Export Variety and Country Productivity

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1. Introduction

The hallmark of the endogenous growth models (e.g. Romer 1990, Grossman and Helpman, 1991) is their focus on the creation of new or higher quality products, and their effects on productivity and economic growth. Opening a country to trade opportunities will typically increase the product variety of imports available and may also increase the variety of exports, both of which contribute to growth. Despite the microeconomic focus of these model, the link between trade and growth is usually assessed at a more aggregate level, in which case the causality between the two is unclear (Frankel and Romer, 1999, Rodriguez and Rodrik, 2000, Dollar and Kraay, 2001, Hallak and Levinsohn, 2004). To move beyond these aggregate statistics, we need more detailed information on the *product variety* of traded goods. Recent work (Hummels and Klenow, 2002, Schott, 2004) has investigated the extent to which trade between countries consists of a common set of goods, or a larger set of goods from bigger countries, or different quality goods. These authors identify an important role for product variety and quality in explaining trade between countries. It is reasonable to expect, therefore, that these features will also have an influence on country productivity.

The first empirical work on measuring product variety with a CES aggregator function was Feenstra (1994), who applied it to a handful of U.S. import goods. Broda and Weinstein (2003) have recently extended this to all U.S. imports, and find that increased import variety contributes to a 1.2% per year fall in the "true" import price index. This would show up as productivity improvements in importing industries. On the other side of the coin, a direct link between *export* variety and productivity have been found by Feenstra et al (1999) for South Korea and Taiwan. The data used to measure product variety are the disaggregate exports from these countries to the United States, which is the same data that will be used in this study. Funke and Ruhwedel (2001a,b, 2002) have analyzed the link between export product variety and aggregate GDP for the OECD and East Asian countries.[1] They find that a country's export variety (relative to the U.S.) is a significant determinant of its GDP per-capita and export performance. While these latter studies apply to broad groups of countries, the analysis is restricted to a single overall measure of export variety and its impact on aggregate GDP or exports.

The objective of this paper is to examine how export variety affects productivity, using a broad cross-section of advanced and developing countries and disaggregating across sectors. We will be calculating export variety at the sectoral level (sections 2 and 3), and using this within a translog GDP function for the economy (sections 4 and 5) to estimate country productivity differences (section 6). Analogous to Harrigan (1997), the differences in export variety across countries play the role of "price differences" in the GDP function, and therefore influence the shares of value added devoted to each sector. Empirically, the export variety indexes are dependent variables in the output share equations, which are estimated along with a GDP equation for each country. The data cover 34 countries from 1982 to 1997, and the empirical specification is presented in section 6.

In sections 7 and 8, we report estimates of the GDP system including the effects of export variety on productivity. In these estimates, export variety is treated as an *endogenous* variable, as in the endogenous growth models, for example. The instrumental variables used to determine export variety are those suggested by the work of Eaton and Kortum (2002) and Melitz (2003): tariffs, transport costs and other border effects. In their models, firms receive random productivity draws and, depending on the border effects, may become exporters or not. So the

[1] Funke and Ruhwedel (2003) use export variety measures to calculate the welfare gains from trade liberalization in Central and Eastern Europe.

distribution of productivities together with border effects jointly determine export variety. But there is also an important *exclusion restriction* suggested by these models: tariffs and transport costs should not have an impact on productivity *except through* export (and import) variety. This exclusion restriction amounts to a test for overidentification in our system, as we describe. We discuss the impact of tariffs and distance on export variety and formally test this overidentifying restriction, which is satisfied. This confirms the importance of export variety as the *mechanism* (Hallak and Levinsohn, 2004) by which trade affects productivity. The results also show that a 10 percentage point increase in U.S. tariffs would lead to a 3.8% fall in exporting countries productivity, which indicates that tariffs are statistically and economically important in affecting productivity via export variety.

In section 9 we decompose productivity differences across countries into that part explained by export variety and the remaining explained by other determinants, i.e. fixed effects. We find that export variety accounts for 8.5% of the variation in country productivity (though if country fixed effects are not included in productivity differences, then export variety accounts for 77% of the variation). Additional conclusions are given in section 10.

2. Effect of New Varieties

Consider a world economy with many c=1,…,C countries, each of which produce many types of goods. For simplicity in this section we aggregate these goods into a single sector, but the extension to multiple sectors will be immediate. For each period t, let the set of goods produced in country c be denoted by $I_t^c \subset \{1,2,3,....\}$. Then the quantity vector of each type of good produced in country c in period t is denoted by $q_t^c > 0$. The aggregate output of each country c, Q_t^c, is characterized by a CES function of the output of each good in the country, q_{nt}^c:

$$Q_t^c = f(q_t^c, I_t^c) = \left(\sum_{i \in I_t^c} a_i \left(q_{it}^c\right)^{(\sigma-1)/\sigma} \right)^{\sigma/(\sigma-1)}, a_n > 0, \; c = 1,\ldots,C, \tag{1}$$

where the elasticity of substitution between goods is σ. We assume that total output obtained from the economy is constrained by the transformation curve:

$$F[f(q_t^c, I_t^c), V_t^c] = 0, \tag{2}$$

where $V_t^c = \left(v_{1t}^c, v_{2t}^c, \ldots, v_{Mt}^c\right) > 0$ is the endowment vector for country c in year t.

For *outputs*, we suppose that $\sigma < 0$ in (1), which means that the set of feasible varieties q_{nt}^c in any country will lie along a strictly concave transformation curve, satisfying $Q_t^c = \overline{Q}_t^c$. This is shown in Figure 1, where we draw the transformation frontier between two product varieties q_{1t} and q_{2t}, within a country. For a given transformation curve, and given prices, an increase in the number of output varieties will raise revenue. For example, if only output variety 1 is available, then the economy would be producing at the corner A, with output revenue shown by the line AB. Then if variety 2 becomes available, the new equilibrium will be at point C, with an *increase* in revenue. This illustrates the benefits of output variety.

For *inputs*, we would instead use that $\sigma > 1$ in (1), which is then the formula for a CES production function. Given output $Q_t^c = \overline{Q}_t^c$, the inputs would lie along an iso-quant like that illustrated in Figure 2. If only input 1 is available, then the costs of producing $\overline{Q}_t^c$ would be minimized at point A, with the budget line AB. But if input 2 is also available, then the costs are instead minimized at point C, with a *fall* in costs. This illustrates the benefits of input variety. We will use the *output* case to illustrate the effects of export variety, whereas the *input* case would apply to import variety (as in Feenstra, 1994, and Broda and Weinstein, 2003).

3. Measuring Output Variety

Considering maximizing the value of output obtained in each industry, as in Figure 1. Under the assumption of perfect competition, and given equation (1), the value of output obtained in each country will be $P_t^c Q_t^c$, where P_t^c is a CES function of the prices of all product varieties produced in the country:

$$P_t^c \equiv c(p_t^c, I_t^c) = \left(\sum_{i \in I_t^c} b_i \left(p_{it}^c\right)^{1-\sigma} \right)^{1/(1-\sigma)}, b_i = a_i^\sigma > 0, \;\; c = 1,..., C, \tag{3}$$

and $p_t^c > 0$ is the domestic price vector for each country.

The right-hand side of expression (3) is a CES cost function, with potentially differing sets of product varieties across countries and over time. These cannot be evaluated with knowledge of the parameters b_i. But a standard result from index number theory is that the *ratio* of cost function can be evaluated, using data on price and quantities in the two periods or two countries. Feenstra (1994) shows how this result applies even when the number of goods is changing. In particular, the ratio of the CES cost functions over two countries a and b, equals to the product of the Sato-Vartia price index of goods that are common, $I \equiv \left(I_t^a \cap I_t^b\right) \neq \varnothing$, multiplied by terms reflecting the revenue share of "unique" goods:

$$\frac{P_t^a}{P_t^b} = \prod_{i \in I} \left(\frac{p_{it}^a}{p_{it}^b} \right)^{w_i(I)} \left(\frac{\lambda_t^a(I)}{\lambda_t^b(I)} \right)^{1/(\sigma-1)}, \quad a, b = 1,..., C, \tag{4}$$

where the weights $w_i(I)$ are constructed from the revenue shares in the two countries:

$$w_i(I) \equiv \left(\frac{s_{it}^a(I) - s_{it}^b(I)}{\ln s_{it}^a(I) - \ln s_{it}^b(I)} \right) \Big/ \sum_{i \in I} \left(\frac{s_{it}^a(I) - s_{it}^b(I)}{\ln s_{it}^a(I) - \ln s_{it}^b(I)} \right), \tag{5}$$

$$s_{it}^{c}(I) \equiv p_{it}^{c} q_{it}^{c} / \sum_{i \in I} p_{it}^{c} q_{it}^{c}, \text{ for c = a,b,} \tag{6}$$

$$\lambda_{t}^{c}(I) = \frac{\sum_{i \in I} p_{it}^{c} q_{it}^{c}}{\sum_{i \in I_t^c} p_{it}^{c} q_{it}^{c}} = 1 - \frac{\sum_{i \in I_t^c, i \notin I} p_{it}^{c} q_{it}^{c}}{\sum_{i \in I_t^c} p_{it}^{c} q_{it}^{c}}, \text{ for c = a,b.} \tag{7}$$

Notice that the output shares in (6), for each country, are measured relative to the *common* set of goods I. Then the weights in (5) are the *logarithmic mean* of the shares $s_{it}^{a}(I)$ and $s_{it}^{b}(I)$, and sum to unity over the set of goods $i \in I$.[2]

To interpret (7), notice that $\lambda_t^c(I) \leq 1$ due to the differing summations in the numerator and denominator. This term will be strictly less than one if there are goods in the set I_t^c that are *not found* in the common set I. In other words, if country a is selling some goods in period t that are *not sold* by country b, this will make $\lambda_t^a(I) < 1$.

