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Trade Variety and Productivity in Canada

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1 -- Introduction

The relationship between trade variety and productivity is one of the central interests in trade and development. Although the channel of how productivity affects trade variety was articulated centuries ago[1], the other direction, how trade variety affects productivity, is less well understood. A standard monopolistic competition model (MC) in trade (e.g. Dixit and Stiglitz (1977), Krugman (1980)) assumes goods are differentiable and varied. With this framework, economists are able to exposit how trade variety affects productivity from two effects: the input variety effect and the output variety effect.

The output variety effect predicts that the expansion of export varieties can boost the exporting country's productivity. This effect results from the assumption of diminishing technical rate of substitution (i.e. concavity of production possibility frontier (PPF), see figure 1a). Empirically, the link between export variety and productivity has been found by Feenstra et al (1999) for South Korea and Taiwan, and by Funke and Ruhwedel (2001) for OECD and East Asian countries. Using the monopolistic competition model augmented with endogenous technology, Feenstra and Kee (2008) (hereafter FK) test the effects of sectoral export variety on country productivity. Analyzing a panel data containing 34 countries (developed and developing) across 16 years, they found that while export variety accounts for only 2% of cross-country productivity differences, it explains 13% of within-country productivity growth.

The input variety effect is similar to that found in endogenous growth models (e.g. Romer, 1990; Grossman and Helpman, 1991), where greater variety of inputs leads to higher productivity. This effect results from the assumption of diminishing marginal productivity of productive factors (i.e. the convexity property of the iso-quant curve). Under the

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[1] For example, the pioneer work of Adam Smith's "Absolute Advantage" and David Ricardo's "Comparative Advantage".

assumption that imports are typically used as intermediate inputs in production rather than final consumption goods, an expansion in import varieties will boost productivity growth (see Figure 1b). Broda, Greenfield, and Weinstein (2006) (hereafter BGW) find that new imported varieties on average account for 10% of productivity growth. The effects are larger in developing countries, where the median impact of new imported varieties equals 25% of national productivity growth.

The underlying contention that imports are typically intermediate inputs is problematic. For instance, research on imports and welfare treats imports as final consumption goods (e.g. Broda and Weinstein, 2004). If a variety of import is for final consumption, the direct effect (based on the output effect) is that it lowers the importing country's productivity growth if it competes with the domestic varieties and makes the latter disappear.[2] In practice, it is nearly impossible to distinguish imports by intermediate inputs and final consumption goods. So the mixture of these two kinds of imports may result in an insignificant or even negative effect on importing country's productivity (I will discuss this problem in section 4 and the Appendix).

However, the existing literature on the effects of trade variety on productivity is restricted to either export variety or import variety; the total effects of both export and import varieties have not been studied. In addition, empirical studies using industry level trade data (e.g. Harmonized System (HS) data or Standard International Trade Classification data) can only estimate the "average" (of sample countries) effects of export or import variety on productivity. Country-specific effects are usually estimated by using firm level data whose results largely rely on the sample firms and thus may not truly reflect the actual effects.

By extending FK's (2008) model to include both export and import varieties, this paper uses Canadian provincial foreign trade data (HS data) to analyze the effects of trade variety and productivity in Canada. There are two contributions in the paper: first of all, including both export and import varieties allows me to study the total effect of import and export varieties on productivity; secondly, by exploring the Canadian provincial data, I am able to estimate the country-specific effect of trade variety and productivity based on the actual industrial data rather than the approximation of firm level data. Furthermore, employing Canadian provincial panel data makes my results more reliable: an implicit but important assumption about the price-factor GDP function (used in FK and here) is that the prices and production factors are all given, i.e., exogenous. However, FK's data is obtained from US imports from 34 countries including the major developed ones. Thus it is very likely that the prices are actually endogenous since the major developed countries may have monopolistic power over some of their major exports such as electronic products from Japan and machines from Germany. Furthermore, the US itself is the largest open economy in the world suggesting it has monopsonistic power over many of its imports. As a result, if monopoly dominates, estimates of the elasticities of productivity on export varieties tend to be overstated, while if monopsony dominates, the estimates tend to be understated. On the contrary, Canada is a typical small open economy, as most of its exports and imports only have negligible effects on the world market. So prices facing Canadian exports and imports are mainly exogenous.

The rest of the paper will be organized in five parts. In section 2, I survey Canadian imports and exports over the last 19 years. In section 3, I derive the mechanism through which import/export variety affects productivity in an extension of FK's model. I also describe my

[2] Of course, imports as final consumption goods may benefit the importing country's productivity indirectly (in the long run): by forcing the less efficient domestic variety to shrink or disappear, resources can be redistributed towards more productive varieties.

dataset and estimate a system of equations relating sectoral shares and import shares as well as adjusted total factor productivity (TFP) to export and import variety. In section 4, I present my estimation results. In section 5, I decompose productivity to illustrate the quantitative effects of export and import variety on Canadian provincial productivity differences and productivity growth. In addition, I also calculate the country breakdown contribution in Canadian productivity gain via export and import variety growth. Finally, in section 6, I conclude that export variety and import variety respectively account for 10.41% and 1.57% of the variation in Canadian provincial productivity differences in level. By excluding the joint effects with the province fixed effects, the total trade variety related effects account for 7.06% of the provincial productivity differences in level. Furthermore, the export and import variety respectively account for 9.92% and 6.95% of within-province productivity growth, and if their joint effects are also included, their total effects can account for 17.31%. Evaluated at the sample mean, a 10% increase in all trade varieties leads to a 0.90% increase in Canadian productivity, in which the export variety's contribution is 0.57% and import variety's is 0.33%. Furthermore, the breakdown of country contribution shows that though the US is the single most important source boosting Canadian productivity growth by buying more Canadian varieties, its relative importance is much less in the import side. The emerging and other new developing economies such as China benefit Canada a lot by providing more varieties to Canadian producers.

2 -- An Overview of Canadian Trade: 1988-2006

In 1988, Canada signed the Free Trade Agreement (FTA) with US which has been replaced by the North America Free Trade Agreement (NAFTA) with US and Mexico since 1992. In January 1995, Canada entered the World Trade Organization (WTO) with most of the open economies in the world. These trade agreements all aim at lowering tariff and non-tariff trade barriers between Canada and the other member countries. As a result, the Canadian economy is now broadly and deeply involved in foreign trade. To see this trend in detail, I define openness as the ratio of total value of imports and exports to the corresponding year's GDP. Figure 2 shows that the degree of openness increases from slightly above 40% in 1988 to about 60% in 2006. Apparently, trade plays a more and more important role on GDP and productivity growth in Canada.

To study how trade, especially trade variety, affects Canadian productivity growth quantitatively, I want to clarify first the definition of "variety" in this paper. The ideal definition for a variety is a market-based firm-brand such as Honda Civic and Ford Focus. In micro-level studies researchers often use the market-based survey data to study the variety effect on welfare or productivity. (for example, Blonigen and Soderbery (2009)). However, survey data has a serious limitation in data coverage: it can only cover one or a few industries for a few years. Therefore survey data can not satisfy macro-level studies which need data on a much boarder scope of economy (i.e. whole tradable sectors). Researchers usually employ trade data (such as SITC or HS data system) to carry out their macro-level studies and typically adopt the Armington definition that a variety is a country-good pair. (see, amongst many others, Feenstra and Kee (2008)). For example, the beer produced in France and that produced in Britain are treated as two varieties of the product "beer". In this paper, I define an export/import variety based on the trade data provided by Trade Analyser. Trade Analyser is a Canadian trade database which provides the most detailed (macro) level trade data for Canada. In this database, the trading commodities are described by the so-called Harmonized System (HS). The HS is an international 6-digit commodity classification developed under the auspices of the World Custom Organization (WCO). Canada has extended the HS system to 10 digits for import purposes and to 8 digits for export purposes. In the HS, goods are classified by what they are, and not according to their stage of fabrication, their use, or origin. Specifically, a product is a HS 6-digit commodity, such as "live Sheep". An import variety is defined as a country-specific good (whereas it is a state-good pair for the US imports) such as "live Sheep from France", and an export variety is defined as a province-specific good such as "live Sheep from Ontario, Canada". I "abuse" the concept of "country" for the US a little bit by treating each US states[3] as an independent "country". Such a special treatment for the US is due to the dominant status of the US goods in Canadian import market. It accounts for 54.89% of Canadian import share in 2006. Treating the US as a whole will significantly reduce the count of import varieties and understate the impact of them on productivity. In fact, it is very likely that large countries produce multiple varieties for one goods. But the likelihood is reduced when we disaggregate the data to provincial/state level. One can imagine that the HS data will converge to the ideal market-based data if they can be further disaggregated to city level. Therefore, treating the US states as separate countries in Canadian imports is justified.[4]

Trade growth can be decomposed into the expansion of the intensive and extensive margins. Given the variety defined in this paper, the expansion in the intensive margin refers to the growth in value due to surviving (existing) varieties, while the expansion of the extensive margin refers to the rest of growth due to newly added varieties. Table 1 reports the trade performance in value and variety during two sub-periods: 1988-1995 and 1995-2006, that is, the periods of pre- and post-WTO. The growth in Canadian exports is largely explained by expansion on the intensive margin. Pre-WTO, 74% of the growth is due to intensive margin expansion, while the fraction increases to 86.4% post-WTO. On the contrary, 63.31% of Canadian imports growth is attributed to expansion of the extensive margin pre-WTO, and the importance of extensive margin is strengthened to be nearly two thirds post-WTO. Finally, the total export variety pre-WTO is decreasing (-0.69% annually) while the total export value is increasing fast (5.54% annually). The reduction of varieties is mainly due to the US trade diversion since the entry of Mexico in NAFTA caused cheaper Mexican goods to replace some Canadian counterparts. However, the surviving Canadian exports reap more revenue thanks to NAFTA reducing the trade resistance (tariff and non-tariff barriers) such that the expansion in intensive margin overwhelms the loss in extensive margin. Regarding import, though the value growth is decreasing (4.27% pre-WTO vs. 2.91% post-WTO), the import variety increases more rapidly post-TWO (3.38% post-WTO vs. 1.92% pre-WTO). The reason is that the reduction of trade barriers thanks to WTO makes Canadian market more accessible to the rest of the world, and thus more varieties are available to Canadian consumers and producers.

