impact of the lambda ratio on the price index depends on the substitutability of varieties. The effect is dampened if varieties are close substitutes; i.e., if σ_g is large.

Aggregating the corrected price indices over all product categories yields the corrected import price index:

$$\Pi^M(I_t, I_{t-1}) = \prod_{g \in G} (\pi_g^M(I_{gt}, I_{gt-1}))^{w_{gt}}. \quad (6)$$

The ratio of the corrected import price index Π^M to the conventional price index \mathcal{P}^M —aggregated in the same manner as Π^M —expresses the bias from ignoring the change in variety. This ratio is called the *endpoint ratio (EPR)* and it is defined as

$$EPR = \frac{\Pi^M(I_t, I_{t-1})}{\mathcal{P}^M(I)} = \prod_g \left(\frac{\lambda_{gt}}{\lambda_{gt-1}} \right)^{w_{gt}/(\sigma_g - 1)}. \quad (7)$$

It is a weighted geometric mean of the lambda ratios. Imposing a Cobb-Douglas structure between domestic production and imports, the impact of import prices on the economy can be evaluated separately from the domestic sector. The GFV can then be defined as

$$GFV = \left[\frac{1}{EPR} \right]^{w_t^M} - 1. \quad (8)$$

Hence, the welfare gains are calculated by weighting the inverse of the weighted aggregate lambda ratios with the fraction of imported goods relative to total economic activity, w_t^M .

3. Adjusting for Unobserved Variety Growth

Applying the described methodology, the magnitude of the variety gains estimate naturally depends on the variety definition which is normally imposed by the employed dataset. Mostly, conventional trade datasets are used as for example in Broda and

Weinstein (2006). Such data are available for many countries covering at least the last 20 years. In these datasets, varieties are defined as particular goods stemming from distinct countries of origin. In other words, one country provides not more than one variety of a specific good. As Blonigen and Soderbery (2010) put it, this “Armington assumption ‘hides’ substantial variety change”. For example, one particular variety that is observed using these trade data is “Plastic Dolls from China”. In reality, however, it is likely that many differing makes of plastic dolls are imported from China. Assume now that this number of different toy models increases over time and that this causes a rise in the total expenditure on plastic dolls from China. Because this change in the variety set is not revealed by conventional trade data, it will not be reflected in the lambda ratios. As long as the category “Plastic Dolls from China” is imported throughout the observation period, expenditures on this Armington variety are comprised in the sets I_{gt} and I_{gt-1} as well as in the common set I_g . Hence, these expenditures cancel one another out in the lambda ratios. On the other hand, if the true variety increase within the Armington variety “Plastic Dolls from China” was observed, the lambda ratio would, c.p., decrease.

Feenstra (1994) recognizes this issue, albeit in a slightly different context. He argues that applying the methodology as stated above using standard trade datasets ignores potential quality changes of varieties over time. Quality improvements are expected to lower the price index. To adjust for unobserved quality changes, the author excludes the varieties supplied by developing countries and Japan from the common set I_g in one of his specifications. As a consequence, an increase in the expenditure on these varieties—assumed to be due to quality enhancements—leads, c.p., to a decrease in the lambda ratios. Note that quality improvements can be interpreted as replacements of old varieties by new and enhanced varieties. This intuition is reflected in the approach of Feenstra (1994): With the exclusion of varieties from the common set, these varieties are treated as *new and disappearing* at the same time, as they remain in the sets I_{gt}

and I_{gt-1} . Hence, this adjustment of the common set not only addresses unobserved quality changes but also unobserved changes in the variety set. Returning to my example of Chinese plastic dolls, an exclusion of this observed Armington variety from the common set implies that the increase in the expenditure on Chinese plastic dolls is fully attributed to the emergence of (in the trade dataset unobserved) new makes and models of Chinese plastic dolls. If this assertion is true, the exclusion of Chinese plastic dolls from the common set yields the accurate correction of the price index via a lambda ratio decrease.

Given the vast number of varieties observed in conventional trade data, the problem in practice is the identification of those varieties that are believed to exhibit unobserved changes in variety.⁶ Is such an assumption realistic in the case of Chinese plastic dolls? What about Mexican plastic dolls? Or French red wine? Furthermore, it is unlikely that the change in the expenditure on an observed Armington variety is caused only by the introduction of new models. The change will probably also stem from intensive margin adjustments of existing makes. These issues are difficult to solve without additional information. I address these questions in Section 4.2.