We can re-express equation (4) in logs as:

$$\ln \frac{P_t^a}{P_t^b} = \sum_{i \in I} w_i(I) \ln\left(\frac{p_{it}^a}{p_{it}^b}\right) + \left(\frac{1}{\sigma - 1}\right) \ln\left(\frac{\lambda_t^a(I)}{\lambda_t^b(I)}\right), \qquad a, b, = 1, \ldots, C. \tag{8}$$

The first term on the right of (8) is the Sato (1976)-Vartia (1976) price index, which is simply a weighted average of the price ratios, using the values $w_i(I)$ as weights. What is new about equation (8) is the second term on the right, which reflect changes in product variety. If country c in period t has new, unique outputs (not in the common set I), we will have $\lambda_t^c < 1$. From (8), when $\sigma < 0$ this will *raise* the price index of outputs, P_t^a / P_t^b. In other words, the introduction of

[2] More precisely, the numerator of (5) is the logarithmic mean of the output shares of the two countries, and lies in-between these shares. The denominator of (5) is introduced so that the weights $w_i(I)$ sum to unity,

new output varieties will act in the same way as an increase in prices in a sector: it will draw resources towards that sector.[3]

In practice, we will measure the ratio $\lambda_t^a / \lambda_t^b$ using exports of countries to the United States. While it would be preferable to use their worldwide exports, our data for the U.S. is more disaggregate, and allows for a finer measurement of "unique" products sold by one country and not another. Specifically, for 1972 – 1988 we will use the 7-digit Tariff Schedule of the U.S. Annotated (TSUSA) classification of U.S. imports, and for 1989 – 2001 we shall use the 10-digit Harmonized System (HS) classification of imports.

To measure the ratio $\lambda_t^a / \lambda_t^b$, we need to decide on a consistent "comparison country." For this purpose, we shall use the *worldwide exports* from all countries to the U.S. as the comparison. Denote this comparison country by *, so that the set $I_t^* = \bigcup_{c=1}^{C} I_t^c$ is the complete set of varieties imported by the United States in year t, and $p_{it}^* q_{it}^*$ is the total value of imports for good i. Then comparing country c to country * in year t, it is immediate that the common set of goods exported is $I_t^c \cap I_t^* = I_t^c$, or simply the set of goods exported by country c. Therefore, from (7) we have that $\lambda_t^c(I_t^c) = 1$, and:

$$\lambda_t^{c*} \equiv \lambda_t^*(I_t^c) = \frac{\sum_{i \in I_t^c} p_{it}^* q_{it}^*}{\sum_{i \in I_t^*} p_{it}^* q_{it}^*} = 1 - \frac{\sum_{i \in I_t^*, i \notin I_t^c} p_{it}^* q_{it}^*}{\sum_{i \in I_t^*} p_{it}^* q_{it}^*}. \tag{9}$$

Noting from (8) that product variety in country c relative to the comparison is measured as $\lambda_t^c(I_t^c) / \lambda_t^*(I_t^c)$, but this has a negative coefficient when $\sigma < 0$, let us instead invert it and

[3] If instead we consider the case of input variety, then $\sigma > 1$ in (8). Then the introduction of new inputs will *lower* their price index. Thus, new input varieties would have the same positive efficiency effect as would a drop in input prices.

measure product variety of country c relative to the world by $\lambda_t^*(I_t^c)/\lambda_t^c(I_t^c) = \lambda_t^*(I_t^c)$, which enters (8) with a positive coefficient 1/(1– σ). For brevity we denote this by λ_t^{c*} in (9). It is interpreted as the *share of total U.S. imports from products that are exported by country c.* Equivalently, it is *one minus the share of total U.S. imports from products that are* not *exported by country c.* Note that this measure depends on the *set of exports* by country c, I_t^c, but not on its value of exports, except insofar as they affect the value of worldwide exports.

4. GDP Function

To study the effects of trade through the introduction of new export varieties, we need to model the allocation of factor endowments among the production of goods in all industries. Suppose there are M kinds of factor endowments in the economy, denoted by the endowment vector $V_t^c = (v_{1t}^c,..., v_{Mt}^c) > 0$. There are N sectors in the economy with output denoted by $Q_t^c = (Q_{1t}^c,..., Q_{Nt}^c) > 0$, each of which is a CES aggregate as in (1) with $\sigma_n < 0$.[4] The aggregate sectoral prices are $P_t^c = (P_{1t}^c,..., P_{Nt}^c) > 0$, as defined by the CES unit-costs in (3). Given the assumption of perfect competition, total revenue or GDP of the economy in period t is:

$$G_t^c\left(P_t^c, V_t^c\right) \equiv \max\left\{ P_t^c \cdot Q_t^c : F_t^c\left(Q_t^c, V_t^c\right) = 0 \right\}, \tag{10}$$

where $F_t^c(Q_t^c, V_t^c) = 0$ is the transformation curve in period t that generalizes (2) when there are many sectors. $G_t^c\left(P_t^c, V_t^c\right)$ is homogeneous of degree one with respect to prices, and with the assumption that F is homogeneous of degree one, then $G_t^c\left(P_t^c, V_t^c\right)$ is also homogeneous of

[4] In the case that some of these sectors are imported rather than exported, we would denote $Q_{nt}^c < 0$ as the negative of the CES aggregate (1), with $\sigma_n > 1$.

degree one with respect to endowments. As usual, the derivative of the GDP function with respect to P_t^c equals the sectoral outputs Q_t^c, and the derivative with respect to endowments V_t^c can be interpreted as the factor prices w_t^c.

To implement the above GDP function empirically, we will assume that it follows a translog functional form:

$$\ln G_t^c\left(P_t^c, V_t^c\right) = \alpha_0^c + \beta_0^c t + \sum_{n=1}^{N} \alpha_n \ln P_{nt}^c + \sum_{k=1}^{M} \beta_k \ln v_{kt}^c + \tfrac{1}{2} \sum_{m=1}^{N} \sum_{n=1}^{N} \gamma_{mn} \ln P_{mt}^c \ln P_{nt}^c$$
$$+ \tfrac{1}{2} \sum_{k=1}^{M} \sum_{\ell=1}^{M} \delta_{k\ell} \ln v_{kt}^c \ln v_{\ell t}^c + \sum_{n=1}^{N} \sum_{k=1}^{M} \phi_{nk} \ln P_{nt}^c \ln v_{kt}^c. \qquad (11)$$

Notice that we allow this function to differ across countries based on the constant α_0^c and also the exogenous time trend $\beta_0^c t$. To satisfy the properties of homogeneity in prices and endowments as well as symmetry, we impose the following restrictions:

$$\gamma_{mn} = \gamma_{nm}, \ \sum_{n=1}^{N} \alpha_n = 1, \ \sum_{n=1}^{N} \gamma_{mn} = \sum_{n=1}^{N} \phi_{nk} = 0,$$
$$\delta_{k\ell} = \delta_{\ell k}, \ \sum_{k=1}^{M} \beta_k = 1, \ \sum_{k=1}^{M} \delta_{k\ell} = \sum_{k=1}^{M} \phi_{nk} = 0. \qquad (12)$$

The share of factor k in the GDP of the economy in period t equals to the derivative of $\ln G_t^c\left(P_t^c, V_t^c\right)$ with respect to $\ln v_{kt}^c$:

$$s_{kt} = \beta_k + \sum_{\ell=1}^{M} \delta_{k\ell} \ln v_{\ell t}^c + \sum_{n=1}^{N} \phi_{kn} \ln P_{nt}^c, \quad k = 1,\ldots, M. \qquad (13)$$

Similarly, the share of sector n in GDP of period t equals to the derivative of $\ln G_t^c\left(P_t^c, V_t^c\right)$ with respect to $\ln P_{nt}^c$:

$$s_{nt} = \alpha_n + \sum_{m=1}^{N} \gamma_{mn} \ln P_{mt}^c + \sum_{k=1}^{M} \phi_{nk} \ln v_{kt}^c, \quad n = 1,\ldots, N. \qquad (14)$$

5. Estimating the Share and GDP Equations

Given that empirical data on the shares of different factors in GDP is rarely available, we estimate the output share equations (14) but not the factor shares in (13). To implement this, we difference with respect to the shares s_{nt}^{*} of the hypothetical country. We assume that the prices of goods sold by each country are the same across countries, but that they differ in the *variety* of export products sold by each. Denote the set of varieties produced by industry n as I_{nt}^{c}, so the aggregate price P_{nt}^{k} is a CES function of the prices of these varieties:

$$P_{nt}^{c} \equiv c(p_t^c, I_t^c) = \left(\sum_{i \in I_{nt}^{c}} b_i \left(p_{it}^{c}\right)^{1-\sigma} \right)^{1/(1-\sigma)}, b_i = a_i^{\sigma} > 0, \ \ c = 1,\ldots,C, \ n = 1,\ldots,N.$$

Using the union of all exporting countries as the comparison country, then from (8) and (9),

$$\ln \frac{P_{nt}^{c}}{P_{nt}^{*}} = \sum_{i \in I_{nt}} w_i(I) \ln\left(\frac{p_{it}^{c}}{p_{it}^{*}}\right) + \left(\frac{1}{\sigma_n - 1}\right) \ln\left(\frac{\lambda_{nt}^{c}}{\lambda_{nt}^{c*}}\right) \Rightarrow \ln \frac{P_{t}^{c}}{P_{t}^{*}} = \left(\frac{1}{1-\sigma_n}\right) \ln \lambda_{nt}^{c*}, \qquad (15)$$

where the latter equality comes from assuming that $p_{it}^{c} = p_{it}^{*}$ for every tradable good. Thus, the ratio of CES price indexes depends only on the relative product variety of country c. A similar approach was used by Harrigan (1997) to model the effective price differences across countries as reflecting total factor productivity in the exporting sectors, whereas we are modeling the price differences as reflecting product variety of exports.