Table 2a and 2b respectively report exports and imports in value and variety of major Canadian partner countries in 1988, 1995, and 2006. Table 2a shows Canadian exports rely heavily on the US market. Over 80% of Canadian varieties are exported to US in 2006, which helps Canada collected 81.26% of total export revenue from the US. Compared to 1988 and 1995, the export variety in 2006 in all the countries in table 2a increases significantly both in number and ratio, which implies that more and more Canadian varieties (especially the surviving ones from 1988 and 1995) have kept and enhanced their competitive power advantage successfully entered more countries. From table 2b, we can

[3] According to the data obtained from the World Trade Analyser, we "separate" the US to the following "countries" : Michigan, Illinois, New York, California, Texas, Washington, Ohio, Pennsylvania, New Jersey, Minnesota, Massachusetts, Tennessee, Indiana, New Hampshire, Kansas, Georgia, Florida, Wisconsin, North Carolina, Montana, Connecticut, Kentucky, Iowa, Vermont, Missouri, Colorado, Oregon, Wyoming, Maine, Maryland, North Dakota, Virginia, Alabama, South Carolina, Louisiana, Utah, Oklahoma, Arizona, West Virginia, Arkansas, Nebraska, Nevada, Mississippi, Rhode Island, Idaho, Alaska, Delaware, Puerto Rico, South Dakota, New Mexico, Hawaii, District of Columbia, US Virgin Islands, other unspecified US. state.

[4] It will be clear in our empirical strategy that the further disaggregation to state level will not falsely increase the variety impact on welfare in empirical test even if it just artificially increases the count of varieties.

observe that though overall the US is still the most important importing source country for Canada, the relative importance is decreasing fast post-WTO, with 54.89% of import value and 54.23% of import varieties in 2006 compared to 66.36% and 68.84% in 1988 respectively. On the contrary, imports from China increased rapidly especially post-WTO. The import value and variety from China increased by 1500% and 150% respectively from 1988 to 2006, resulting in the share of Chinese imports in value and variety increasing from 1.61% and 2.22% in 1988 to 8.82% and 3.25% in 2006 respectively. However, in aggregate, the shares of value and variety of these 8 major partner countries decrease steadily during 1988 to 2006, which implies that Canadian imports are more and more diversified owing to the reduction of its trade barriers with the rest of the world and more country competing with each other in the Canadian market.

Finally, to illustrate the relationship between productivity and trade variety, figures 3a and 3b show the scatter plots of Canadian multifactor productivity (TFP) against export and import variety respectively. The annual multifactor productivity is obtained from Statistic Canada (CANSIM table: 3830021). To make the variety comparable with the productivity index (base year: 2002), I index the varieties using 2002 variety as the base (index=100). Furthermore, I also detrend the productivity and variety index to avoid the possible effect of common time trend.

Both figures show the significantly positive effect of export and import variety on TFP. Of course, such aggregate data is far from enough for strictly demonstrating the positive effect of trade variety on productivity. We need many more observations sharing the same trade characteristics of Canada, i.e. under the same economic circumstances. Thus, a natural way is to collect data from Canadian provinces. The panel data of all the 10 Canadian provinces is employed in section 4 after the introduction of the empirical model in section 3.

3 -- The Empirical Model

3.1 Effect of New Varieties in Price Indices

Feenstra (1994) derives an exact price index from a CES (constant elasticity of substitution) aggregate good allowing both variety and quality/taste changes in existing varieties. This index can also apply for several goods or industries as long as they are CES aggregates.

Suppose there exist many c=1…..C countries. Each country c can produce a set of output varieties, I_t^c, at time *t*. The quantity of type j ($\in I_t^c$) variety produced in country c in period *t* is denoted by q_{jt}^c. In a standard MC model, the aggregate output of country *c*, Q_{jt}^c, is characterized by a CES function of the output of each specific good produced in that country:

$$Q_t^c = (q_j^c, I_j^c) = (\sum_{j=I_j^c} d_j (q_{jt}^c)^{\sigma-1/\sigma})^{\sigma/\sigma-1}, d_j > 0, c = 1,....C \qquad (1)$$

where d_j is the unknown productivity/quality parameter for good q_{jt}^c. Note, If q_{jt}^c is an output, then eq(1)refers to a transformation function with $\sigma < 0$; If q_{jt}^c is an (intermediate) input, then eq(1) refers to a production function with $\sigma > 1$.

As demonstrated by Feenstra, the ratio of aggregate price levels between countries (*c = a, b*) associated with the CES production function can be evaluated by the product of the Sato

(1976)-Vartia (1976) price index of varieties that are common, $I_t \equiv (I_t^a \bigcap I_t^b) \neq \phi$, and by terms reflecting the revenue share of "unique" varieties. The log form is given by:

$$\ln \frac{P_t^a}{P_t^b} = \sum_{j \in I_t} w_j(I_t) \ln\left(\frac{p_{jt}^a}{p_{jt}^b}\right) + \left(\frac{1}{\sigma - 1}\right) \ln\left(\frac{\lambda_t^a(I_t)}{\lambda_t^b(I_t)}\right), a, b = 1,.., C. \qquad (2a)$$

where p_t^c the aggregate price level, and the weights $w_j(I_t)$ are constructed from the revenue shares in the two countries:

$$\omega_j(I_t) = \left(\frac{s_{jt}^a - s_{jt}^b}{\ln s_{jt}^a(I_t) - \ln s_{jt}^b(I_t)}\right) \Bigg/ \sum_{j \in I_t} \left(\frac{s_{jt}^a - s_{jt}^b}{\ln s_{jt}^a(I_t) - \ln s_{jt}^b(I_t)}\right) \qquad (3)$$

$$s_{jt}^c(I_t) \equiv p_{jt}^c q_{jt}^c \Big/ \sum_{j \in I_t} p_{jt}^c q_{jt}^c, \ for\, c = a, b, \qquad (4)$$

$$\lambda_t^c(I_t) = \frac{\sum_{j \in I_t} p_{jt}^c q_{jt}^c}{\sum_{j \in I_t^c} p_{jt}^c q_{jt}^c} = 1 - \frac{\sum_{j \in I_t^c, j \notin I_t} p_{jt}^c q_{jt}^c}{\sum_{j \in I_t^c} p_{jt}^c q_{jt}^c}, \ for c = a, b, \qquad (5)$$

Where s_{jt} measures the revenue share of variety j relative to the revenue of all the varieties that are common in county a and b at period t; and $\lambda_t^c(I_t)$ is the revenue share of common varieties($j \in I_t$) to total varieties ($j \in I_t^c$).

The first term on the right hand side of (2) is the traditional price index, which only captures the weighted average of the price ratios for varieties in the common set I_t ; in other words, it actually omits the effect of variety change. The second term is a correction term, which reflects changes in product variety given that the quality of the same type of good is the same. Given (2a), we can easily see that the final effect of the new product that is uniquely produced in country *a* will cause the exact price ratio on the left to increase because the new product increases the competition for resources and drives up the factor prices; as a result, the prices of output increase.

In a special case where country b "contains" country a (e.g. *a* is a province of *b*); and the prices of the same varieties sold are the same (i.e. $p_{jt}^a = p_{jt}^b \forall j \in I_t$), then $\ln\left(\frac{p_{jt}^a}{p_{jt}^b}\right) = 0$ and $\lambda_t^a(I_t) = 1$, and eq(2a) is simplified to:

$$\ln \frac{P_t^a}{P_t^b} = (\frac{1}{1-\sigma}) \ln\left(\lambda_t^b(I_t)\right) \qquad (2b)$$

3.2 An Empirical GDP Function with both Export and Import Variety

First shown by Samuelson (1953), GDP can be treated as a variable profit function, which can be expressed as follows:

$$GDP \equiv \pi = \underset{Q_Y, Q_M}{Max} \left\{ P_Y Q_Y - P_M Q_M \,\middle|\, (Q_Y, Q_M, V) \in T \right\} \qquad (6)$$

where *T* is the production technology, P_Y ($> \underline{0}$) and P_M ($> \underline{0}$) are the exogenous aggregate price levels for output QY and variable input QM(intermediate input) respectively, and *V*(> $\underline{0}$) is a vector of fixed inputs. Furthermore, I assume the only variable intermediate inputs are imports. Note given GDP form in eq(6) and the duality theory, the GDP is homogenous of degree one in both prices (P_Y and P_M) and fixed input (V).[5] Empirically, the most popular variable profit form of GDP is the translog functional form proposed by Diewert (1973). For example, Kohli (2004) used it to estimate real GDP fluctuation due to the changes in terms of trade for 26 countries. Therefore, I implement a translog empirical GDP function where there are N differentiated tradable output sectors, M import sectors, a homogenous non-traded output sector (N +M +1), and K types of productive factors:

$$\begin{aligned}
\ln G_t^c(P_t^c, V_t^t) &= \alpha_0^c + \beta_0^t + \sum_{m=1}^{M} \alpha_m \ln P_{mt}^c + \sum_{n=m++1}^{N+M+1} \alpha_n \ln P_{nt}^c + \sum_{k=1}^{K} \beta_k \ln v_{kt}^c \\
&+ \frac{1}{2}\sum_{i=1}^{M}\sum_{j=1}^{M} \delta_{ij} \ln P_{it}^c \ln P_{jt}^c + \frac{1}{2}\sum_{i=M+1}^{M+N+1}\sum_{j=M+1}^{M+N+1} \delta_{ij} \ln P_{it}^c \ln P_{jt}^c \\
&+ \frac{1}{2}\sum_{i=1}^{K}\sum_{j=1}^{K} \tau_{ij} \ln \upsilon_{it}^c \ln \upsilon_{jt}^c + \sum_{m=1}^{M}\sum_{n=M+1}^{M+N+1} \delta_{mn} \ln P_{mt}^c \ln P_{nt}^c \\
&+ \sum_{m=1}^{M}\sum_{k=1}^{K} \rho_{mk} \ln P_{it}^c \ln \upsilon_{jt}^c + \sum_{n=M+1}^{M+N+1}\sum_{k=1}^{K} \omega_{nk} \ln P_{it}^c + \ln \upsilon_{jt}^c
\end{aligned} \qquad (7)$$

Notice that in a panel data regression setting, a_0^c and β_0^c refer to section and time fixed effects respectively. The properties of homogeneity in prices and endowments as well as symmetry have the following implications:

$$\begin{aligned}
&\sum_{m=1}^{M} \alpha_m + \sum_{n=N+1}^{M+N+1} \alpha_n = 1, \sum_{K=1}^{k} \beta_k = 1, \\
&\sum_{j=1}^{m} \delta_{mj} + \sum_{n=M+1}^{M+N+1} \delta_{mn} = \sum_{k=1}^{K} \rho_{mk} = 0, m = 1, ..., M, \\
&\sum_{j=M+1}^{M+N+1} \delta_{jn} + \sum_{m=1}^{M} \delta_{mn} = \sum_{k=1}^{K} \rho_{kn} = 0, n = M+1, ...M+N+1, \\
&\sum_{m=1}^{M} \rho_{mk} + \sum_{n+M+1}^{M+N+!} \omega_{nk} = \sum_{j=1}^{k} \tau_{nj} = 0, k = 1, ...K, \\
&\delta_{ij} = \delta_{ji}, i, j = 1, ...M+N+1, \\
&\tau_{ij} = \tau_{ji}, i, j = 1, ...K
\end{aligned} \qquad (8)$$