As a limiting case, there is the possibility to exclude *all* observed Armington varieties from the common set. To illustrate how this affects the lambda ratio presented above, I first rewrite it as

$$\frac{\lambda_{gt}}{\lambda_{gt-1}} = \frac{\sum_{c \in I_{gt-1}} p_{gct-1} x_{gct-1}}{\sum_{c \in I_{gt}} p_{gct} x_{gct}} \frac{\sum_{c \in I_g} p_{gct} x_{gct}}{\sum_{c \in I_g} p_{gct-1} x_{gct-1}}, \quad (9)$$

I now assume that all varieties are dropped from the common set, except one arbitrarily small variety, labeled “zero variety”, 0. This yields⁷

⁶In 1990, over 14,000 products were imported into the United States, stemming from more than 150 countries and resulting in a total of more than 180,000 varieties, see Table 1 discussed on page 11

⁷Alternatively, assume that the second term on the right-hand side is a function with well-defined derivatives (i.e., that the number of varieties included in the common sets is very large). Let $I_g \rightarrow \emptyset$.

$$\frac{\Lambda_{gt}}{\Lambda_{gt-1}} = \frac{\sum_{c \in I_{gt-1}} p_{gct-1} x_{gct-1}}{\sum_{c \in I_{gt}} p_{gct} x_{gct}} \frac{p_{g0t} x_{g0t}}{p_{g0t-1} x_{g0t-1}} = \frac{e_{gt-1}}{e_{gt}} \frac{p_{g0t} x_{g0t}}{p_{g0t-1} x_{g0t-1}}, \quad (10)$$

where e is the total expenditure within a given product group. To interpret this *modified* lambda ratio consider the first term on the right-hand side of equation (10). It captures the essence of the adjustment proposed here. The lambda ratio falls—and thus lowers the import price index—whenever the total expenditure on a product category is higher in t than in $t - 1$. Thus, every increase in the expenditure on a particular product is interpreted as an increase in the variety within this product. Now consider the second term on the right-hand side of equation (10). It has an important function as a correction term. If imports are subject to positive inflation, c.p., thereby nominally increased expenditure would be falsely interpreted as variety growth. By assuming that the “zero variety” exhibits constant real expenditures and is affected by inflation in the same way as other varieties in this particular product category, one can use this term to correct for a potential inflation bias.⁸

I label this extreme case “no intensive margin”. It relies on the strong assumption that real variations in U.S. import values are caused solely by extensive margin adjustments, i.e., that every cent is spent on new varieties not present in the base year. While this is an extreme case, it will serve as a useful reference.

4. Empirical Analysis

In a first step of the analysis, I use the U.S. trade data from 1990 to 2006 provided by the Center of International Trade Data (CID) at UC Davis to estimate the

Applying l’Hôpital’s rule, this yields the same result as found above:

$$\frac{\Lambda_{gt}}{\Lambda_{gt-1}} = \lim_{I_g \rightarrow \emptyset} \frac{\lambda_{gt}}{\lambda_{gt-1}} = \frac{\sum_{c \in I_{gt-1}} p_{gct-1} x_{gct-1}}{\sum_{c \in I_{gt}} p_{gct} x_{gct}} \lim_{I_g \rightarrow \emptyset} \frac{\sum_{c \in I_g} p_{gct} x_{gct}}{\sum_{c \in I_g} p_{gct-1} x_{gct-1}} = \frac{\sum_{c \in I_{gt-1}} p_{gct-1} x_{gct-1}}{\sum_{c \in I_{gt}} p_{gct} x_{gct}} \frac{p_{g0t} x_{g0t}}{p_{g0t-1} x_{g0t-1}}.$$

⁸Note that the issue of inflation is not present in the lambda ratio of equation (3). The lambda ratio divides expenditure *shares*, and not expenditures, and thus general price increases cancel one another out.

elasticity of substitution for every HTS-10 product using the methodology presented in Feenstra (1994).⁹ In this dataset, products are defined at the HTS-10 level. A detailed description of this dataset, specifically regarding the imported variety set, is given in Broda and Weinstein (2006).¹⁰ Summary statistics of the estimated elasticities are displayed in Table 2.¹¹ The median elasticity of substitution is 3.28, the mean 11.84. These values are similar in magnitude to the Broda and Weinstein (2006) estimates for the period from 1990 to 2001. These elasticities are used throughout the subsequent analysis.¹²

Insert Table 2 approximately here

4.1. Two Variety Gains Estimates

Using the aforementioned dataset, I first calculate the baseline estimate of the variety gains. As in Broda and Weinstein (2006), I compute the lambda ratios of equations (4) and (5) using the Armington definition of a variety derived from this data set. The first column of Table 3 presents summary statistics on these ratios.¹³ For example, the median product category exhibits a lambda ratio of 0.95. This value can be interpreted as variety growth of about 5.3%.