If we difference (14) with respect to the share equation of the comparison country, we obtain an expression that relates the industry share in country c in period t to λ_{nt}^{c*}:

$$s_{nt}^{c} = s_{nt}^{*} + \sum_{k=1}^{M} \phi_{kn} \left(\ln v_{kt}^{c} - \ln v_{kt}^{*} \right) + \sum_{m=1}^{N} \frac{\gamma_{mn}}{(1-\sigma_{m})} \ln \lambda_{mt}^{c*} + \gamma_{N+1,n} \left(\ln P_{N+1,t}^{c} - \ln P_{N+1t}^{*} \right), \qquad (16)$$

where the last term captures the effect of a nontraded good on the industry shares. Here we assume that in addition to the N traded goods, each country has one nontraded good, denoted by N+1. The shares s_{nt}^{*} of the comparison country will be estimated as industry fixed-effects when pooling (16) across countries. We measure the endowments of the hypothetical country by the *sum of endowments* of all sample countries, $v_{kt}^{*} = \sum_{c=1}^{C} v_{kt}^{c}$, while the non-traded goods price for the comparison country is a weighted average of the country non-traded good price indexes.[5]

In addition to the share equations (16), we want to add an equation to estimate how the expansion of product varieties contributes to GDP and therefore to country productivity. We assume that the comparison country also has the translog function shown in (11), where without loss of generality we can normalize $\alpha_0^{*} = \beta_0^{*} = 0.$ Then using the share equations in (13)-(14), it can be confirmed that the difference between GDP of country c and the comparison country is:

$$\begin{aligned} &\ln G\left(P_t^{c}, V_t^{c}\right) - \ln G\left(P_t^{*}, V_t^{*}\right) \\ &\quad = \alpha_0^{c} + \beta_0^{c} t + \sum_{n=1}^{N} \tfrac{1}{2}\left(s_{nt}^{c} + s_{nt}^{*}\right)\left(\ln P_{nt}^{c} - \ln P_{nt}^{*}\right) + \sum_{k=1}^{M} \tfrac{1}{2}\left(s_{kt}^{c} + s_{kt}^{*}\right)\left(\ln v_{kt}^{c} - \ln v_{kt}^{*}\right). \end{aligned} \qquad (17)$$

The right-hand side of (17) equals a time trend, plus a Törnqvist index of relative prices, plus a Törnqvist index of relative endowments. These indexes provide a decomposition of relative GDP into its price and factor-endowment components.[6]

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[5] The non-traded good price indexes of the sample countries are obtained by netting the prices of traded goods, both export and import, from the country GDP deflators.

[6] The decomposition in (17) is a special case of results in Diewert and Morrison (1986), which are summarized by Feenstra (2004, Appendix A, Theorem 5).

In our case, the price differences of the traded goods industries are due entirely to export variety, so using (15) we can re-express (17) initially as:

$$\ln G\left(P_t^c, V_t^c\right) - \ln G\left(P_t^*, V_t^*\right) - \sum_{k=1}^{M} \tfrac{1}{2}\left(s_{kt}^c + s_{kt}^*\right)\left(\ln v_{kt}^c - \ln v_{kt}^*\right) =$$
$$\alpha_0^c + \beta_0^c t + \sum_{n=1}^{N} \tfrac{1}{2}\left(s_{nt}^c + s_{nt}^*\right) \frac{\ln \lambda_{nt}^{c*}}{(1-\sigma_n)} + \tfrac{1}{2}\left(s_{N+1t}^c + s_{N+1t}^*\right)\left(\ln P_{N+1t}^c - \ln P_{N+1t}^*\right), \qquad (17')$$

where the differences in factor endowments between country c and the hypothetical country are moved to the left hand side, and the last term of the right hand side is the difference in the non-traded good price between the countries. The left hand side of this equation is interpreted as the productivity differences between the countries – it is the GDP of country c relative to that of the hypothetical country, net of the differences in factor endowments.

Equation (17') is not immediately useful since the GDP level of the hypothetical country, and its factor shares, are not observable. For the unobserved factor shares, given that we use the sum of sampled countries endowments to proxy for the endowments of the hypothetical country, it is reasonable to assume that its factor shares are the average of the sampled countries factor shares. As for the unobserved GDP level, given that it is common across all countries in any year, it is possible to be controlled by year fixed-effects in a panel regression setting, i.e. $\alpha_t^* = \ln G\left(P_t^*, V_t^*\right)$, and moving it to the right hand side of the equation,

$$\ln G\left(P_t^c, V_t^c\right) - \sum_{k=1}^{M} \tfrac{1}{2}\left(s_{kt}^c + s_{kt}^*\right)\left(\ln v_{kt}^c - \ln v_{kt}^*\right) =$$
$$\alpha_t^* + \alpha_0^c + \sum_{n=1}^{N} \tfrac{1}{2}\left(s_{nt}^c + s_{nt}^*\right) \frac{\ln \lambda_{nt}^{c*}}{(1-\sigma_n)} + \tfrac{1}{2}\left(s_{N+1t}^c + s_{N+1t}^*\right)\left(\ln P_{N+1t}^c - \ln P_{N+1t}^*\right) + \varepsilon_t^c \,. \qquad (18)$$

Notice that the year fixed-effects completely absorb the explanatory power of time trend appearing in (17'), which makes the latter redundant. In addition, a classical error term ε_t^c is introduced in (18) to capture the productivity difference between country c and the hypothetical country. Equation (18) shows that the difference in country c productivity relative the hypothetical country can be estimated by a year fixed effect, a country fixed effect, its relative export variety, and the relative non-traded good price index.

6. Data and Estimating Equations

With data on GDP, factor endowments, nontraded good prices, and industry shares, we can estimate (18) with the sample data set together with the system of share equations to improve efficiency of the estimation, by imposing cross equation restrictions. Most importantly, such a system of equations enables us to estimate the elasticity of substitution of between different variety goods within an industry, σ_n , which is not sufficiently identified by the share equations alone. The output shares of the hypothetical country, appearing as s_{nt}^* in (18), are estimated as the industry fixed effects in the share equations (16). Then the equality of σ_n can be imposed between (16) and (18) to identify these elasticities.

Our data set covers 34 countries from 1982 to 1997, a total of 342 observations. GDP is measured in constant 1995 U.S. dollars to make cross country and time series comparisons appropriate. We will use (9) to measure export variety from country c to the U.S. in every years 1972 – 1988 (using the TSUSA data), and 1989 – 2001 (using the HS data). This gives a consistent comparison of export variety in each country relative to the hypothetical country producing all varieties.

There are three kind of primary factor endowments: labor, capital and agriculture land. Labor is defined as the number of labor force in a country. Capital is constructed using perpetual inventory method using real investment of the countries. Real investment is constructed by deflating the gross domestic capital formation of the countries with the respective GDP deflator on domestic capital formation. In addition, we construct the base year capital stock using an infinite sum series of investment prior to the first year, assuming that the growth rate of investment of the first five years are good proxy for investment prior to the first year. All these data, together with price deflators of GDP, exports and imports are available in World Development Indicators (World Bank, 2003).

We aggregate up all export goods into seven sectors: agriculture, textiles & garments, woods & papers, petroleum & plastics, mining & basic metals, machinery & transport equipment, and the electronics. The value added of these sectors are available in the UNIDO data set, which we compare to the GDP values to construct the value added share of each sector in GDP. We also need information on factor shares in national income, and obtained United Nations national account data which has information on labor share in GDP.[7] One minus the labor share gives us the sum of capital share and land share, which we are not be able to separately identify. To overcome this shortcoming, we chose to estimate the land share in the GDP equation as follows. It can be shown from (18) that log of GDP is the sum of the log of overall prices (denoted P_t for brevity), productivity (A_t), and the weighted log of endowments. Then we can estimate the share of land (T_t) according to:

$$\ln(GDP_t) = \ln A_t + \ln P_t + s_{Lt} \ln L_t + s_{Kt} \ln K_t + (1 - s_{Lt} - s_{Kt}) \ln T_t$$

so,

[7] We thank Ann Harrison for providing this data.

$$\ln(GDP_t) - s_{Lt}(\ln L_t - \ln T_t) - (1-s_{Lt})(\ln K_t - \ln T_t) = \\ \ln A_t + \ln P_t + \ln T_t - (1-s_{Lt}-s_{Kt})(\ln K_t - \ln T_t). \quad (19)$$

Thus, when we use the labor share and one minus the labor share to weigh labor per unit of land and capital per unit of land, respectively, we should also include capital per unit of land in the right-hand side ($\ln k_t \equiv \ln K_t - \ln T_t$) of the equation as shown in (19). The estimated coefficient associated with capital per unit of land is interpreted as the negative value of the average share of land in GDP. In addition, (19) shows that land area should also be included in the right hand side of the equation which, under the assumption of homogeneity of GDP in endowments, should have the estimated coefficient of one.

We proceed with a system of eight equations, consists of the seven sectoral share (16) equations and the GDP equation. According to (18), let the dependent variable of the GDP equation be country total factor productivity (TFP), measured as:

$$TFP_t^c \equiv \ln G\left(P_t^c, V_t^c\right) - \tfrac{1}{2}\left(s_{Lt}^c + s_{Lt}^*\right)\left(\ln \ell_{kt}^c - \ln \ell_{kt}^*\right) - \left(1 - \tfrac{1}{2}\left(s_{Lt}^c + s_{Lt}^*\right)\right)\left(\ln k_{kt}^c - \ln k_{kt}^*\right). \quad (20)$$

Making use of the homogeneity restriction $\sum_{m=1}^{N}\gamma_{mn} = 0$, and introducing land and capital per unit of land onto the right of the TFP equation, our estimating system becomes:

$$s_{nt}^c = s_{nt}^* + \phi_{Ln}\left(\ln \ell_{kt}^c - \ln \ell_{kt}^*\right) + \phi_{Kn}\left(\ln k_{kt}^c - \ln k_{kt}^*\right) \\ + \sum_{m=1}^{7}\gamma_{mn}\left(\frac{\ln \lambda_{mt}^{c*}}{(1-\sigma_m)} - \left(\ln P_{8t}^c - \ln P_{8t}^*\right)\right) + \varepsilon_{nt}^c, \quad n = 1,\ldots,7, \quad (21a)$$

$$TFP_t^c = \alpha_t^* + \alpha_0^c + \sum_{n=1}^{7}\tfrac{1}{2}\left(s_{nt}^c + s_{nt}^*\right)\left(\frac{\ln \lambda_{nt}^{c*}}{(1-\sigma_n)} - \left(\ln P_{8t}^c - \ln P_{8t}^*\right)\right) \\ + \beta_8\left(\ln P_{8t}^c - \ln P_{8t}^*\right) + \beta_T\left(\ln T_t^c - \ln T_t^*\right) + \beta_K\left(\ln k_{kt}^c - \ln k_{kt}^*\right) + \lambda TFP_{t-1}^c + \varepsilon_t^c \ . \quad (21b)$$

If the homogeneity constraints are not violated we expect β_8 and β_T to equal to one, whereas β_K represents the negative value of the share of land in GDP. Finally, we include a lagged dependent variable in the GDP function to control for autocorrelation.