From (7), the share equations are given by the derivative of $\ln G_t^c(P_t^c, V_t^c)$ with respect to $\ln P_{nt}^c$ and $\ln P_{mt}^c$,

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[5] The duality theory states that the GDP measured by value-added (variable profit) method should be equivalent to that measured by aggregate cost of (fixed) inputs. That is,

$$\begin{aligned}
GDP \equiv \pi &= \underset{Q_Y, Q_M}{Max}\left\{ P_Y Q_Y - P_M Q_M \,\middle|\, (Q_Y, Q_M, V) \in T \right\} \\
&\equiv c = \underset{v}{Min}\left\{ w \cdot V \,\middle|\, (Q_{Y,} Q_M, V) \in T \right\},
\end{aligned}$$

where ω is the wage vector associated with the fixed input vector V.

$$s_{mt}^{c} = \alpha_m + \sum_{j=1}^{M+N+1} \delta_{mj} \ln P_{mt}^{c} + \sum_{k=1}^{K} \rho_{mk} \ln \upsilon_{kt}^{c}, m = 1,....,M \qquad (9)$$

and

$$s_{nt}^{c} = \alpha_n + \sum_{j=1}^{M+N+1} \delta_{nj} \ln P_{nt}^{c} + \sum_{k=1}^{K} \rho_{nk} \ln \upsilon_{kt}^{c}, n = M+1,......, N+m+1. \quad (10)$$

Where $s_{mt}^{c} \equiv -P_{mt}^{c} Q_{mt}^{c} / GDP_{n}^{c}$ and $s_{nt}^{c} \equiv p_{nt}^{c} Q_{nt}^{c} / GDP_{n}^{c}$ are the negative GDP shares of import m and the GDP shares of sector n; respectively: In this paper, since the prices of the same types of varieties sold by any Canadian province and Canada are the same, if we take the difference of eq(7) and eq(10) of any province (c) with that of the Canada (*), the difference of traded sector prices are replaced by eq (2b), thus we can map trade variety into the empirical GDP function as well as the share equations with minimal computation.

$$s_{it}^{c} - s_{it}^{*} = \sum_{m=1}^{M} \frac{\delta_{mi}}{(1-\sigma_m)} \ln \lambda_{mt}^{c*} + \sum_{n=M+1}^{M+N} \frac{\delta_{ni}}{(1-\sigma_n)} \ln \lambda_{nt}^{c*}$$

$$+\sum_{k=1}^{K} \rho_{ik} (\ln \upsilon_{kt}^{c} - \ln \upsilon_{kt}^{*}) + \delta_{M+N+1,i} (\ln P_{M+N+1,t}^{c} - \ln P_{M+N+1,t}^{*})$$

i=1,……M+N+1. (11)

and

$$\ln G_{t}^{c}\left(P_{t}^{c}, V_{t}^{c}\right) - \ln G_{t}^{c}\left(P_{t}^{*}, V_{t}^{*}\right) - \sum_{k=1}^{K} \frac{1}{2}\left(s_{kt}^{c} + s_{kt}^{*}\right)\left(\ln v_{kt}^{c} - \ln v_{kt}^{*}\right)$$

$$-\frac{1}{2}\left(s_{M+N+1t}^{c} + s_{M+N+1t}^{*}\right)\left(\ln P_{M+N+1t}^{c} - P_{M+N+1t}^{*}\right)$$

$$= a_{0}^{c} + \beta_{0}^{c} t + \sum_{i=1}^{M+N} \frac{1}{2}\left(s_{it}^{c} + s_{it}^{*}\right) \frac{\ln \lambda_{it}^{*}}{\left(1-\sigma_{i}\right)} \qquad (12)$$

The left hand side of (12) can be interpreted as the productivity difference between province (*c*) and Canada (*): it is the difference of GDP net of the differences in factor endowments and prices in non-traded goods. The remaining difference is the productivity difference due to province and time fixed effects and trade variety shown on the right.

3.3 Data and Estimating Equations

With equations (11) and (12), we can estimate the parameters of interest such as the elasticity of substitution between different varieties within a sector (σ), the relative price effects on the relative industry shares (δ), as well as the effects of relative endowments on sectoral shares and productivity.

The balanced panel dataset covers all 10 provinces in Canada (excluding 3 territories) from 1988 to 2006. It contains 190 observations for each regression. The trade variety data is obtained from Trade Analyser while the remaining data are all from CANSIM.

I assume there are three factors of production: Labor (*L*), Capital (*K*), and (arable) Land (*T*). Labor and Land (as well as real GDP (chained 1997 Canadian dollars)) are directly reported by CANSIM. Capital is constructed by the perpetual inventory method using real investment of the whole nation as well as the 10 provinces across the 19 years. Real investment is obtained by deflating the regional gross domestic capital formation with their respective GDP deflators. In addition, I construct the base year capital stock using an infinite sum of series of investment prior to the first year (1988), assuming that the average growth rate of investment of the 18 years is a good proxy for the investment prior to the first year.

Based on the North American Industry Classification System (NAICS), I aggregate all the tradable industries into 4 sectors: agriculture and forestry (AF), mining and basic metals (MB), light manufacturing (LM), and heavy and electronic manufacturing (HE)[6]. I compare the provincial value-added and import value of these four sectors to the corresponding regional GDP to construct the sectoral and import shares, respectively. That is, I have altogether 8 shares: four sectoral shares and four corresponding import shares. The non-traded goods price is obtained by taking an equally-weighted average of the price indices of Education and Construction. The regional labor share in GDP, s_{Lt}^{c}, is constructed by comparing the labor income to the corresponding regional GDP.

I use each of the 10 provinces as a specific "country", i.e. c = 1,……, 10, and Canada as a whole as the comparison country *. By implementing the homogeneity properties on productive factors(i.e. $\sum_{n=1}^{3} s_{nt}^{c} = 1$) and prices (i.e. $\sum_{m=1}^{9} \delta_{mn=0}$), we can rewrite (11) and (12) as follows:

$$R_{s_{nt}^{c}} = \varnothing_{Ln}\left(\ln \ell_t^c - \ln \ell_t^*\right) + \varnothing_{Kn}\left(\ln k_t^c - \ln k_t^*\right)$$
$$+\sum_{m=1}^{8} \delta_{mn}\left(\frac{\ln \lambda_{mt}^{c*}}{(1-\sigma_m)}\right) - \left(\ln P_{9t}^c - \ln P_{9t}^*\right) + \varepsilon_{nt}$$

$n = 1, \ldots .8$ (13a)

$$Adj.TFP_t^c \equiv \ln G_t^c\left(P_t^c, V_t^c\right) - \ln G\left(P_t^*, V_t^*\right)$$
$$-\frac{1}{2}\left(s_{Lt}^c + s_{Lt}^*\right)\left(\ln \ell_t^c - \ln \ell_t^*\right) - \frac{1}{2}\left(1 - \left(s_{kt}^c + s_{kt}^*\right)\right)\left(\ln k_t^c - \ln k_t^*\right)$$
$$-\frac{1}{2}\left(\ln T_t^c - \ln T_t^*\right) - \sum_{n=1}^{8} \frac{1}{2}\left(s_{nt}^c + s_{nt}^*\right)\left(\ln P_{9t}^c - \ln P_{9t}^*\right)$$
$$= \alpha_t^* + \alpha_0^c + \beta_k\left(\ln k_t^c - \ln k_t^*\right) + \beta_9\left(\ln P_{9t}^c - \ln P_{9t}^*\right)$$
$$+\sum_{n=1}^{8} \frac{1}{2}\left(s_{nt}^c + s_{nt}^*\right)\frac{\ln \lambda_{nt}^*}{(1-\sigma_n)} + \zeta_t \qquad (13b)$$

where $\ln(\ell_t) = \ln\left(L_t / T_t\right)$ and $\ln(k_t) = \ln\left(K_t / T_t\right)$, ε_{nt} and ζ_t are the residuals of (13a) and (13b) respectively. If homogeneity in prices of non-traded sector is not violated, β_9 in (13b) should be equal to unity, whereas β_k in (11b) represents the negative

[6] According to NAICS industry code, AF contains 11, 3111, 3113-7, 31211-4, 3122, 321, 3221, 3222, 323, and miscellaneous food; MB contains 21, 324, 3251-3, 3261, 3262, 3273, miscellaneous chemical products, miscellaneous non-metal products, and primary & fabricated metal products; LM contains 315, 316, 3352, 337, 339, and textile products; HE contains 3254, 333, 3341, 3361-6, 3369, electronic products, and electrical equipment & component manufacture.

value of the share of Land in GDP.[7] $RS_{nt}^{c} = S_{nt}^{c} - S_{nt}^{*}$ is the residual sector share (n = 1, 2,3, 4) or the negative residual import share (n = 5, 6, 7, 8). $Adj.TFP_{t}^{c}$ is the residual TFP which is the residual GDP (the GDP difference between province c and Canada*) net of the effects of difference in fixed product factors and the nontraded good price. Again, I emphasize that all the import shares are negative. In summary, I will regress the panel data for four relative sectoral share equations and four relative corresponding import share equations and a TFP equation (with both region and time fixed effects).

Furthermore, with the estimated parameters, the regional estimated productivity is given by (12):

$$Est.TFP_{t}^{c} = Adj.TFP_{t}^{c} - \hat{\alpha}_{t}^{*} - \hat{\beta}_{k}(\ln k_{t}^{c} - \ln k_{t}^{*}) + \hat{\beta}_{9}(\ln P_{9t}^{c} - \ln P_{9t}^{*})$$

$$= \hat{\alpha}_{0}^{c} + \sum_{n=1}^{8} \frac{1}{2}\left(s_{nt}^{c} + s_{nt}^{*}\right) \frac{\ln \lambda_{nt}^{*}}{\left(1 - \hat{\sigma}_{n}\right)} + \hat{\varepsilon}_{t} \qquad (14)$$

Due to the cross equation restrictions on $1/(1-\sigma_{n})$ and δ_{mn}, and the multiplicative nature of these parameters, I use nonlinear system estimation for the eight share equations (13a) and one TFP equation (13b). The optimal estimates for these parameters are derived by minimizing the variance-covariance matrix of the residuals in the full system of the regression equations.