Secondly, I calculate the modified lambda ratios for the “no intensive margin” case as shown in equation (10). Note that this estimate can be calculated using vastly more

⁹See <http://cid.econ.ucdavis.edu/>.

¹⁰Broda and Weinstein (2006) describe import data from 1990 to 2001. The qualitative findings of this analysis largely remain unchanged and are therefore omitted here. I add an updated version of Table I of Broda and Weinstein (2006) to Appendix A.

¹¹Note that a value for sigma cannot be obtained for all product categories presented in Table 1. For some product categories, the number of observations is not sufficiently high to estimate a sigma.

¹²Alternatively, I use the Broda and Weinstein (2006) estimates. The results of the analysis presented below are not sensitive to this change.

¹³Note that for HTS-10 goods the lambda ratio is not defined if there is no common variety in the first and the last period. Where this occurs, the lambda ratio of the HTS-8 good is used for all the HTS-10 goods within this HTS-8 category. If the lambda ratio is not defined at the HTS-8 level, the HTS-6 category is used. To obtain an elasticity for these aggregated goods, the geometric mean of the sigmas of the HTS-8 goods is used. In consequence, only 858 lambda ratios are defined (and not 16,322), a combination of HTS-2, HTS-4, HTS-6, HTS-8 and HTS-10 goods. Note however, that *all* 16,322 sigmas are used for the calculation of the index.

aggregate data. I use the “zero variety” to correct for inflation. Employing import price indices from the Bureau of Labor Statistics (BLS), I am able to use a different rate of inflation for every imported HTS section.¹⁴ In column 2 of Table 3, summary statistics on the modified lambda ratios are shown. The ratio of the median product category takes the value of 0.48 which corresponds to a variety increase of approximately 108%.

Insert Table 3 approximately here

Using equations (2) to (7), I compute the EPR under both specifications. It is displayed in the first row of the first and the last column of Table 4, respectively. In the second row, the total biases, defined as $TB = 1/EPR - 1$, are depicted, expressing the percentage by which the conventional price index is biased upwards. It can be inferred from the table that over the last 17 years, this bias amounted to 5.26% in the baseline specification comparable to Broda and Weinstein (2006) and to 36.09% in the “no intensive margin” specification. This corresponds to annual biases in the import price index of 0.30% and 1.83%, respectively (third row in Table 4).

Insert Table 4 approximately here

Following equation (8), the biases are then weighted by the import share to obtain the GFV. As in Broda and Weinstein (2006), I determine that share simply by taking the fraction of imports relative to GDP. I obtain an average import share of 10.6% for the period from 1990 to 2006. Defining varieties as product-country pairs using the U.S. trade dataset results in welfare gains of 0.54% of GDP as can be inferred from the fourth row of Table 4. These gains are substantially higher if the “no intensive margin” case is considered and amount to 3.32% of GDP.

¹⁴Assume, for example, that the BLS reports a price increase of 20% between 1990 and 2006 within a particular product category. Then, the “zero variety” takes the value $\frac{p_{g0t}x_{g0t}}{p_{g0t-1}x_{g0t-1}} = 1.2$. If nominal expenditure on this product—as measured in the trade data—rises by 40%, the modified lambda ratio becomes $\frac{\Lambda_{gt}}{\Lambda_{gt-1}} = 1/1.4 * 1.2 = 0.86$.

The two estimates of the GFV presented in this section differ greatly in magnitude, the second being six times larger than the first. While the first estimate is likely to understate variety gains due to the relatively coarse variety definition imposed by the trade dataset, the second result overestimates these welfare gains: Variations of trade values are likely to be at least partly due to intensive margin adjustments. This case serves as a maximum variety gains estimate given the variation in U.S. import flows. However, I will argue that since this estimate is of modest size, it is still a valuable contribution to the variety gains discussion. In the next section, findings from the existing literature are used to attenuate the extreme assumptions of the “no intensive margin case”.