7. Estimation Results

Tables 1 – 3 present the results of the nonlinear system of share equations (21a) with the country TFP equation (21b), with all homogeneity and symmetric constraints imposed. Table 1 and the first column of Table 3 report results of the system estimation using iterative SUR, but not correcting the export variety indexes for possible endogeneity. In Table 2 and the second column of Table 3, we use instruments for export variety and 3SLS estimation.

In the top part of Table 1 we report γ_{mn}, which are the price effects of a change in export variety on the industry shares. All the own-price effects γ_{nn} are estimated to be positive and highly significant.[8] In other words, the underlying supply curves of these industries are non-negative sloping. The bottom part of Table 1 presents the Rybczynksi effects of endowments on the share of each sector. Thus, an increase in labor endowment, relative to that of land, hurts agriculture, wood & paper industry, and the machinery & transport industry. On the other hand, an increase in labor endowment relative to land benefits textiles & garments, petroleum & plastics, mining & metals, and the electronics industry. Similarly, while an increase in capital relative to land hurts textiles & garments, petroleum & plastics, and mining & metals, such an increase benefits woods & paper, machinery & transport, and the electronics industry. These finding are reasonable and broadly similar to those of Harrigan (1997).

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[8] Due to convergence problem, the γ_{nn} coefficient of the petroleum & plastics industry (industry 4), is estimated separately, by fixing all the rest of the parameters in the optimal values. We repeated the process a few rounds, and the estimation results are very stable, as presented in Table 1.

Given that export product variety indexes could be endogenous, Table 2 presents the estimated coefficients using 3SLS. Our initial set of instruments consists of U.S. tariffs by industry, exporting country and year, as well as indicator variables for various trade agreements between the U.S. and the exporting countries. After estimating with these, we will experiment with a broader set of instruments, including transportation costs. The 3SLS estimates of the own-price effects reported in Table 2 are significantly larger than the iterative SUR estimates from Table 1. This is not surprising since the export variety indexes may have measurement errors which bias the estimates toward zero, as well as endogeneity.

Table 3 presents selected parameters of the estimated GDP function. The first column shows the SUR estimates when the export variety indexes are taken as exogenous, and the second column refers to 3SLS estimates when we use instruments for export variety. Once again we observe that the 3SLS estimates are larger than the SUR estimates. As such, we focus our post regression analysis based on the 3SLS estimates.

The top part of the Table 3 shows the estimated value for $1/(1-\sigma_n)$ in each sector. For example, the 3SLS estimates of $1/(1-\sigma_n)$ for agriculture is 0.349, which implies an elasticity of substitution of around –1.87. Similarly, the implied elasticity of substitution of the electronics industry is around –0.18. In other words, agriculture industry is more homogenous than the electronics industry in production. Thus an variety increase in the electronics industry would contribute more to the underlying country productivity and the value of GDP than the agriculture industry. The ranking of the industry according to their implied elasticity of substitution is as following: mining & basic metals (-0.11), electronics (-0.18), machinery & transport (-0.52), textiles & garments (-0.92), woods & paper (-1.58), agriculture (-1.87), and the petroleum & plastics industry (-5.00).

The lower part of Table 3 presents the control variables in the GDP function. As mentioned above, the estimated coefficient associated with the log capital-land ratio has the interpretation of the negative of the average share of land in GDP. Thus, on average, the land share is about 8%. Given that the average labor share in GDP in our sample is 52%, this would imply a capital share of 40%, which seems reasonable. In addition, the coefficient of the lagged dependent variable is significantly less than one, which suggests that we do not have a unit root problem in our country TFP regression.

Finally, the coefficients on the log-difference in the nontraded goods price and land can be used to test the validity of the homogeneity constraints on goods prices and endowments in the GDP function. Table 3 shows that both the estimated coefficients are significantly less than one, which indicate that there are some missing goods and factors in the GDP function. However, with the country and year fixed effects, and the inclusion of these two variables as controls, as long as the prices of the missing goods or the quantity of the missing factors are not systematically related to the country productivity or our product variety indexes, our estimation results should remain robust.

8. Effects of Tariffs and Transport Costs

In our initial system estimation, we have used U.S. tariffs by industry, exporting country and year as instruments for export variety, along with indicator variables for trade agreements. We would now like to broaden the list of instruments to include transportation costs. In addition, we would like to test for the *exclusion* restriction that these instruments do not enter the share or country TFP equations *except through* their impact on export variety.

To perform these diagnostics, it is helpful to simplify the nonlinear system consisting of (20) and (21) and work with a linear system instead. To achieve this, we take the initial set of parameter estimates from Tables 2 and 3 (second column), and use these to construct *estimated country TFP*, which we define as the sum of the country fixed effects, the product variety differences and the fitted regression errors:

$$\text{Estimated Country TFP}_t^c \equiv \hat{\alpha}_0^c + \sum_{n=1}^{N} \tfrac{1}{2}\left(s_{nt}^c + \hat{s}_{nt}^*\right)\frac{\ln \lambda_{nt}^{c*}}{(1-\hat{\sigma}_n)} + \hat{\varepsilon}_t^c \ . \qquad (22)$$

Comparing (22) with (21b), we can see that the estimated country TFP does not include all of the variables appearing in the country TFP equation: the nontraded goods price, as well as land and the capital-land ratio that appear in (21b), have been ignored in constructing (22). Implicitly, we moving these variables to the left-hand side of (21b), and focusing on export variety and the country fixed-effects as the variables of interest. We will treat (22) as an estimate of the "true" country productivity differences.

Using (22) as the dependent variable, we can easily run estimated country TFP on the country fixed effects and export variety again, using alternative instruments.[9] In addition, we can readily test for the exclusion of these instruments in that regression, meaning that the instruments affect country productivity *only through* their impact on export variety. The instrumental variables used to determine export variety are those suggested by the work of Eaton and Kortum (2002) and Melitz (2003): in addition to tariffs, we use transport costs and distance. The exclusion of these instruments from the restriction amounts to a test for overidentification in our system, as we describe. Failure to reject the overidentification hypothesis would also indirectly provide an evidence that confirms the importance of export variety as the *mechanism* (Hallak and Levinsohn, 2004) by which trade affects productivity.

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[9] Notice that estimated country TFP is dependent variable that is heteroskedastic by construction. We bootstrapped the standard errors to overcome this problem.

Table 4a and 4b present the results of a first stage IV regression when we instrument export variety indexes of the countries to U.S. tariffs, country endowments, transportation costs and an interaction terms between transportation costs and distance of the countries from US.[10] The tariffs are constructed from detailed U.S. custom data by taking the ratio of duties paid over imports. As a result, unlike the MFN tariffs, these tariffs vary by industries, countries and years. We expect industry export variety to decrease with the own tariff of the industry, while there may exist some positive effects due to reallocation of resources among industries when there is a tariff increase in *other* industries.

Similar argument hold for transportation costs, which we expect own transportation costs to be negatively correlated to export variety, and transportation costs in *other* industry may have some positive effects on export variety due to the reallocation of resources. In addition, for countries that are further away from US, the adverse effect of a higher transportation cost could be larger than otherwise similarly countries that is close by. We test this hypothesis by interacting transportation costs with a dummy variable for the close by countries, defined as those have a shorter distance than the median distance (7,037 km), and one for the further away countries.[11] Finally, we expect endowments of countries to have effects on export variety according to the factor intensity of the industries.

Table 4a reports the effects of tariffs and endowments on export variety. All industry export variety indexes are negatively correlated with own tariffs except for the textiles & garments, which MFA quotas are known to be more restrictive and binding. Among industries that have negative own tariff effects, the effects in agriculture, wood & paper, and the petroleum

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[10] Distance from US is the geographical distance in kilometers between the capitol cities, as obtained from Nicita and Olarreaga (2004).

[11] We would not need to include distance dummies directly in the regressions since they will be perfectly collinear with the country fixed effects.

& plastics industry are highly significant, so that a one percentage point increase in U.S. tariffs will lower export product variety of the three industries by 3.5 percent, 3.9 percent and 9.5 percent respectively.

The export variety in textiles & garments, wood & paper, and the machinery & transport industry increases with the labor endowments of exporting countries, while export variety in agriculture increases with the land mass of the exporting countries. Industries where export variety increases with capital endowments include wood & paper, petroleum & plastics and electronics, while textiles and garments variety decreases with the capital endowment.

Table 4b is a continuation of the same regressions reported in Table 4a, where the effects of transportation cost and distance on export varieties are reported. The top part of the table shows the marginal impacts of a one percentage point increase in transportation cost on the export variety of the industries located in *nearby* countries. Similarly, the lower part of the table shows the effect of transportation costs for *far away* countries. Nearly all industries, as expected, have lower export variety when transportation costs are higher. This is especially true for industries located in those countries that are further away. Overall transportation costs are statistically significant in agriculture, textiles & garments, machinery & transport, and the electronics industries.

Table 5 reports the second stage regression result where the estimated country productivity differences are related to the instrumented export variety indexes. Country productivity increases with export variety in all industries except textiles & garments and wood & paper. The industry that has the biggest marginal impact on country productivity is the electronics, followed by the mining & basic metal industry.

How valid are tariffs and transportation costs interacted with distance as instruments? To assess this, we apply the test for over-identification test proposed by Hausman (1983). The test statistic is constructed by multiplying the number of observations with the uncentered R-squared in an auxiliary regression of the second stage residuals on all the exogenous variables and instruments in the model.[12] A large value of the test statistic is taken as evidence that there are exogenous variables in the model that have been inappropriately omitted from the second stage regression. In our context, failure to reject the overidentification restrictions hypothesis would suggest that not only are tariffs and transport valid instruments for the industry export variety indexes, they do not in fact have any addition direct effect on country productivity, except through their influence on export varieties. This would confirm the importance of export variety as the *mechanism* (Hallak and Levinsohn, 2004) by which trade affects productivity.