4 -- Estimation Results

Before running the nonlinear regressions, there are two problems that need to be corrected. First, the error terms of the four sectoral share equations in (13a) may be correlated. For instance, the Rybczynksi effect state that, ceteris paribus, an increase in a factor endowment will benefit the sectors (industries) using that factor intensively but hurt the others. The sectoral share and their corresponding import shares may also be correlated. An expansion in one import share may benefit (hurt) a sector due to the complementary (substitute) effects. I need implement a seemingly unrelated regression (SUR) to have more efficient estimates if there is error correlation (Zellner, 1962). Secondly, endogeneity might arise since there may be correlation between export variety and the regression errors. That is, in the adjusted TFP equation (21b), productivity can also affect the export variety as productivity growth may help some products gain competitive advantages over their international counterparts so that they can become new exported varieties. Ignoring this potential endogeneity problem will cause the estimates to be biased. To correct for such an endogeneity problem, we need to identify some instrumental variables (IVs) which are only correlated with export variety but not productivity. Furthermore, because the possible measurement error in non-traded goods price index, I also treat it endogenous.[8] In order to overcome these two problems, I conduct a three-stage Nonlinear Least Squares regression (N3SLS) which is a commonly used remedy for both SUR problem and endogeneity problem.

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[7] In fact, from (18) and (20), β_k should be $\beta_{kt}^{i} = 1 - \frac{1}{2}\left(s_{Lt}^{i} - s_{Lt}^{*}\right) - \frac{1}{2}\left(s_{Kt}^{i} - s_{Kt}^{*}\right)$,which is a random parameter. For the sake of simplicity, we assume the relative labor share and the relative capital share do not change for different regions and across periods so that we treat β_k as a time- and region-invariant parameter.

[8] Import varieties are not treated endogenous because of two reasons. Theoretically, based on the ideas of MC, a country will not invent a new variety that is identical to existing import varieties which implies perfect substitution is impossible. In practice, existing varieties also try to maintain their market status by improving quality, see table 1 for the Canadian example.

However, empirically IV estimates are the always biased (though they are consistent asymptotically), the biasness is determined by the following three factors (given the variance of error term and the IVs): the correlation of the (excluded) IVs and the error term, that of the (excluded) IVs and the endogenous variables, and the R-squared from the first stage regression (projection of the endogenous variables onto the IV space. Good (excluded) IVs should have small correlations with the error term that will converge to zero asymptotically and their correlations with the endogenous variables should converge to a non-trivial number (i.e. the excluded IVs should not be too "weak"). Furthermore, the variance of the endogenous variables should be explained by the IVs as much as possible (i.e. the R-squared should be big). The effectiveness of the excluded IVs (the non-trivial correlation with endogenous variables) and the overall fitness of IVs (R--squared) is shown in section 4.1, the overall validity of excluded IVs (uncorrelation with error terms) is shown in section 4.2 by an over identifying test statistic.

4.1 The Selected Instrumental Variables

Many economists (e.g. Eaton and Kortum, 2002; Melitz, 2003) have suggested various IVs such as tariff, transport costs and distance as these trade costs can only affect productivity through export variety. However, since all Canadian provinces face the same tariffs against their exports, only IVs concerning transportation costs and distance will be useful here. In order to find enough IVs, I also consider market demand/supply and related indicators.

Besides the included exogenous variables of productive factors (that is, the log difference in capital/land ratio and labor/land ratio), time fixed effects, and the four import varieties, I find six additional IVs along four dimensions. They are weighted distance and railway density for transportation; international resident ratio for demography; effective sales tax, lagged CPI for market sales and demand; the log difference in land for factor supply. All the data are available from CANSIM.

With respect to the distance IVs, since the exports destinations are all over the world, I have to use a weighted distance to approximate the real trade distance facing each province. The majority of Canadian goods are exported to North America, Western Europe, and East Asia.[9] I assume all the exports are shipped to the following four destinations: New York (Eastern America), Los Angeles (Western America), Hong Kong (for East Asia) and Amsterdam (for Europe). Then I approximate the export distance by calculating the weighted distance between the capital city of each province to the four destinations with the distance weights of 40%, 40%, 10%, and 10% respectively. These weights roughly reflect the export shares of those regions represented by the four destinations according to table according to table 2a.

Since most Canadian cities (and population) are located near the Canada-US borders, the densities of railway is calculated by dividing total provincial mileage of railway by the corresponding Canada-US border length respectively.[10] The international resident is defined in this paper as a temporary visitor or an immigrant who has been in Canada since 1948. Of course, an immigrant who have been offered a Canadian passport is legally no longer an international ; however, he is still treated as an international in my paper since in general, he may still have links with the people of his home country so that it is easier for

[9] According to Statcan 2007, the biggest ten importing countries for Canadian goods are: US, U.K., Japan, China, Mexico, Germany, Korea (South), Netherlands, France, Belgium.

[10] There are three provinces, Newfoundland and Labrador, Prince Edward Island, and Nova Scotia, do not have land border with USA, then the corresponding border length is replaced by the length of their southern sea line.

him to access his original country's market. The ratios of urban residents and international residents are obtained by comparing the population of them to the total provincial population respectively.

Finally, the effective sales tax rate is calculated as the ratio of the total tax revenues on product sales to their corresponding provincial GDP. In addition, all the IV values in OLS except effective sales tax are logarithm values. The effective sales tax in OLS is transformed to be the logarithm of one plus the initial value.

Table 3 shows the OLS of the four export varieties on all the included and excluded IVs.[11] Most of IVs have significant effects on each export varieties. For example, trade distance negatively affects LM and HE while positively affects AF and MB. These results may be explained by the facts that Asia is the increasing sales market for AF and MB varieties after 1990 and more than half of such varieties are produced in inland provinces which have longer trade distance; on the other hand, industries in LM and HE experienced various vertical and horizontal integration with US thanks to FTA and NAFTA. Not surprisingly, railway density benefits all the export sectors because it can help to effectively reduce the transportation cost. Furthermore, theoretically international residents may affect international for they have the informational advantages on both their motherlands and the host countries (see Gould, 1994 and Rauch and Trindade, 1999). The results of OLS reveal that the international resident ratio plays a (significantly) negative role on AF and MB while positive in LM and HE. It may suggest that international residents (especially those from developing countries) are more likely to boost the exports of manufacturing sectors (LM and HE) since they are more technology-intensive sectors while hurt resource processing sectors (AF and MB) since varieties of these sectors are less technology-intensive and may be substituted by imports from developing countries (the residents' motherlands).
All the four R-squares are all above 0.96, which shows that the IV regression can preserve most of the variation (information) of the 4 export varieties. Overall, the six excluded IVs significantly affect the endogenous variables even after controlling the included IVs. These results show the overall fitness of all IVs in explaining the endogenous variables and the effectiveness of the exogenous IVs which, loosely speaking, help to reduce the biasness of the coefficient estimates for the endogenous variables.[12]

4.2 The Three-Stage Nonlinear Least Squared System Estimation

After finding enough excluded IVs, I conduct N3SLS System Regressions to estimate the interesting coefficients. Table 4 presents the results of the nonlinear system of share equations (11a) with the TFP equation (11b). All the homogeneity properties on prices and endowments as well as the symmetric property on cross-price effects are implemented in the share equations, and the last column shows the estimated coefficients of the regional productivity equation.

The upper part of Table 4 reports δ_{mn} , which are the partial price effects on the share of

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[11] The OLS is slightly different from the first stage of N3SLS which regresses the derivatives of the unknown parameters on all the IVs.

[12] There are two points make this statement not so strict. First of all, in the first stage of N3SLS, it actually projects the derivatives of the unknown parameters onto the IV space (see last footnote). Secondly, the effectiveness of excluded IVs would better be shown by testing the "weak IV" hypothesis (see Staiger and Stock 1997, Stock and Yogo, 2003). However, I choose to use OLS for two reasons. Above all, the direct OLS of endogenous variables on all IVs is straightforward and the results should not be very different from the first stage of N3SLS. In addition, most of the estimates of the excluded IVs are significant in explaining the endogenous variables which make us confidently ignore the "weak IV" problem.

traded sectors and corresponding import sectors in columns (1) to (8) due to export and import variety changes in the rows. Particularly, the diagonal of the upper-left shows the own-price effects. Theoretically, the own-price effects should be positive for exports to reflect the upward-sloping supply curves and should be negative for imports to reflect the downward-sloping demand curves. However, except for AF in exports and MB in imports, the rest of the own-price estimates are insignificant and even have wrong signs. The overall poor estimation of own-prices is mainly attributed to the inherent multilinearity problem between the export and import sectors (see table 3).

The lower part of table 4 of column (1) to (4) presents the Rybczynksi effects of endowments on the traded sector shares. We can observe that, in general, an increase in capital relative to land hurts the sectoral supplies (except MB) while a relative increase in labor has the opposite effect: it benefits the sectoral supplies (except MB). The lower part of column (5) to (8) shows that a relative increase in capital benefits the import demands; on the other hand, a relative increase in labor hurts the import demands. The results are surprising and interesting since theoretically, as a capital abundant country, Canada is supposed to import labor intensive goods and export capital intensive goods. However, the results suggest that Canadian traded output sectors except MB are mainly labor intensive while import sectors are mainly importing capital goods. Two reasons may account for this "puzzle". First of all, about 80% of the Canadian exports and 60% of imports occur with the US. Such deep trade dependence is at least partly owing to the horizontal and vertical integration with US traded sectors. Not surprisingly, it is a typical production pattern that the US branches main focus on R&D (capital intensive) while Canadian branches focus on intermediate production (relatively labor intensive). Secondly, Canadian nontraded sector (e.g. financial service, real estate, insurance etc.) is overall capital intensive. Nevertheless, it is an interesting phenomenon and further investigations and comparative studies with the other similar countries (e.g. Australia) are worthwhile.

The upper part of column (8) presents the NSUR estimates of $1/(1-\sigma_n)$ for each industry in the row. By assumption, the elasticities (σ_n) among outputs should be strictly negative while those among intermediate inputs (i.e. the imports) should be more than unity. In other words, we expect the estimates of $1/(1-\sigma_n)$ to be strictly between zero and one for export variety and negative for import variety. Furthermore, these estimates imply that the smaller (in absolute value) the σ_n is, the less substitutive between varieties (as inputs or outputs) and the larger contribution in productivity growth a new variety will make. As shown in column (8), all the top four estimates (for export variety) are significant and fall in the range of zero to one. The ranking of industries according to their implied elasticities of substitution are: HE (-0.45), LM (-0.77), AF (-3.33), and MB (-5.10). The results show that the average substitution levels facing Canadian outputs are small in HE and LM, and modestly high in AF and MB. The results are quite intuitive: goods in AF and MB are in general homogenous and contain little technology, thus they are more easy-to-substitute than LM and HE. The lower four estimates (for import variety) are, however, not all negative, and the estimate for HE is insignificant. The elasticities of substitution are: MB (0.25), LM (1.27), AF (1.35), and HE (142.86). The elasticity of import variety in MB is 0.25 (violating the "above-unity assumption") and the elasticity of HE is 142.86 which seems too high to fit the reality. These odd estimates may suggest that a significant fraction of the imports in MB and HE may be used as final consumption goods rather than intermediate inputs, and they may eventually substitute for the domestic counterparts.(See Appendix) Nevertheless, the coefficient estimates are still useful since they can be treated as the net the effect of the new import variety on productivity.