4.2. The Impact of Additional Extensive Margins on the Variety Gains

Several contributions in the literature evaluate the relative importance of the extensive and the intensive margins of trade. Cross-section calculations predominantly find that the extensive margin is central in explaining the differences between countries or firms in export or import values. Examples from the literature are Hummels and Klenow (2005) and Bernard et al. (2009b). In this contribution, however, I am interested in the share that new varieties acquire after a certain time, or, in other words, in the share of the extensive margin on the intertemporal variation of U.S. import values. Estimates of this share using standard trade data are typically small. For example, Amiti and Freund (2010) find that between 1997 and 2005, most of the variation in U.S. imports from China was due to adjustments at the intensive margin. These findings also explain the relatively low variety gains obtained using the Armington variety definition.

However, this changes substantially if more detailed data sources are considered. Bernard et al. (2009b) use data on U.S. firms that import goods from abroad.¹⁵ If firm

¹⁵Data stem from the U.S. Linked/Longitudinal Firm Transaction Database (LFTTD). A more detailed description of the data can be found in Bernard et al. (2009c).

entry and exit as well as product turnover within firms are part of the extensive margin of trade, then most variation in import flows is due extensive margin adjustments if a sufficiently long period is considered: The authors show that between 1993 and 2003, 76% of all import value variations were caused by adjustments at extensive margins.¹⁶ As the authors recognize, this result suggests that variety gains from trade may be much larger than previously estimated if the additional extensive margins—firm entry and exit and product turnover within firms—are taken into account.¹⁷

I now make use of the information extracted by Bernard et al. (2009b). Specifically, the revealed expenditures on new and disappearing firm-product-country combinations allow for the calculation of a single common set and therefore a single lambda ratio for total U.S. merchandise imports.¹⁸ This aggregate lambda ratio takes a value of 0.77 which is substantially lower than the median lambda ratio of 0.95 in the baseline specification under the Armington assumption as shown in Table 3. I then calculate the endpoint ratio using the full distribution of substitution elasticities.¹⁹

The results of this specification, labeled “firm-product-country margin”, are presented in the second column of Table 4. Differentiating varieties according to the firm-product-country dimension results in a bias in the import price index of 13.38%, or 0.74% annually. Hence, additional variety differentiation at the firm-level reveals

¹⁶Newly imported varieties tend to be unimportant in the first few years. Over time, however, these varieties acquire a larger share on total imports. For example, Bernard et al. (2009b) find that the extensive margin accounts for 50% of the time-series variation of U.S. imports if one considers the period from 1998 to 2003. If this period is extended to 1993, then the extensive margin accounts for 76% of the variation.

¹⁷One possible variety definition at the firm level is to differentiate varieties according to different products stemming from different foreign firms. Bernard et al. (2009b), on the other hand, differentiate varieties according to importing firms instead of supplying firms.

¹⁸Total merchandise imports amount to 460 billion USD in 1990. Adding the total increase of 574 billion USD imports amount to 1034 billion USD in 2006. Of these 1034 billion USD in 2006, 719 billion USD were due to new firm-product-country pairs. Of the 460 billion USD in 1992, 278 billion USD were lost due to vanishing firm-product-country pairs. This yields the following formula for the lambda ratio: $\lambda_{gt}/\lambda_{gt-1} = ([1034 - 719]/1034) / ([460 - 278]/460) = 0.77$.

¹⁹In other words, I use the same lambda ratio structure as in the baseline specification, i.e. replace the 858 lambda ratios by 0.77 (see footnote 13) and aggregate these lambda ratio as described by Equation 7. The stark assumption of one single lambda ratio is assessed in the following section.

substantially more variety growth as compared to the baseline case, indicated by the 2.5 times higher GFV, amounting to 1.34% as compared to 0.54% of GDP. To summarize, additional extensive margins of trade, not revealed by conventional trade data, have a large impact on the variety gains from trade. These results conform to empirical insights of the existing literature, namely that the inclusion of firm-level information increases the relevance of the extensive margin considerably.

4.3. Discussion of the Results

How useful is the “no intensive margin” case as a measure of the upper bound of variety gains? One possibility to investigate this issue is to apply this measure to cases where it can be compared to findings from the existing literature. Blonigen and Soderbery (2010) analyze the U.S. automobile market. Concentrating on imports, the authors calculate an endpoint ratio of 0.959 for the period of 1990 to 2005 using the Armington assumption. Additionally differentiating between different car brands and models, the endpoint ratio drops to 0.922, indicating that variety gains approximately double using a more detailed variety definition. My approach suggests an endpoint ratio of 0.843 for imports in this industry using the “no intensive margin” case, hinting at GFV that are slightly more than three times larger compared to the Armington case. Hence, the “accurate variety set” used in Blonigen and Soderbery (2010) travels about half the distance between Armington and the “no intensive margin” case. Assuming that even the more disaggregated variety set of Blonigen and Soderbery (2010) still hides some variety growth or unobserved quality changes, the “no intensive margin” specification seems to be a sensible measure to put an upper bound on the variety gains.