There are 7 endogenous variables in the second stage regression, which are the export variety indexes of the seven industries. On the other hand, there are 21 excluded instruments, which are the three sets of seven industry specific variables (U.S. tariffs, transportation cost for nearby countries and transportation cost for the far away countries). This amounts to 14 degrees of freedom. The uncentered R-square of the auxiliary regression is 0.0602, which gives us a chi-squared test statistics of 20.6, given the sample size of 342. At 14 degree of freedom, the chi-squared critical value at a confident level of 95% is 23.7, which is larger than our test statistics. Thus we fail to reject the overidentification hypothesis, and we conclude that not only are tariffs, transportation costs and their interaction with distance important in determining export varieties, these "border effects" only affect country productivity via their influence on export variety.

[12] The test statistics has a limiting chi-squared distribution with a degree of freedom equals the number of excluded instruments minus the number of endogenous variables

Finally, to assess the economic importance of tariffs, we ran a policy experiment to study the fall in productivity of the exporting countries if the U.S. were to increase tariffs all across the board by 10 percentage points. Based on the estimated coefficients in Tables 4a & 4c, a 10 percentage point increase in US tariff would lead to a fall in country productivity by 3.8%. This is both large and statistically significant at a 95% confidence level using a bootstrapped standard error of 1.8. The large impact on productivity seems reasonable, however, given that a 10 percentage point increase in tariff is nearly a threefold increase from an average tariff of 3.5 percent in the sample. Thus the regression results show not only are U.S. tariffs statistically significant in affecting country productivity via its influence on export variety, such policy variables are also economically important.

9. Productivity Decomposition

Using (22), we can compute the variance of estimated country TFP as:

$$\text{var}(\text{Estimated Country TFP}_t^c) = \text{var}(\hat{\alpha}_0^c) + \text{var}\left[\sum_{n=1}^{7} \tfrac{1}{2}\left(s_{nt}^c + \hat{s}_{nt}^*\right)\frac{\ln \lambda_{nt}^{c*}}{(1-\hat{\sigma}_n)}\right]$$

$$+ \text{cov}\left[\hat{\alpha}_0^c, \sum_{n=1}^{7} \tfrac{1}{2}\left(s_{nt}^c + \hat{s}_{nt}^*\right)\frac{\ln \lambda_{nt}^{c*}}{(1-\hat{\sigma}_n)}\right] + \text{var}(\hat{\varepsilon}_c^t)\,. \qquad (23)$$

The first term on the right is the variance of country fixed effects, the second is the contribution of export variety constructed as a weighted average across industries, the third is the covariance between these, and the fourth is the error variance. If we remove the country fixed effects, then "variety-induced" country TFP is defined as:

$$\text{Variety-induced Country TFP}_t^c \equiv \sum_{n=1}^{N} \tfrac{1}{2}\left(s_{nt}^c + \hat{s}_{nt}^*\right)\frac{\ln \lambda_{nt}^{c*}}{(1-\hat{\sigma}_n)} + \hat{\varepsilon}_t^c\ , \qquad (24)$$

with the variance:

$$\text{var(Variety-induced Country}\, TFP_t^c) = \text{var}\left[\sum_{n=1}^{7} \tfrac{1}{2}\left(s_{nt}^c + \hat{s}_{nt}^*\right) \frac{\ln \lambda_{nt}^{c*}}{(1-\hat{\sigma}_n)}\right] + \text{var}(\hat{\varepsilon}_c^t). \qquad (25)$$

The first column of Table 6 shows the variance of country TFP with and without fixed effects, the variation due to export variety, and the variance of the regression error. The next column compares the variation due to product variety with the other variances. It shows that with country fixed effects included, the variation due to export variety accounts for 8.5% of the overall productivity variance. When country fixed effects are not included, however, than the variation due to export variety accounts for 77% of the overall variance in residual country TFP. In other words, controlling for country specific differences, the variation in export variety can explain nearly 77% of the variation in the underlying productivity in the sample. Figures 3 and 4 plots the partial correlation graphs of the country TFP with and without country fixed effects, against the fitted productivity due to product variety. It is evident that export variety has significant explanatory power for the variation of the country productivity differences, with or without the fixed effects.

Figure 5 presents a cross country scatter plot of the country TFP (without fixed effects) against the average export variety in 1991. Both variables are shown in deviation from their sample means. There is a clear positive relationship between the export variety of a country and its productivity, which is highlighted by the positive sloping regression line. Canada has the most export variety, which is nearly twice as high as the sample mean. In terms of the productivity differences, Canada is 8% higher than the sample mean. Japan has the highest productivity which is 10% higher than the sample mean. In terms of export variety, an industry in Japan produces 80% more export products than the sample mean.

Other countries that have higher than productivity and export variety in Table 5 include South Korea, Singapore, and some other OECD countries such as France and Australia. These countries appear on the first quadrant. Countries that perform poorly in terms of the country productivity and export variety are in the third quadrant. They include Kenya, Greece, the Philippines, Turkey and Uruguay. For example, exporting industries in Uruguay produce only one third of the variety relative to the sample mean in 1991, and productivity is 7% less than the sample average. Similarly, export industries in Turkey produces 73% less variety than the sample mean, and its productivity is 9% lower. We can also compare country pairs from the figure. For instance, in 1991, Singapore produces nearly 64% more export products than the Philippines, and the TFP advantage of Singapore over the Philippines is about 2%.

We further explore the movement of export variety and productivity within a country over time. Figure 6 compares Canada to the sample mean in terms of productivity, variety-induced productivity differences, and the weighted-average export variety, from 1983 to 1997. The two productivity series are presented in bars relative to the left-hand scale. The export variety index is shown as a line in the figure, measured relative to the vertical right-hand scale. In 1983, Canada's productivity is 8.5% higher than the sample mean, while it produces 89% more export products relative to the sample mean. In 1997, the productivity gap reduces to 7% while the export variety difference is about 60%. Thus over the years, we see a gradual decline of export variety in Canada, especially since the early 1990s, and this is reflected in the productivity series.

Figure 7 compares Japan to South Korea. Similar to the previous figure, the two productivity series are presented in bars relative to on left-hand scale. The export variety index is shown as a line in the figure, relative to the right-hand scale. The line series shows that, in

1982, industries in Japan produced 53% more export variety than South Korea. The Japanese advantage over Korea deteriorates over time such that in 1995, an industry in Japan produced only 18% more variety than Korea. On the other hand, the first bar series shows that, over the same period of time, the underlying TFP advantage of Japan declines from 13% to near zero. Thus, with Korea catching up in export variety, the underlying productivity gap between Korea and Japan is also narrowing. The second bar series is the variety-induced TFP difference, which ignores the estimated error in (22). According to the above variance analysis, this line can account for nearly 77% of the variation of the second line (when measured over all countries and years, and controlling for fixed effects).

A similar comparison can be done for Israel and Greece, as shown in Figure 8. In 1983, Israel produced 29% more export variety than in Greece, and by 1995, the advantage of Israel over Greece widens to 80%. On the other hand, with a negative 5% TFP difference in 1982 Israel is less productive than Greece, but by 1995, Israel had became 7% more productive than Greece. Thus, there is a positive correlation between the observed export variety difference and the country productivity difference, as predicted by the variety-induced productivity difference, the second bar series in the figure.

10. Conclusions

Existing analyses of export variety and growth have been restricted to a limited range of countries (e.g. Feenstra et al, 1999), or a single aggregate measure of export variety correlated with GDP (Funke and Ruhwedel, 2001a,b, 2002). In this paper we have attempted to improve the estimation of product variety on country productivity by allowing for multiple sectors, and introducing export varieties into the GDP function. In exploiting the translog GDP function we are following Harrigan (1997), who hypothesized that export prices would differ across countries due to total factor productivity in exports. We have hypothesized that the industry CES price indexes differ across countries due to export variety, which therefore enter as “price effects” into the GDP function and sectoral share equations. Estimating the share equations simultaneously with the GDP equation (transformed to become country relative productivity) allows us to identify and estimate the elasticity of substitution σ_n between export varieties in each sector, and then infer the contribution of export variety to country productivity.

The resulting elasticity estimates range from a low of -0.11 in the mining & basic metals industry and –0.18 in the electronics industry, to a high of -1.87 in agriculture and –5.00 in the petroleum & plastics industry. Because these are the elasticity of substitution between *outputs* (measuring the curvature of the concave production possibilities frontier), we have less intuition about the magnitude of the expected estimates than for inputs. But the ranking we have obtained, with the least substitution between export varieties within mining & basic metals and within electronics, and the greatest substitution between varieties within agriculture and petroleum & plastics, seems reasonable. In electronics, the estimate of -0.18 indicates that a 10% expansion of product varieties has the same effect as a 10/1.18 = 8.5% increase in prices, in terms of drawing resources into that sector. For petroleum and plastics, however, a 10% increase in product variety has the same effect as a 10/6 = 1.7% rise in prices, since these products are more highly substitutable.

We have treated export variety as an endogenous variable, and as instruments use those suggested by the work of Eaton and Kortum (2002) and Melitz (2003): tariffs, transport costs and other border effects. We have also been able to test the important exclusion restriction suggested by these models, that tariffs and transport costs should not have an impact on productivity *except through* export variety. This restriction cannot be rejected, and confirms the importance of export variety as the mechanism (Hallak and Levinsohn, 2004) by which trade affects productivity. Our results also show that a 10 percentage point increase in U.S. tariffs would lead to a 3.8% fall in exporting countries productivity, which indicates that tariffs are statistically and economically important in affecting productivity via export variety.

Finally, we have also calculated the impact of export variety differences across countries on their respective productivities. Not surprisingly, country fixed effects in a panel regression still account for the vast majority of country productivity differences, so that export variety explains only 8.5% of the total variation in country productivity. But setting aside country fixed effects, export variety can explain nearly 77% of the residual productivity differences. By considering specific pairs of countries over time, we have also traced out quite plausible patterns between changes in export varieties and changes in country productivities. These patterns certainly fit the idea of the endogenous growth models, and allow a more direct test of these models that the correlation between aggregate trade flows and productivity.