One approach to assess the reasonableness of these elasticities is by comparing them with priors. Unfortunately, there are no comparable studies for Canada. Then the second best is to compare similar studies for US or a group of countries, for instance, FK (2008) for 34 countries' exports (to US) and BGW (2006) for 73 countries' imports. FK split all the exports into seven sectors whereas four in mine. The correspondence of the estimated elasticities in FK and mine are shown in table 5. Compare with FK's elasticities, my estimates for HE and LM lie between FK's, but AF and MB are larger (that is, the contribution in productivity growth is smaller). Considering FK's estimates contain a lot of developing countries such as India and Mexico whose exports are supposed to be more important in boosting productivity than the developed ones, my estimates for Canada still seem reasonable. As for import elasticities, BGW estimate the import elasticities for more than 200 industries (based on 3-digit HS industry categorization) of 73 countries. Unfortunately, the detailed elasticities for Canada are unavailable; they only provide a median elasticity of 5. Simply comparing this median import elasticity with my results is not meaningful due to the poorly estimated elasticities of MB and HE. However, BGW also estimate that the contribution of new import varieties on Canadian productivity is 0.057% annually during 1994~2003. The aggregate import contribution based on my estimates is can be compared to BGW's which will be shown in section 4.3.

The lower part of column (8) presents the effects of the capital-land ratio and non-traded goods prices on adjusted TFP. As predicted in the model, the coefficient on the capital-land ratio should be the negative value of the land share in GDP. That is, the estimate, -0.251, implies that the estimated share of land in Canadian GDP is about 25.1%. However, the estimated coefficient of non-traded goods price is significantly less than unity which suggesting a violation of the homogeneity assumption on price which I do not impose in my estimation system.

Overall, this system introduces six excluded IVs for five endogenous variables. Thus, the system has nine over identifying restrictions (one in each of the nine regressions). The over identifying statistic is 6.9868 (with nine degrees of freedom) and its p-value is 0.5379, which implies that we cannot reject the null hypothesis of no correlation between the excluded IVs with the error terms in the system. In other word, there is no reason to reject the overall validity of the selected IVs.

4.3 Productivity Decomposition

To highlight the effects of export and import variety on productivity in Canada, I perform a post-regression decomposition of estimated productivity based on the results in table 4. Using (14), I compute the variance of estimated provincial TFP as:

$$\begin{aligned}
&\operatorname{var}\left(Est.TFP_t^c\right) = \operatorname{var}\left(\hat{\alpha}_0^c\right) + \operatorname{var}\left(variety.ex\right) + \operatorname{var}\left(variety.im\right) \\
&+2\operatorname{cov}\left(variety.ex, variety.im\right) + 2\operatorname{cov}\left[\hat{\alpha}_0^c, variety.ex\right] \\
&+2\operatorname{cov}\left[\hat{\alpha}_0^c, variety.im\right] + \operatorname{var}(\hat{\varepsilon}_t^c) \qquad (15)
\end{aligned}$$

Where

$$variety.ex_t = \sum_{n=1}^{4} \frac{1}{2}\left(s_{nt}^c + s_{nt}^*\right)\frac{\ln \lambda_{nt}^*}{\left(1-\hat{\sigma}_n\right)}, \quad variety.im_t = \sum_{n=5}^{8} \frac{1}{2}\left(s_{nt}^c + s_{nt}^*\right)\frac{\ln \lambda_{nt}^*}{\left(1-\hat{\sigma}_n\right)}$$

The first term on the right hand side is the variance of province fixed effects, the second and the third term are the variance of export variety and import variety respectively, the covariance of the export and import variety and their respective covariance with the province fixed effects are presented from the fourth to the sixth term. The last term is the error variance. By removing variance of the fixed effects and the regression error, the "variety-induced" provincial TFP is defined as:

$$\text{Variety-induced } TFP_t^c \equiv \sum_{n=1}^{N} \frac{1}{2}\left(s_{nt}^c + s_{nt}^*\right) \frac{\ln \lambda_{nt}^*}{\left(1-\hat{\sigma}_n\right)} \equiv \text{var}iety.ex_t + \text{var}iety.im_t$$

(16)

In addition, the first order difference of (14) within a province across two years reveals the growth decomposition of provincial productivity into three terms, which is the growth of variety induced provincial TFP in export and import plus the change in regression errors:

$$\text{Growth of } TFP_t^c \equiv \text{Variety-induced } TFP_t^c + \text{Variety-induced } TFP_{t-1}^c + \left(\hat{\varepsilon}_t^c - \hat{\varepsilon}_{t-1}^c\right)$$
$$\equiv \left(\text{var}iety.ex_t - \text{var}iety.ex_{t-1}\right) + \left(\text{var}iety.im_t - \text{var}iety.im_{t-1}\right)$$
$$+\left(\hat{\varepsilon}_t^c - \hat{\varepsilon}_{t-1}^c\right) \qquad (17)$$

The variance in the growth rate of provincial TFP is therefore the sum of the variance of the growth rate of variety-induced provincial TFP (in export and import), and the variance of the difference in error terms, along with the covariance between them. Table 6 shows the variance decomposition of country TFP in levels and growth rates. 85.37% of the cross-province differences in the TFP levels are explained by province fixed effects while trade variety-induced provincial TFP can account for about 7.06% of the provincial productivity levels. Particularly, the variance of export variety induced TFP can account for 10.41% of the provincial productivity levels and 1.57% by import variety but their accountability is reduced slightly by 0.48% if the joint effect of them (the covariance between them) is included. Furthermore, variety-induced TFP and province fixed effects are correlated, jointly with the province fixed effects, the contribution of export variety to the cross-province variation in TFP levels is reduced by 12.35% which means the total effect of export variety is completely absorbed by the province fixed effect; however, such joint effect of province fixed effect with import variety is increased by 7.91%. The second column of table 6 shows the growth decomposition of provincial productivity. About 17.31% of the within-province growth in TFP can be explained by the year-to-year growth in trade variety. Specifically, growth in export variety and import variety can respectively explain 9.92% and 6.95% of within-province TFP growth, and their joint effect accounts for 0.44%. FK find that the export variety can explain, on average of the 34 countries, 13% of within country productivity growth. Compared to 9.92% in my result, FK's is a little bit higher. Again, the difference is reasonable considering FK includes developing countries whose exports play a more important role in productivity growth. The reminder within-province growth is explained by the change in regression errors and the error correlation with the trade variety terms.

To further illustrate the effects of trade variety on Canadian productivity, according to (16) a 1% increase in the export variety of each sector n would increase provincial productivity by $\frac{1}{2}\left(s_{nt}^i + s_{nt}^*\right)\frac{1}{\left(1-\hat{\sigma}_n\right)}$ %. Thus, at the sample mean, a 10% increase in trade varieties of all industries could lead to a 0.90% increase in Canadian (the average province) productivity, of which the export variety's contribution is 0.57% and the import variety is 0.33%. This effect reveals that trade variety plays an economically significant role in TFP growth.

Furthermore, since the annual growth rate in import varieties is about 2.2% (by author's calculation from table 1), the annual gain in Canadian productivity due to import variety growth is 0.0726, higher than BGW's estimation, 0.057%. The difference can be explained by two reasons. First of all, there is a TFP measurement difference between mine and BGW. My estimated TFP is the TFP of traded sectors while BGW's includes the nontraded sector. Secondly, the accuracy of variety measurement is different. Mine is based on 10-digit HS data (for imports) while BGW's is based on 6-digit HS data. BGW find that the productivity gain from import variety will be much higher if they use more detailed HS data. In a word, my estimation for the aggregate effect of the import variety on TFP is justifiable.

4.4 Country Contribution in Canadian Productivity Growth

To estimate how much a country contributes to Canadian productivity gain via trade variety growth, we need first correctly measure the variety growth. The growth in simple count data of varieties as shown in table 1 and table 2a and 2b is far from accurate since apparently a new variety in beverage and that in electrical products have different impact on productivity gain. In fact, Feenstra (1994) suggests that the variety growth should be measured as a weighted variety change and the weights are the corresponding import revenue (price times quantity) of each variety. That is, a weighted variety growth from 1988 to 2006 should be

$$\frac{\lambda_{88}}{\lambda_{06}} = \left(\frac{\sum_{j\in I} p_j q_j}{\sum_{j\in 88} p_j q_j}\right) \Bigg/ \left(\frac{\sum_{j\in I} p_j q_j}{\sum_{j\in 06} p_j q_j}\right) \text{ or } \left(1-\frac{\sum_{j\notin I,\, j\in 88} p_j q_j}{\sum_{j\in 88} p_j q_j}\right) \Bigg/ \left(1-\frac{\sum_{j\notin I,\, j\in 06} p_j q_j}{\sum_{j\in 06} p_j q_j}\right).$$

where $I \equiv \left(I_{88} \cap I_{06}\right) \neq \varnothing$.

Therefore, a country can make contribution to variety growth via two channels: one is surely contributing more new variety share in 2006 (i.e., a lower λ_{06}); alternatively, the other way is to survive more of its 1988 varieties in 2006 (i.e. a higher λ_{88}). Furthermore, one can see that the weighted variety growth will be identical to the growth of simple count varieties, I_{06} / I_{88}, if and only if the revenue of each variety is identical.

An accurate country effect should be derived from the comparison of the exact price change by including and excluding that country. Apparently doing such exercises is computationally cumbersome. I approximate the country contribution by procedures similar to "comparative statics". That is, I assume all the estimated sigmas are the same (regardless the country impact on them). Feenstra (1994) shows that the exact price index can be compared not only across regions but across time. Therefore, everything else equal, a country's variety change will affect the aggregate productivity growth by a modification of eq(16),

$$\text{Vareity-induced}\, TPF^c \equiv \sum_{n=1}^{8} \frac{\overline{s^*_{nt}}}{(1-\hat{\sigma}_n)} (\ln \lambda^c_{88} - \ln \lambda^c_{06}).c = 1, \ldots, C. \qquad (18)$$

where $\overline{s^*_{nt}}$ denotes the mean of sector n during 1988 to 2006.