Regarding the interpretation of the “firm-product-country margin” specification, I quote Bernard et al. (2009b) who state: “To the extent that HTS categories are too broad to discern the adding and dropping of even more disaggregate product varieties, the true contribution of the extensive margin may be even greater”. Recent research

supports the notion of further horizontal and vertical differentiation within HTS-10 categories. These contributions include Schott (2004), Hummels and Klenow (2005), Hallak (2006) and Hallak and Schott (2008), implying that even using more disaggregated data sets, hidden variety changes will occur, potentially leading to downward biased estimates of the GFV. Thus, even though variety gains including the product-firm dimension may be nearer to the true unobserved variety gains, they may still be too small if one expects remaining hidden variety increases. This again accentuates the usefulness of an upper bound of the GFV.

Having said that, crowding of the variety space with not-so-useful varieties may be an important issue—also in the context of the present paper.²⁰ If many very similar varieties appear with doubtful value to the consumer, this should, in principle, be captured by higher elasticity estimates and therefore drive down variety gains for given lambda ratios. In the present paper, however, even though I assume more detailed variety definitions in the two latter specifications of Table 4, I have to rely on estimates calculated from conventional trade data due to data limitations. This may lead to biased GFV. To address this and other potential sensitivity issues, I provide several robustness checks in the next section.

4.4. Robustness Checks

There are three main issues for evaluating the robustness of the results presented above. First, the last two specifications in Table 4 rely on the assumption that varieties are defined at a more detailed level as compared to the Armington product-country case. The results, however, are calculated by employing elasticities of substitution that are estimated from conventional trade data. These elasticities may underestimate the substitutability between varieties of the specifications that implicitly assume a more detailed variety definition. In rows two and three of Table 5, I therefore increase the

²⁰For example, Broda and Weinstein (2010) note that a large part of within-firm variety churning is due to simple labeling or marketing changes.

estimated elasticities substantially, by 50% and by 100%.^{21,22} Even in the very extreme latter case, the variety gains remain 25% larger in the “firm-product-country margin” and three times larger in the “no intensive margin” case than in the baseline Armington specification.

Insert Table 5 approximately here

Second, there is the question of whether the BLS inflation figures are an accurate measure of the common varieties’ price evolution. On the one hand, the BLS figures are sometimes criticized for overstating inflation due to the neglect of, for example, quality adjustments. However, inflation of the prices of the common varieties required to calculate the modified lambda ratios, can, in principle, be lower or higher than the official figures that reveal inflation for the full basket of goods.²³ While this issue cannot be solved conclusively, I demonstrate in the last two columns of Table 5 that my results are robust to even substantial changes in the inflation figures. I increase and decrease the BLS inflation measures by one percentage point each year in each product category and find that the upper bound of variety gains remains at least five times larger than in the baseline specification.²⁴

Third, the assumption made in the “firm-product-country margin” specification seems bold: Instead of a full set of lambda ratios differentiated according to product categories, one single lambda ratio for total U.S. merchandise imports is used. This

²¹I increase $(\sigma - 1)$ by 50% and 100%, since $\sigma > 1$ is imposed by the modeling approach.

²²Blonigen and Soderbery (2010) compare elasticities estimated from import data with elasticities estimated from more detailed market data. They find that the median of the latter estimates is approximately 17% larger. Broda and Weinstein (2006) change product definitions from SITC-3 to SITC-5—hence inducing the varieties contained within the broader products to be more similar—and this increases the median lambda ratio by 42%. Narrowing the product definition to HTS-10, the median elasticity increases by another 23%.

²³An implicit assumption that is required when applying the lambda ratios in equations 4 and 5 is that inflation is the same for common, new and disappearing varieties. The results of my robustness checks indicate, however, that this issue is not crucial to the results.