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Table 1: Dependent Variables - Industry Value Added Shares in GDP

Estimation method: Iterative Seemingly Unrelated Regressions
Total system observations: 2736
Observations per equation: 342

	Independent Variables:	Eq (1) Agriculture	Eq(2) Textiles & Garments	Eq(3) Wood & Paper	Eq(4) Petroleum & Plastics	Eq(5) Mining & Basic Metals	Eq(6) Machinery & Transports	Eq(7) Electronics
Gamma Coefficients of:	Agriculture	**0.032***** (0.006)	-0.002 (0.003)	-0.016*** (0.005)	0.007** (0.003)	-0.016*** (0.003)	-0.005** (0.002)	0.001 (0.002)
	Textiles & Garments	-0.002 (0.003)	**0.041***** (0.007)	-0.024*** (0.005)	-0.007** (0.003)	0.006*** (0.002)	-0.010*** (0.002)	-0.003* (0.002)
	Wood & Paper	-0.016*** (0.005)	-0.024*** (0.005)	**0.064***** (0.009)	-0.019*** (0.004)	-0.004** (0.002)	0.005** (0.002)	-0.006*** (0.002)
	Petroleum & Plastics	0.007** (0.003)	-0.007** (0.003)	-0.019*** (0.004)	**0.022***** (0.002)	0.004*** (0.002)	0.001 (0.002)	-0.006*** (0.002)
	Mining & Basic Metals	-0.016*** (0.003)	0.006*** (0.002)	-0.004** (0.002)	0.004*** (0.002)	**0.014***** (0.003)	-0.007*** (0.002)	0.002* (0.001)
	Machinery & Transports	-0.005** (0.002)	-0.010*** (0.002)	0.005** (0.002)	0.001 (0.002)	-0.007*** (0.002)	**0.008***** (0.003)	0.008*** (0.002)
	Electronics	0.001 (0.002)	-0.003* (0.002)	-0.006*** (0.002)	-0.006*** (0.002)	0.002* (0.001)	0.008*** (0.002)	**0.005***** (0.002)
Log of Relative:	Labor-Land Ratio	-0.004*** (0.001)	0.003*** (0.001)	-0.004*** (0.001)	0.007*** (0.001)	0.005*** (0.001)	-0.002** (0.001)	0.006*** (0.001)
	Capital-Land Ratio	0.002 (0.001)	-0.001* (0.001)	0.004*** (0.001)	-0.005*** (0.001)	-0.004*** (0.001)	0.006*** (0.001)	0.002* (0.001)
	Year Fixed-Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	R-squared	0.3377	0.3505	0.4570	0.1802	0.3975	0.5988	0.5987

Notes: All figures in bold are the own partial effects of product prices. Asymptotic standard errors are in parentheses.
*, **, and *** indicate significance at 90%, 95%, and 99% confidence levels respectively.

Table 2: Dependent Variables - Industry Value Added Shares in GDP

Estimation method: Three Stage Least Squares Regressions

Total system observations: 2736

Observations per equation: 342

	Independent Variables:	Eq (1) Agriculture	Eq(2) Textiles & Garments	Eq(3) Wood & Paper	Eq(4) Petroleum & Plastics	Eq(5) Mining & Basic Metals	Eq(6) Machinery & Transports	Eq(7) Electronics
Gamma Coefficients of:	Agriculture	**0.042*****	-0.003	-0.016***	-0.003	-0.016***	-0.007**	0.004*
		(0.004)	(0.003)	(0.004)	(0.003)	(0.002)	(0.003)	(0.002)
	Textiles & Garments	-0.003	**0.054*****	-0.031***	-0.013***	0.013***	-0.022***	0.003
		(0.003)	(0.004)	(0.004)	(0.003)	(0.002)	(0.003)	(0.002)
	Wood & Paper	-0.016***	-0.031***	**0.096*****	-0.035***	-0.006***	0.008**	-0.014***
		(0.004)	(0.004)	(0.007)	(0.004)	(0.002)	(0.004)	(0.003)
	Petroleum & Plastics	-0.003	-0.013***	-0.035***	**0.051*****	-0.001	0.011***	-0.009***
		(0.003)	(0.003)	(0.004)	(0.004)	(0.002)	(0.003)	(0.002)
	Mining & Basic Metals	-0.016***	0.013***	-0.006***	-0.001	**0.018*****	-0.014***	0.005***
		(0.002)	(0.002)	(0.002)	(0.002)	(0.001)	(0.002)	(0.001)
	Machinery & Transports	-0.007**	-0.022***	0.008**	0.011***	-0.014***	**0.019*****	0.006***
		(0.003)	(0.003)	(0.004)	(0.003)	(0.002)	(0.003)	(0.002)
	Electronics	0.004*	0.003	-0.014***	-0.009***	0.005***	0.006***	**0.008*****
		(0.002)	(0.002)	(0.003)	(0.002)	(0.001)	(0.002)	(0.002)
Log of Relative:	Labor-Land Ratio	-0.005***	0.003***	-0.004***	0.007***	0.005***	-0.002**	0.006***
		(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
	Capital-Land Ratio	0.002**	-0.001	0.004***	-0.005***	-0.004***	0.006***	0.001
		(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
	Year Fixed-Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	R-squared	0.3461	0.3238	0.4191	0.1907	0.3519	0.6055	0.6121

Notes: All figures in bold are the own partial effects of product prices. Asymptotic standard errors are in parentheses.

*, **, and *** indicate significance at 90%, 95%, and 99% confidence levels respectively.

Instruments: US tariffs by industry, country, and year, and trade agreement dummies (NAFTA, CANFTA, GSP, CBI, ANDEAN, ISRFTA).

Table 3: Dependent Variable - Country TFP

Total system observations: 2736

Observations per equation: 342

	Industry:	ISUR	IV (3SLS)
Estimated 1/(1-sigma) of:	Agriculture	0.330***	0.349***
		(0.061)	(0.011)
	Textiles & Garments	0.490***	0.520***
		(0.078)	(0.019)
	Wood & Paper	0.366***	0.388***
		(0.051)	(0.009)
	Petroleum & Plastics	0.161***	0.167***
		(0.036)	(0.009)
	Mining & Basic Metals	0.870***	0.902***
		(0.171)	(0.018)
	Machinery & Transports	0.641***	0.657***
		(0.121)	(0.017)
	Electronics	0.810***	0.851***
		(0.209)	(0.032)
Log of Differences of:	Non-traded Goods Prices	0.221***	0.221***
		(0.004)	(0.004)
	Labor-Land Ratio	0.136**	0.116*
		(0.060)	(0.067)
	Capital-Land Ratio	-0.111***	-0.083***
		(0.015)	(0.017)
	Lagged NLGDP	0.753***	0.848***
		(0.035)	(0.039)
	Constant	7.162***	4.432***
		(1.036)	(1.155)
	Year Fixed Effects	Yes	Yes
	Country Fixed Effects	Yes	Yes
	R-squared	0.9995	0.9997

Notes: Asymptotic standard errors are in parentheses.

*, **, and *** indicate significance at 90%, 95%, and 99% confidence levels respectively.

Dependent variable is defined as in Equation (20).

Instruments: same as Table 2.

Table 4a: Dependent Variables - Export Variety Index

Estimation method: Ordinary Least Squares

Observations per equation: 342

	Independent Variables:	Eq (1) Agriculture	Eq(2) Textiles & Garments	Eq(3) Wood & Paper	Eq(4) Petroleum & Plastics	Eq(5) Mining & Basic Metals	Eq(6) Machinery & Transports	Eq(7) Electronics
Log of 1+ US Tariff of :	Agriculture	**-3.468*** **	-1.03	-1.265	4.674*	0.233	3.090**	-2.756*
		(1.310)	(1.005)	(1.191)	(2.437)	(1.351)	(1.528)	(1.438)
	Textiles & Garments	-0.452	**1.683*** **	1.200**	-1.743	-1.117*	-0.266	1.249*
		(0.577)	(0.443)	(0.525)	(1.074)	(0.596)	(0.673)	(0.634)
	Wood & Paper	0.346	0.578	**-3.942*** **	4.239	-2.349	0.097	-0.834
		(1.472)	(1.129)	(1.338)	(2.739)	(1.519)	(1.717)	(1.616)
	Petroleum & Plastics	-3.458***	-0.203	0.15	**-9.514*** **	3.583***	0.977	-2.141
		(1.310)	(1.005)	(1.190)	(2.436)	(1.351)	(1.527)	(1.438)
	Mining & Basic Metals	-0.534	1.786	0.629	-7.277**	**-0.546**	4.665**	0.523
		(1.914)	(1.469)	(1.740)	(3.562)	(1.975)	(2.233)	(2.102)
	Machinery & Transports	-1.161	0.491	2.209	-3.507	-2.194	**-0.175**	-0.904
		(1.934)	(1.484)	(1.757)	(3.597)	(1.995)	(2.255)	(2.123)
	Electronics	2.444	-2.29*	-1.289	-1.382	0.557	-1.166	**-0.889**
		(1.737)	(1.333)	(1.579)	(3.232)	(1.792)	(2.026)	(1.908)
Log of :	Labor	0.387	1.527***	0.647**	-0.226	-0.253	0.605*	-0.203
		(0.288)	(0.221)	(0.261)	(0.535)	(0.297)	(0.336)	(0.316)
	Capital	0.062	-0.177**	0.246**	0.831***	0.029	-0.193	0.609***
		(0.106)	(0.082)	(0.097)	(0.198)	(0.110)	(0.124)	(0.117)
	Land	0.782*	0.464	0.186	1.155	-0.581	0.241	0.385
		(0.400)	(0.307)	(0.363)	(0.743)	(0.412)	(0.466)	(0.439)
	Years	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Countries	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	R-squared	0.9146	0.9083	0.9382	0.9091	0.9553	0.9622	0.9397

Notes: All figures in bold are the own partial effects of US tariffs. Standard errors are in parentheses.

*, **, and *** indicate significance at 90%, 95%, and 99% confidence levels respectively.

US tariffs are the ratios of duties paid over industry exports. It varies by industry, country and year.