Table 7 reports the top 20 countries that contribute the most in Canadian productivity gain via export variety and import variety growth, respectively. As consistent with table 2a, the

US is the single most important exporting destination to Canada. 17 out of 20 top countries for Canadian exports are the US states. The other NAFTA country, Mexico, also nails the 3rd position. Overall, NAFTA is the most important source that boosts Canadian productivity growth via Canadian export variety increase. Compared to the export side, the import side, however, has a significantly different picture. Though the US is still very important to Canadian productivity gain in terms of import varieties, its relative importance is much less than that in Canadian exports. Only 9 states are on the top 20 list in imports. (Puerto Rico is not included) As implied in table 2b, fast growth in import value and varieties makes China become the importing source country that contributes the most in Canadian productivity gain. Furthermore, the contribution is fairly striking in terms of the magnitude. During 1988 to 2006, Canadian productivity reaps about 1.54% growth from more import varieties from China, whereas the following 14 countries' total contribution is only around 1.51%. Besides China, other supplying countries in East and South Asia such as Viet Name, India, etc. also contribute a lot in Canadian productivity growth. Finally, it is worth noting that the ranking of import variety contribution, is somewhat "surprising" since it reports relatively high contributions from emerging economies and other newly developing countries whereas some of the traditional Canadian import partners (such as the western European countries) are not found in the top 20 club. I want to emphasize that the contributions are only made through variety growth, which is a new aspect of productivity gain from trade. First of all, unlike the traditional study of import and productivity, this productivity gain is not concerned with importing capital goods or other "knowledge intensive" goods. Second, traditionally important partners to Canada already have high level of varieties in 1988 which makes them more difficult to maintain a high growth in variety when facing fierce competition from those emerging economies.

5 -- Conclusions

Existing literature using macro-level data analyzes of the effects of trade variety on TPF variation by export or import separately and has been restricted under a cross-country circumstance. In this paper I have attempted to study the case for Canada by estimating the effects of both export and import variety on province productivity with multiple sectors.

Estimating the eight share equations (four sectoral shares and four corresponding import shares) simultaneously with the GDP equation (transformed to become relative province productivity) allows me to identify and estimate the elasticity of substitution between trade varieties in each sector, and then infer the contribution of export variety to province productivity. The resulting elasticity estimates of export variety (degree of competition) range from a low of -0.45 in HE sector, to a high of -5.10 in the MB sector. The ranking I have obtained seems quite intuitive: goods in AF and MB are in general easy-to-substitute, thus their elasticities of substitution are larger than LM and HE. The estimated elasticities of import variety seem not so consistent with assumption in section 1. The elasticity of import variety in MB is 0.25 (smaller than the "above unity assumption") and the elasticity of Heavy and Electronic Manufacturing is 142.86 which seems too high to fit the reality. These odd estimates may suggest that a significant fraction of the imports in MB and HE may be used as final consumption goods rather than intermediate inputs, and they may eventually substitute for the domestic counterparts. My estimates for export elasticities seem reasonable compared to those of FK's; furthermore, the aggregate productivity contribution of import varieties in this paper is also comparable to that of BGW.

Finally, based on the N3SLS estimation, I have also calculated the impact of trade variety differences across provinces on their respective productivities. I find that export variety and import variety respectively account for 10.41% and 1.57% of the variation in Canadian provincial productivity differences in level. By excluding the joint effects with the province fixed effects, the total trade variety related effects account for 7.06% of the provincial productivity differences in level. Furthermore, the export and import variety respectively account for 9.92% and 6.95% of within-province productivity growth, and if their joint effects of them are also included, their total effects can account for 17.31%. Evaluated at the sample mean, a 10% increase in all trade varieties leads to a 0.90% increase in Canadian productivity, in which the export variety's contribution is 0.57% and import variety's is 0.33%. Furthermore, the analysis of country contribution shows that though the US is the single most important source boosting Canadian productivity growth by buying more Canadian varieties, its relative importance is much less in the import side. The emerging and other new developing economies such as China benefit Canada a lot by providing more varieties to Canadian producers.

There are many worthwhile extensions to this work. For example, a comparative study with other developed and developing countries (all should be small open economies) such as Australia and South East Asian countries could help us study quantitatively the different roles played by export and import variety on TFP and economic growth. In addition, since a real exchange rate can be modeled as a ratio of exact price index, a cross-country study using the link of exact price index and variety can help us investigate the effects of relative variety change (between a pair of countries) on real exchange rate dynamics.

APPENDIX: Effect of Imports as Final Consumption Varieties

Suppose the aggregate imports for final consumption also follow the CES form as shown by eq (1) and the expenditure share of imports on intermediate inputs is $\alpha (0<\alpha<1)$; then the comprehensive price index of imports is given by

$$P = \frac{1}{\alpha^{\alpha}(1-\alpha)^{1-\alpha}} P_I^{\alpha} P_F^{(1-\alpha)}$$

where *I* and *F* are the sets of imports used for intermediate input and final consumption respectively;

$$P_I = \left(\sum_{i=I} e_i (p_i)^{(1-\sigma_I)} \right)^{1/(1-\sigma_I)} \quad \text{and} \quad P_F = \left(\sum_{f=F} e_f (p_f)^{1-\sigma_F} \right)^{1/(1-\sigma_F)}$$

Thus, if conditions for the special case (for deriving 2b) are held , the exact price ratio between region a and b shown by eq(2) is,

$$\ln \frac{P_t^a}{P_t^b} = (\frac{1}{1-\sigma}) \ln(\lambda_t^b (I_t))$$

$$= (\frac{\alpha}{1-\sigma_I}) \ln(\lambda_t^b (I_{I,t})) + (\frac{1-\alpha}{1-\sigma_F}) \ln(\lambda_t^b (I_{F,t})) - C \qquad \text{(2b)}$$

where $I_{I,t}$ and $I_{F,t}$ are the sets of imports used for intermediate input and final consumption by region a (which is "contained" in *b*); *C* is a constant with $C = \alpha^{\alpha}(1-\alpha)^{1-\alpha}$.
Finally, though σ_I > 1 (for it is the elasticity of input), σ_F < 0 since by competition, the imports for final consumption may replace some of domestic output varieties which thus play a reverse role in output variety on productivity, i.e. the substitution effect decreases productivity by reducing domestic output varieties.
For the sake of simplicity, I assume $\lambda_t^b (I_{I,t}) = \lambda_t^b (I_{F,t}) = \lambda_t^b (I_t)$. Then

$$\sigma = 1 - (\frac{\alpha}{1-\sigma_I} + \frac{1-\alpha}{1-\sigma_F})^{-1}$$

Therefore, σ is not consistent with σ_I for two reasons: first of all, not all imports are used as intermediate inputs, i.e. α < 1; secondly, some imports may replace the domestic outputs, i.e. $-\infty << \sigma_F < 0$: Therefore, as an estimation of σ_I :

$$\sigma \text{ will be } \left\{ \begin{array}{l} \text{equal to } \sigma_{\text{I}} \text{ if } \alpha\text{=1;} \\ \text{overstated if } \dfrac{(\sigma_{\text{I}}\text{-1})}{(\sigma_{\text{I}}\text{-}\sigma_{\text{F}})} \leq \alpha\text{<1;} \\ \text{wrong } (\sigma_{\text{I}}\text{<1}) \text{ if } \alpha\text{<}\dfrac{\sigma_{\text{I}}\text{-1}}{\sigma_{\text{I}}\text{-}\sigma_{\text{F}}}. \end{array} \right\}$$

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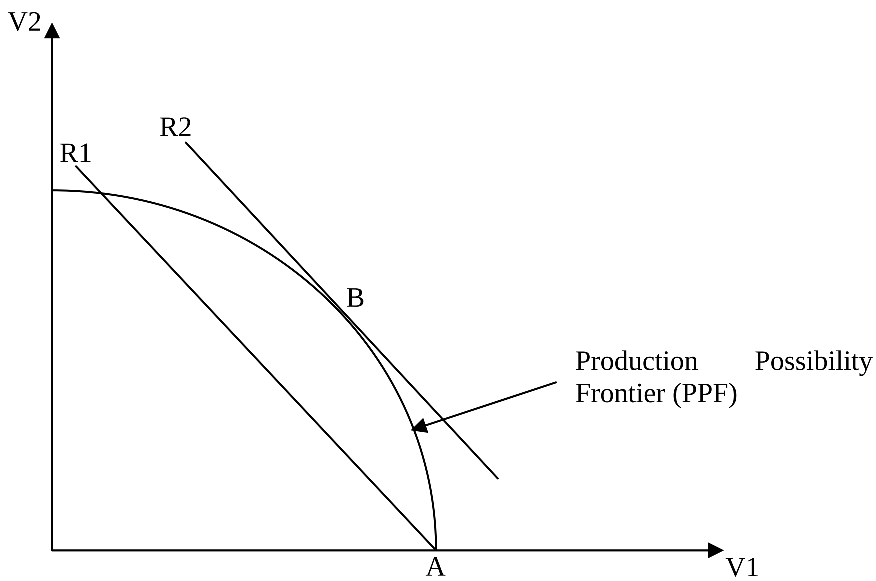