²⁴For example, Boskin et al. (1998) estimate an upward bias in the consumer price index (which also includes imports) of approximately 1% per year in the 1997 to 1998 period. However, improvements in the measurement of prices are likely to have reduced these biases since then; see for example Gordon (2000).

certainly is a severe issue if higher lambda ratios were systematically related to higher or lower elasticities of substitution. I test the validity of this assumption by applying it to the conventional trade data and compare the result to the baseline estimates in Table 4. The assumption is acceptable if these two estimates yield similar results. The endpoint ratio resulting from employing a single lambda ratio with conventional trade data amounts to 0.943 and is not substantially different from the 0.950 using the baseline specification. I conclude that the use of a single lambda ratio is an acceptable simplification.

Summarizing, the results of Table 4 prove to be robust to alternative assumptions. The variety gains from trade remain substantially higher than in the baseline Armington specification if additional extensive margins are considered.

5. Concluding Remarks

I motivate this contribution by arguing that conventional trade data hides significant variety growth. As a consequence, estimates of the variety gains from trade that rely on such data may be underestimated. The objective of my contribution is to present realistic estimates of the variety gains from trade—under the presumption that products are thought to be differentiated between or even within firms.

I proceed with the empirical analysis in two steps. First, using U.S. import data from 1990 to 2006, I calculate the variety gains from trade as in Broda and Weinstein (2006); i.e., assuming that products are differentiated between countries of origin. Using this specification, I find modest variety gains of 0.54% of GDP for a period of 17 years. By modifying the lambda ratios, I then presume—as a counterfactual—that all variation in U.S. import values can be attributed to the extensive margin of trade. This extreme assumption yields a maximum estimate of the variety gains. In the case of the United States, these gains amount to 3.32% of GDP between 1990 and 2006.

In the second step of the analysis, I use results from the empirical literature on

multi-product firms in international trade to position the variety gains between the two results of the first step. I find that these variety gains account for 1.34% of GDP and are therefore 2.5 times larger than the baseline estimate. I argue that the magnitude of the gains correspond to findings in the empirical literature. While studies using conventional trade data attribute most of the time-series growth in imports to the intensive margin of trade, studies that rely on multi-product firm data find substantially higher contributions of the extensive margin of trade.

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Appendix A. Tables

Table 1: Variety of U.S. Imports, 1990-2006

	Year	Number of HTS categories	Median no. of exporting countries	Average no. of exporting countries	Total no. of varieties (country- good pairs)	Share of total imports in year
	(1)	(2)	(3)	(4)	(5)	(6)
All goods (1990)	1990	14,564	14	12.41	180,831	1.00
All goods (2006)	2006	16,968	18	16.68	282,947	1.00
Common (1990)	1990	9,866	14	12.39	122,205	0.54
Common (2006)	2006	9,866	18	17.37	171,389	0.50
1990 not in 2006	1990	4,698	11	12.48	58,626	0.46
2006 not in 1990	2006	7,102	14	15.71	111,558	0.50

Notes: A good is defined after HTS-10. A variety is defined as a good from a particular country. This table is an updated version of Table 1 in Broda and Weinstein (2006). Calculations are based on U.S. import data available from CID at UC Davis.

Table 2: Summary Statistics: Elasticities of Substitution, United States

Number	16,322
Mean	11.84
StE	1.52
5% percentile	1.57
Median	3.28
95% percentile	18.51

Table 3: Summary Statistics: Lambda Ratios, United States

	Baseline case	No intensive margin
Number	858	858
Mean	1.30	2.20
5% percentile	0.13	0.04
Median	0.95	0.48
95% percentile	2.44	4.72

Notes: Calculations are based on U.S. import data available from CID at UC Davis.

Table 4: Bias in the U.S. Import Price Index and Variety Gains

	Baseline case	Firm-product country margin	No intensive margin
Endpoint ratio	0.950	0.882	0.735
Total bias	5.26%	13.38%	36.09%
Annual bias	0.30%	0.74%	1.83%
GFV (in % of GDP)	0.54%	1.34%	3.32%

Notes: Calculations are based on U.S. import data available from CID at UC Davis, data from the LFTTD presented in Bernard et al. (2009b) and the BLS import price indices.

Table 5: Welfare Impact of Alternative Specifications

	Firm-product- country margin	No intensive margin
Benchmark estimates:	1.34%	3.32%
Higher elasticities:		
$(\sigma_g - 1) * 1.5$	0.91%	2.20%
$(\sigma_g - 1) * 2.0$	0.68%	1.65%
Varying inflation:		
-1.0 percentage points/year	-	3.83%
+1.0 percentage points/year	-	2.81%

Notes: The figures presented in this table express the welfare gains from trade in the United States from 1990 to 2006 as a percentage of GDP.