Table 4b: Dependent Variables - Export Variety Index (Continue from Table 4a)

Estimation method: Ordinary Least Squares

Observations per equation: 342

	Independent Variables:	Eq (1) Agriculture	Eq(2) Textiles & Garments	Eq(3) Wood & Paper	Eq(4) Petroleum & Plastics	Eq(5) Mining & Basic Metals	Eq(6) Machinery & Transports	Eq(7) Electronics
Log of 1+ Nearby Countries Transport Cost of :	Agriculture	**0.764**	0.45	-1.419*	-4.069**	-0.073	-2.576**	-0.193
		(0.861)	(0.661)	(0.782)	(1.602)	(0.888)	(1.004)	(0.945)
	Textiles & Garments	-1.152	**-5.803*** **	-1.229	-4.08	-1.044	5.966***	0.29
		(1.834)	(1.407)	(1.667)	(3.411)	(1.892)	(2.139)	(2.013)
	Wood & Paper	-0.123	0.75	**0.715**	-2.646*	1.629**	0.893	0.409
		(0.760)	(0.583)	(0.691)	(1.415)	(0.784)	(0.887)	(0.835)
	Petroleum & Plastics	1.285	0.143	-0.299	**-3.176**	3.936***	-2.379*	-2.378*
		(1.159)	(0.889)	(1.053)	(2.156)	(1.195)	(1.351)	(1.272)
	Mining & Basic Metals	-0.397	-1.175***	0.051	0.202	**-0.608**	1.037*	-0.046
		(0.505)	(0.387)	(0.459)	(0.939)	(0.521)	(0.589)	(0.554)
	Machinery & Transports	0.603	2.158***	0.413	0.39	0.269	**-0.303**	1.954*
		(1.009)	(0.774)	(0.917)	(1.878)	(1.041)	(1.177)	(1.108)
	Electronics	-0.207	0.601	1.972	-0.479	1.027	-0.219	**-1.478**
		-1.462	-1.121	-1.329	-2.719	-1.508	-1.705	-1.605
Log of 1+ Far Away Countries Transport Cost of :	Agriculture	**-1.788***	-1.179	-0.587	5.440***	2.027*	-0.673	2.314**
		(1.045)	(0.802)	(0.950)	(1.944)	(1.078)	(1.219)	(1.148)
	Textiles & Garments	7.549***	**5.296*** **	2.658	-5.448	0.292	3.391	4.157*
		(2.093)	(1.606)	(1.902)	(3.894)	(2.159)	(2.441)	(2.298)
	Wood & Paper	-0.130	-1.192*	**-0.914**	-0.575	-1.964**	-1.488	-0.69
		(0.880)	(0.675)	(0.800)	(1.637)	(0.908)	(1.026)	(0.966)
	Petroleum & Plastics	0.484	-0.341	0.392	**-0.833**	-0.756	-0.188	-0.628
		(0.700)	(0.537)	(0.636)	(1.302)	(0.722)	(0.816)	(0.768)
	Mining & Basic Metals	1.5	0.883	1.021	-6.082***	**0.062**	0.873	0.138
		(0.974)	(0.747)	(0.885)	(1.812)	(1.005)	(1.136)	(1.069)
	Machinery & Transports	-2.522*	2.527**	1.002	3.843	1.849	**-2.997***	4.266***
		(1.390)	(1.067)	(1.264)	(2.586)	(1.434)	(1.622)	(1.526)
	Electronics	-3.561***	-1.461	0.324	-1.524	-2.498**	-1.887	**-2.191***
		(1.197)	(0.918)	(1.088)	(2.227)	(1.235)	(1.396)	(1.314)

Notes: All figures in bold are the own partial effects of transportation costs. Standard errors are in parentheses.

*, **, and *** indicate significance at 90%, 95%, and 99% confidence levels respectively.

Transport costs are the ratios of freight and insurance in custom values.

Table 5: Dependent Variable - Estimated Country TFP

Observations per equation: 342

	Industry:	IV
Log of Export Variety in:	Agriculture	0.019***
		(0.006)
	Textiles & Garments	-0.008
		(0.011)
	Wood & Paper	-0.005
		(0.010)
	Petroleum & Plastics	0.007*
		(0.004)
	Mining & Basic Metals	0.029***
		(0.007)
	Machinery & Transports	0.018***
		(0.006)
	Electronics	0.039***
		(0.008)
Log of :	Labor	0.013
		(0.018)
	Capital	-0.005
		(0.007)
	Land	0.047***
		(0.016)
	Year Fixed Effects	Yes
	Country Fixed Effects	Yes
	R-squared	0.9987

Notes: Bootstrapped standard errors are in parentheses.
*, **, and *** indicate significance at 90%, 95%, and 99% confidence levels respectively.
Dependent variable is defined as in Equation (19).
Instruments: US tariffs, transport costs by industry, country and year, transportation costs interact with nearby and far away dummies.

Table 6: Analysis of Variance

	Variance	Variety Induced Differences as a Percentage of
Productivity Difference with Country Fixed Effects	0.0374	8.5
Productivity Difference without Country Fixed Effects	0.0041	77.0
Variety Induced Productivity Differences	0.0032	100.0
Regression Error Terms	0.0011	280.7

Source: Authors calculation based on regression results of Tables 2 and 3.

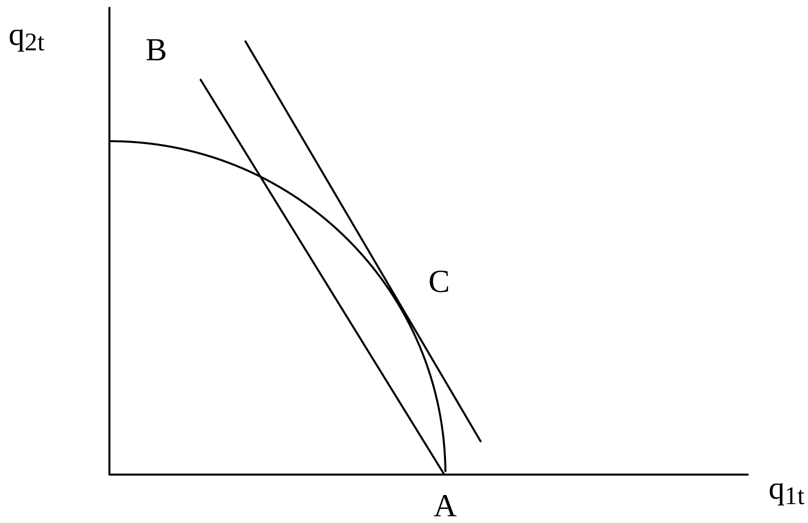

Figure 1: Output Varieties

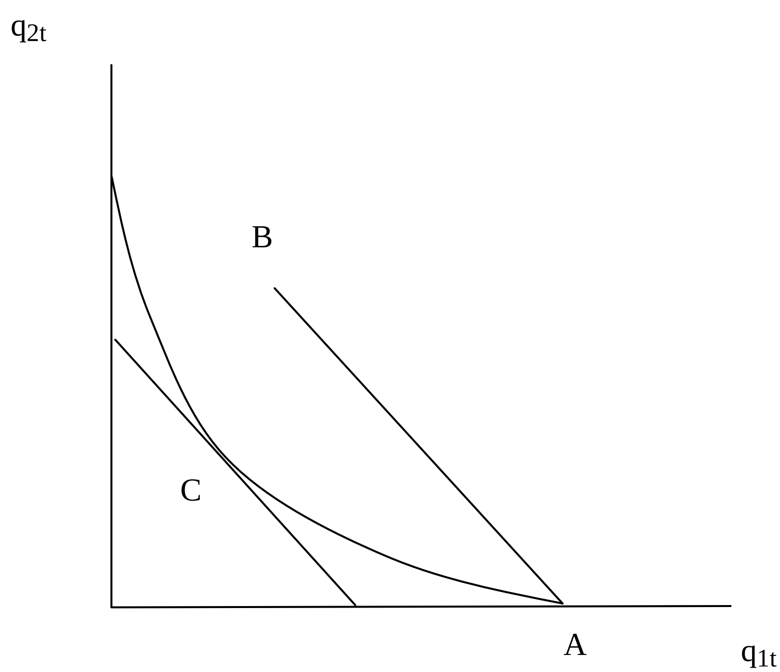

Figure 2: Input Varieties

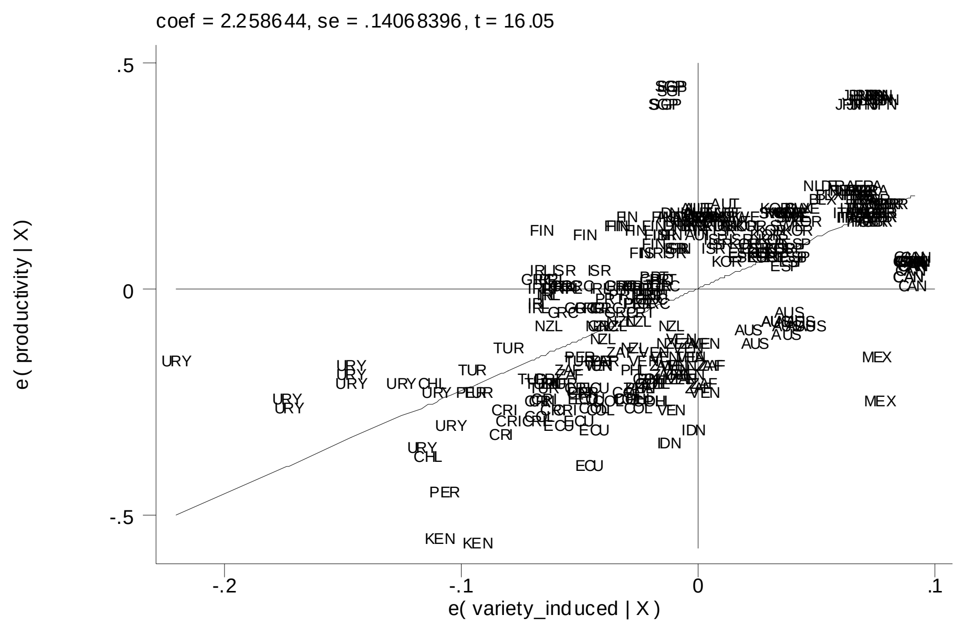

Figure 3: Productivity Differences with Country Fixed Effects versus Variety Induced Productivity Differences