Figure 1a. Output Varieties and Revenue

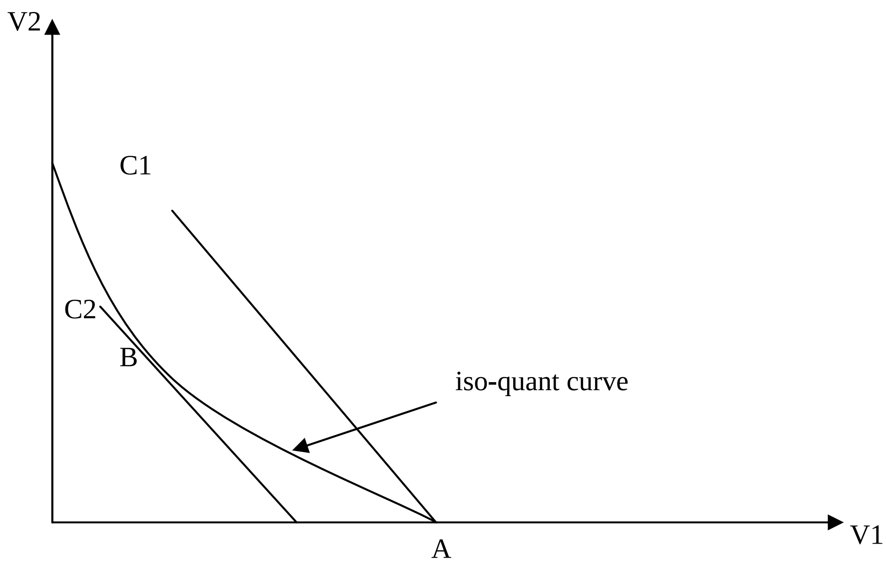
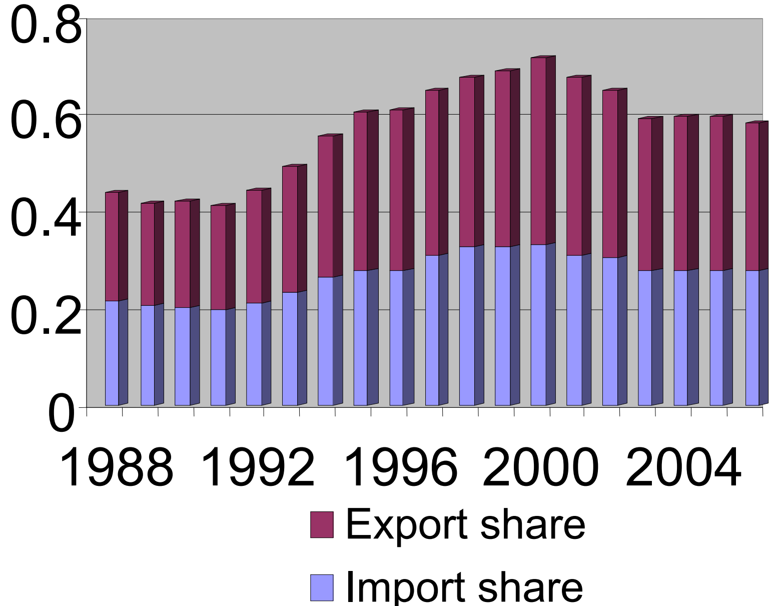


Figure 1b. Input Varieties and Cost

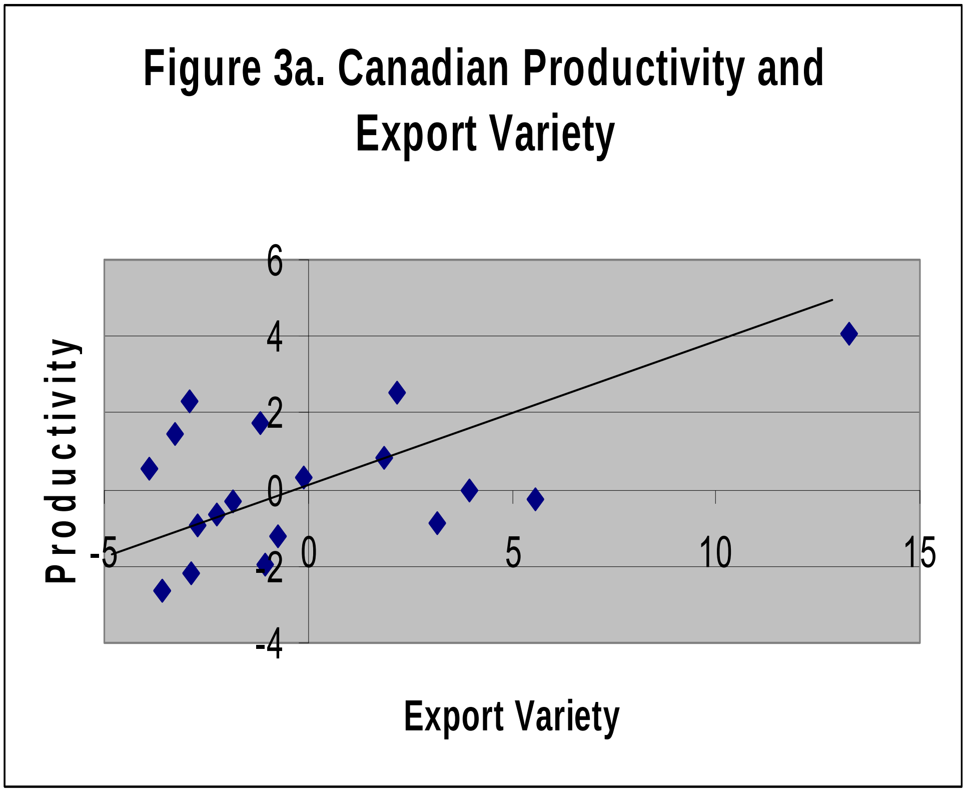
Mechanism of Productivity gain from variety growth:

Suppose the production function is given by (1), where σ <0 for outputs or σ >1 for inputs. As shown on figure 1a (1b), given output prices (input prices), an increase in output (input) varieties from V1 only to V1 *and* V2, the maximum revenue increases from R1 to R2 (minimum cost decreases from C1 to C2). And these gains are purely due to growth in available varieties.

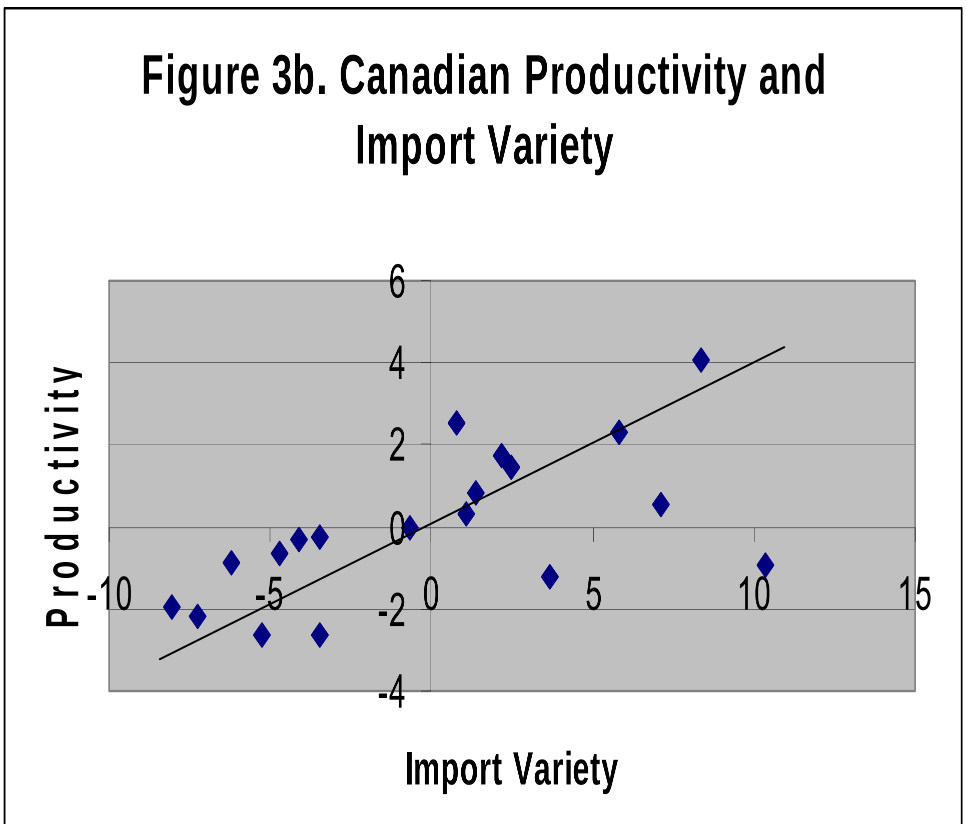
Figure 2. Foreign Trade Dependence of Canada: 1988-2006



Source: World Trade Analyser.



Source: Author's own calculation based on the raw data in the World Trade Analyser.



Source: Author's own calculation based on the raw data in the World Trade Analyser.

Table 1. Trade Performance in Value and Variety during 1988-1995 and 1995-2006

	Export				Import			
	1988-1995		1995-2006		1988-1995		1995-2006	
	Value	Variety	Value	Variety	Value	Variety	Value	Variety
Surviving	201011	16197	300686	16528	101763	154720	12911	128056
Disappeared	37398	7213	39879	5624	83183	167569	12675	247052
New	61270	5955	52222	11083	123815	220388	18925	431090
Annual Growth Rate (100%)	5.54	-0.69	2.73	2.02	4.27	1.92	2.91	3.38
Growth due to intensive margin (100%)	74.00	--	86.40	--	36.69	--	32.64	--
Growth due to extensive margin (100%)	26.00	--	13.60	--	63.31	--	67.36	--

Note: All values are in 1995 million Canadian Dollars unless otherwise indicated.

Source: Author's own calculation based on the raw data in the World Trade Analyser.

Table 2a. Export Value and Variety of Major Canadian Partner Countries: 1988, 1995, 2006

	Country	1988		1995		2006	
		Value	Variety	Value	Variety	Value	Variety
NAFTA	United States	100871 (72.81)	20206 (86.31)	207758 (79.21)	19678 (88.83)	358754 (81.62)	22187 (80.36)
NAFTA	Mexico	501 (0.36)	1430 (6.11)	1161 (0.44)	911 (4.11)	4379 (1.00)	4087 (14.80)
European Union	United Kingdom	3609 (2.60)	4694 (20.05)	3890 (1.48)	3547 (16.01)	10063 (2.29)	6342 (22.97)
European Union	France	1229 (0.89)	2941 (12.56)	1978 (0.75)	2358 (10.64)	2887 (0.66)	4796 (17.37)
European Union	Germany	1778 (1.8)	3739 (15.7)	3318 (1.6)	2897 (13.8)	3878 (0.88)	5173 (18.74)
Asia	China	3620 (2.61)	2814 (12.02)	5226 (1.99)	3507 (15.83)	9254 (2.11)	6644 (24.06)
Asia	Japan	8814 (6.36)	3860 (16.49)	12061 (4.60)	3390 (15.30)	9443 (2.15)	4920 (17.82)
Asia	Korea, South	1212 (0.87)	1407 (6.01)	2740 (1.04)	1605 (7.25)	3266 (0.74)	3108 (11.26)
Total		121633 (87.80)	21701 (92.70)	238131 (90.79)	20847 (94.11)	401926 (91.45)	24493 (88.71)

Note: All values are in 1995 million Canadian Dollars. The figures in parenthesis are the corresponding shares with respect to the Canadian total. China includes Hong Kong, and Germany includes East Germany before 1990.

Source: Author’s own calculation based on the raw data in the World Trade Analyser.

Table 2b. Import Value and Variety of Major Canadian Partner Countries: 1988, 1995, 2006

	Country	1988 Value	1988 Variety	1995 Value	1995 Variety	2006 Value	2006 Variety
NAFTA	United States	87050 (66.36)	221871 (68.84)	154576 (68.52)	239811 (63.93)	217633 (54.89)	303198 (54.23)
	Mexico	1328 (1.01)	1851 (0.57)	5353 (2.37)	4065 (1.08)	15983 (4.03)	7481 (1.34)
European Union	United Kingdom	4630 (3.53)	7704 (2.39)	5477 (2.43)	8090 (2.16)	10844 (2.73)	9970 (1.78)
	France	2884 (2.20)	6351 (1.97)	3124 (1.39)	6674 (1.78)	5175 (1.31)	9598 (1.72)
	Germany	3842 (2.93)	7828 (2.43)	4800 (2.13)	8489 (2.26)	11118 (2.80)	11370 (2.03)
Asia	China	2108 (1.61)	7140 (2.22)	5944 (2.63)	10292 (2.74)	34988 (8.82)	18198 (3.25)
	Japan	9268 (7.06)	6159 (1.91)	12095 (5.36)	6944 (1.85)	15335 (3.87)	9595 (1.72)
	Korea, South	2270 (1.73)	3799 (1.18)	3204 (1.42)	4284 (1.14)	5763 (1.45)	7242 (1.30)
Total		113379 (86.43)	262703 (81.51)	194572 (86.26)	288649 (76.95)	316839 (79.91)	376652 (67.36)

Note: All values are in 1995 million Canadian Dollars. The figures in parenthesis are the corresponding shares with respect to the Canadian total. China includes Hong Kong, and Germany includes East Germany before 1990.

Source: Author's own calculation based on the raw data in the World Trade Analyser.

Table 3: Dependent Variables-Export Variety Index
Estimation Method: Ordinary Least Squares
Observation per equation: 190

Independent Variables		**(1) Agriculture & Forestry**	**(2) Mining & Basic Metals**	**(3) Light Manufacturing**	**(4) Heavy & Electronic Manufacturing**
Market Sales & Demand	Effective Sales Tax	0.1016 (0.8871)	5.6866*** (1.5300)	-6.8517*** (2.3755)	0.2039 (1.3043)
	(lag) CPI	0.4618 (1.0781)	-7.1790*** (1.8594)	-1.0810 (2.8869)	4.4652*** (1.5851)
Factor Supply	Capital/Land Ratio	-0.2562** (0.1200)	1.6168*** (0.2069)	-2.5345*** (0.3213)	-0.1802 (0.1764)
	Labor/Land Ratio	1.0280*** (0.1281)	-1.5045*** (0.2209)	4.8273*** (0.3430)	1.5778*** (0.1884)
	Difference in Land	1.1883*** (0.0929)	0.0091 (0.1603)	1.8203*** (0.2489)	1.1431*** (0.1366)
Import Variety	Agriculture & Forestry	1.0300*** (0.1028)	0.8082*** (0.1772)	-1.6405*** (0.2752)	-0.9881*** (0.1511)
	Mining & Basic Metals	0.0191 (0.0978)	0.9934*** (0.1687)	0.4373* (0.2620)	0.0341 (0.1438)
	Light Manufacturing	-0.2038*** (0.0627)	0.0841 (0.1081)	0.5793*** (0.1678)	0.6027*** (0.0921)
	Heavy & Electronic Manufacturing	-0.4218*** (0.0725)	-0.4647*** (0.1250)	-0.1011 (0.1941)	-0.4296*** (0.1066)
Demo-graphy	International Residents Ratio	-3.0551*** (0.4228)	-3.1578*** (0.7292)	5.4625*** (1.1321)	5.2730*** (0.6216)
Transpo rta-tion	Trade Distance	6.7183*** (0.6479)	7.3077*** (1.1174)	-13.5105*** (1.7348)	-11.7075*** (0.9526)
	Railway Density	0.0451*** (0.0034)	0.0676*** (0.0059)	0.0189** (0.0091)	0.0168*** (0.0050)
Fixed Effec	Years	NO	YES	NO	YES
R-squared		0.9799	0.9801	0.9698	0.9884

Note: *, **, and *** indicate significance at 90%, 95% and 99% confidence levels respectively, and White-robust standard errors are in parentheses.

Table 4: Dependent Variables-Industry shares in Column (1) to (4), import shares of corresponding industries in column (5) to (8), and adjusted TFP in column (9)
Estimation Method: Three Stage Non-linear Least Squares
Total system observations: 1710
Observation per equation: 190

Independent Variables	**(1) Agricul-ture& Forestry**	**(2) Mining & Basic Metals**	**(3) Light Manufac-ture**	**(4) Heavy & Electronic Manufac-ture**	**(5) Import in AF**	**(6) Import in MB**	**(7) Import in LM**	***(8)* Import in H&E**	**(9) Adj.TFP**
Agriculture& Forestry	0.111*** (0.030)	-0.018 (0.0149)	-0.023*** (0.004)	-0.053** (0.022)	-0.006** (0.003)	-0.004 (0.005)	0.003** (0.001)	-0.046 (0.038)	0.231*** (0.056)
Mining & Basic Metals	-0.018 (0.0149)	-0.033 (0.0241)	0.020*** (0.005)	-0.017 (0.019)	0.001 (0.004)	0.001 (0.007)	-0.002 (0.002)	0.300*** (0.060)	0.164*** (0.028)
Light Manufacture	-0.023*** (0.004)	0.020*** (0.005)	0.000 (0.001)	0.018*** (0.005)	-0.001 (0.001)	-0.000 (0.001)	-0.001* (0.0003)	-0.062*** (0.011)	0.566*** (0.099)
Heavy & Electronic Manufacture	-0.053** (0.022)	-0.017 (0.019)	0.018*** (0.005)	-1.257 (3.187)	-0.013*** (0.004)	-0.023*** (0.006)	-0.002* (0.001)	1.278 (3.189)	0.692*** (0.070)
Import in AF	-0.006** (0.003)	0.001 (0.004)	-0.001 (0.001)	-0.013*** (0.004)	0.007*** (0.002)	0.003 (0.002)	-0.000 (0.000)	0.027*** (0.008)	-2.787*** (0.604)
Import in MB	-0.004 (0.005)	0.001 (0.007)	-0.000 (0.001)	-0.023*** (0.006)	0.003 (0.002)	-0.031*** (0.007)	-0.007*** (0.001)	0.029** (0.012)	1.329*** (0.139)
Import in LM	0.003** (0.001)	-0.002 (0.002)	-0.001* (0.0003)	-0.002* (0.001)	-0.000 (0.000)	-0.007*** (0.001)	-0.000 (0.000)	0.007*** (0.003)	-3.753*** (0.897)
Import in H&E	-0.046 (0.038)	0.300*** (0.060)	-0.062*** (0.011)	1.278 (3.189)	0.027*** (0.008)	0.029** (0.012)	0.007*** (0.003)	-1.595 (3.192)	0.007 (0.017)
Capital-Land Ratio	-0.029*** (0.006)	0.228*** (0.015)	-0.015*** (0.002)	-0.023*** (0.006)	0.024*** (0.003)	0.060*** (0.011)	0.019*** (0.003)	0.063*** (0.015)	
Labor-Land	0.022***	-0.232***	0.014*** (0.002)	0.029*** (0.006)	-0.026***	-0.075***	-0.020***	-0.097***	-0.251***

Ratio	(0.006)	(0.0142)			(0.003)	(0.011)	(0.003)	(0.015)	(0.036)
Non-traded Goods Prices									0.422*** (0.109)
Year Fixed Effects									YES
Province Fixed Effects									YES
R-squared	0.5616	0.6214	0.6032	0.5050	0.7083	0.5391	0.5403	0.6249	0.6635

Note: For columns (1) to (8), each log of relative export/import variety coefficient is the partial price effect of the industry in that row on the share of the industry in the column, These are the point estimates of δ_{mn}.

For column (9), each log of the relative export/import variety coefficient is the point estimate of $1/(1-\sigma_n)$ of the industry in that row.

*, **, and *** indicate significance at 90%, 95% and 99% confidence levels respectively, and White-robust standard errors are in parentheses.

Table 5: The Correspondence of FK's Export Sectors to Mine

FK		This Paper
Agriculture (-2.086) Woods & Paper (-0.669)	⟺	Agriculture and Forestry (-1.35)
Mining & Basic metals (-0.637)	⟺	Mining & Basic metals (-5.10)
Textile & Garments (-0.698) Petroleum & Plastics (-1.976)	⟺	Light Manufacturing (-3.33)
Machinery & Transport (-0.575) Electronics (-0.024)	⟺	Heavy & Electronic Manufacturing (-0.45)

Source: Author's own calculation and FK (2008).

Table 6: Productivity Decomposition

	Level Decomposition (in % of TFP)	Growth Decomposition (in % of TFP)
Variance of Estimated Province TFP	0.1653 (100)	0.0218 (100)
Variance of Province Fixed Effects	0.1411 (85.37%)	-
Variance of Export Variety Induced TFP	0.0172 (10.41%)	0.0022 (9.92%)
Variance of Import Variety Induced TFP	0.0026 (1.57%)	0.0015 (6.95%)
2*Covariance between Export Variety and Imports Induced TFP	-0.0008 (-0.48%)	9.60E-05(0.44%)
2*Covariance between Province Fixed Effects and Export Variety Induced TFP	-0.0204 (-12.35%)	-
2*Covariance between Province Fixed Effects and Import Variety Induced TFP	0.0131 (7.91%)	-
Total Trade Variety Related Effects	0.0117 (7.06%)	0.0038 (17.31%)

Source: Author’s calculation based on regression results of Table 4.

Table 7. Country Contribution in Canadian Productivity Growth via Variety Growth: 1988 to 2006

Ranking	Export Country	Export Contribution (in 100%)	Import Country	Import Contribution (in 100%)
1	US-California	0.2790	China	1.5396
2	US-Illinois	0.0418	Bangladesh	0.2061
3	Mexico	0.0375	Viet Nam	0.1865
4	US-Texas	0.0329	Mexico	0.1700
5	US-New Hampshire	0.0317	US-Ohio	0.1255
6	US-Utah	0.0233	US-Wisconsin	0.1125
7	US-Wyoming	0.0224	US-Utah	0.1104
8	US-Indiana	0.0210	India	0.0952
9	US-Colorado	0.0198	US-Michigan	0.0928
10	US-Georgia	0.0192	Cambodia	0.0809
11	US-Tennessee	0.0189	Belgium	0.0775
12	US-Connecticut	0.0182	Indonesia	0.0730
13	US-Pennsylvania	0.0152	US-Nevada	0.0661
14	US-Florida	0.0145	Japan	0.0590
15	US-Kentucky	0.0129	US-Missouri	0.0567
16	United Arab Emirates	0.0107	Puerto Rico	0.0499
17	US-Iowa	0.0106	US-South Carolina	0.0475
18	India	0.0104	US-Colorado	0.0434
19	US-Oklahoma	0.0094	US-Georgia	0.0432
20	US-Arizona	0.0090	Honduras	0.0421

Source: Author’s own calculation.