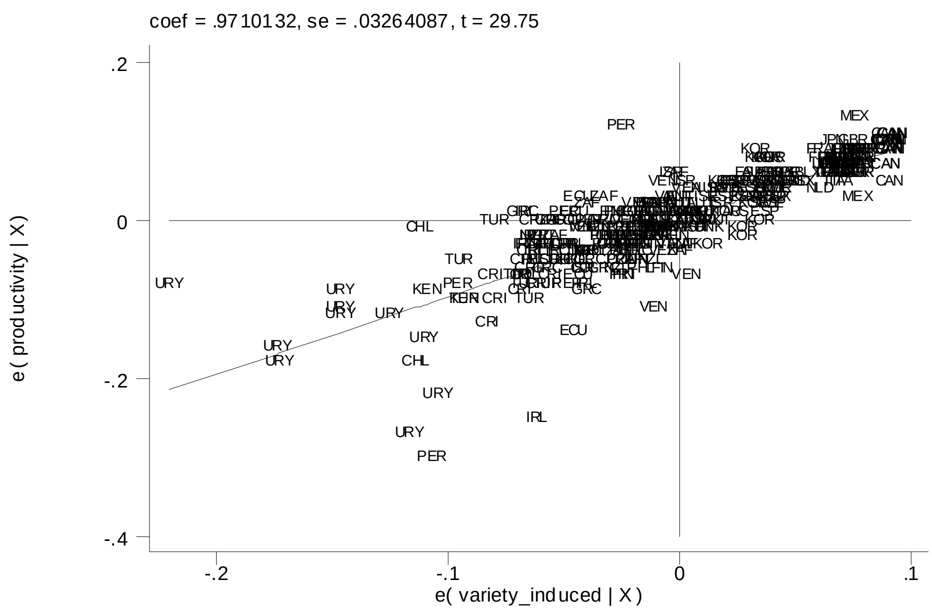

Figure 4: Productivity Differences without Country Fixed Effects versus Variety Induced Productivity Differences

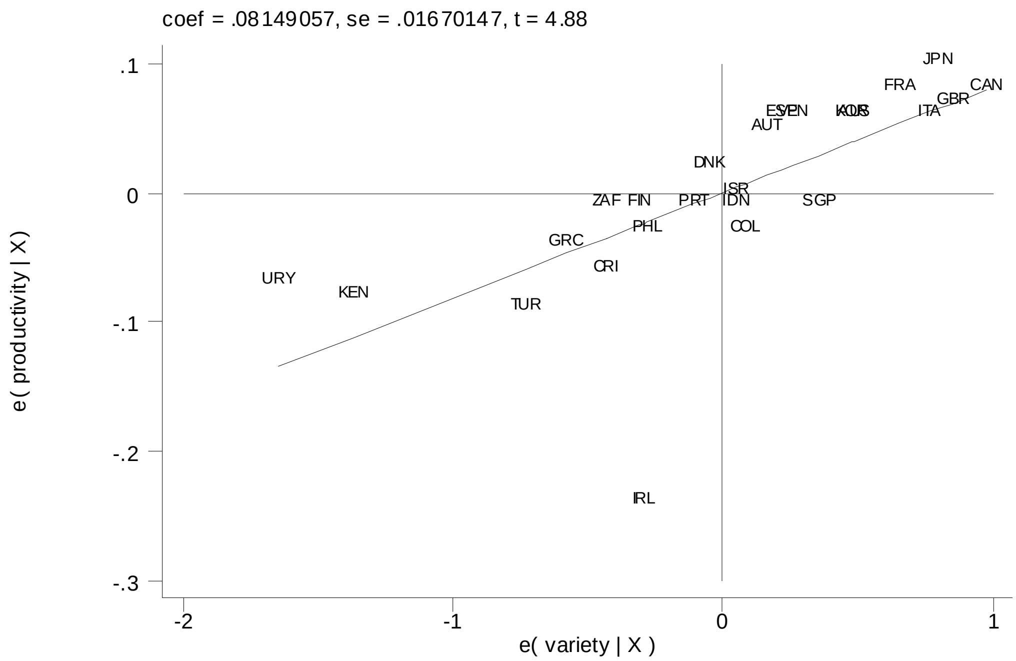

Figure 5: Productivity Differences without Country Fixed Effects versus Product Variety Differences, 1991

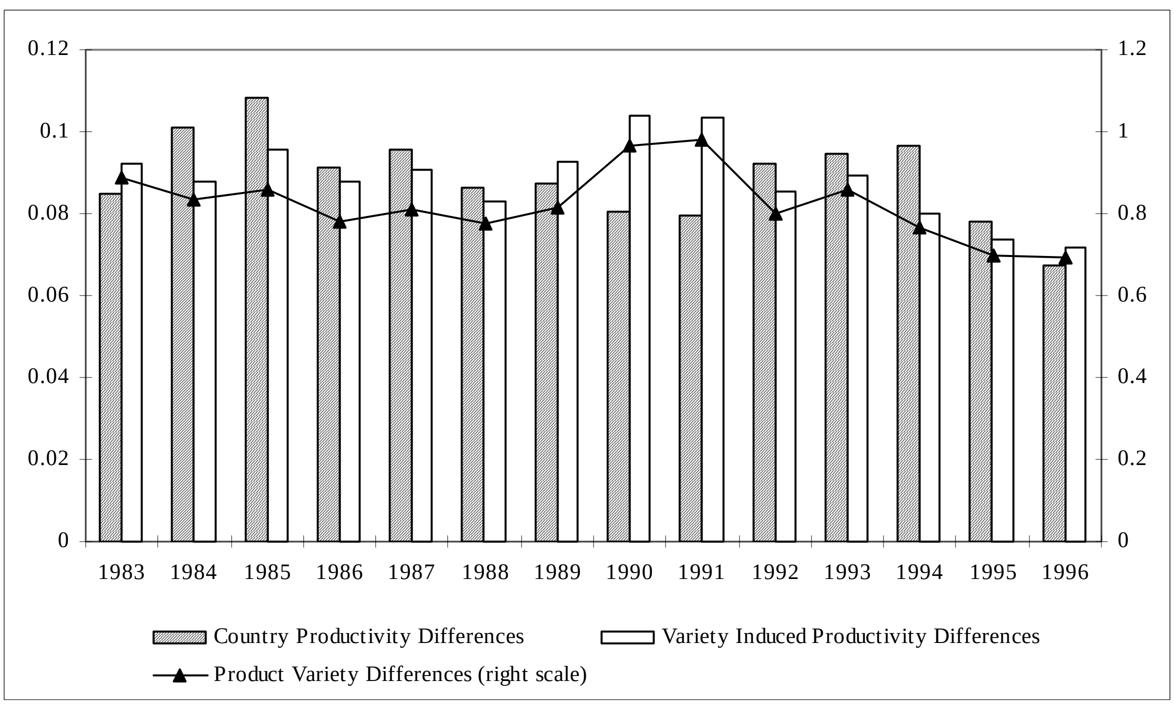

Figure 6: Canada compared to Sample Mean

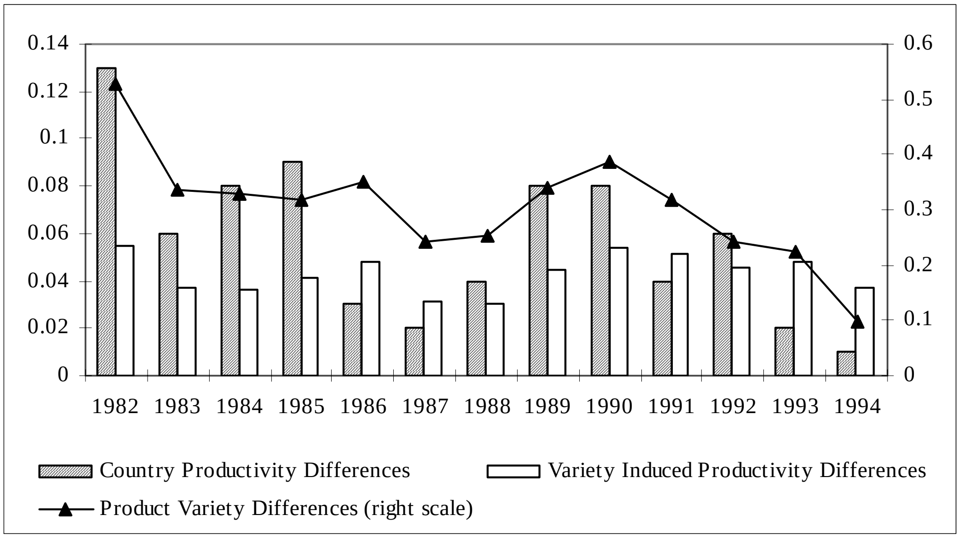

Figure 7: Japan Compared to South Korea

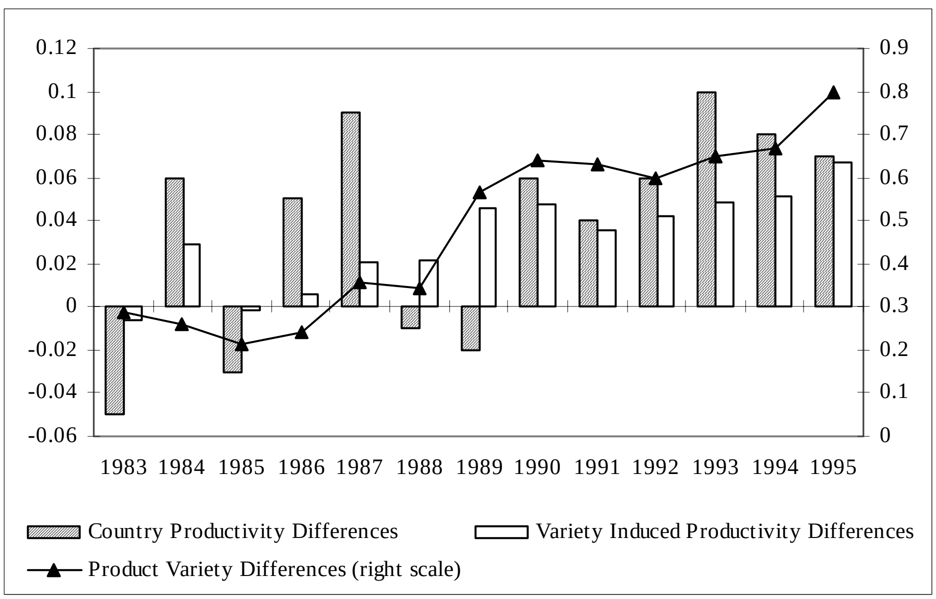

Figure 8: Israel Compared to Greece