Review of Development Economics, 17(3), 414–429, 2013
DOI:10.1111/rode.12040

Trade Variety and Productivity in Canada

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Abstract

This paper combines the effects of import and export variety growth on technological development in a monopolistic competition model with endogenous technology. Using highly disaggregated international trade data at the national and provincial levels from 1988 to 2006, it is found that export variety and import variety account for 10.41% and 1.57% respectively of the variation in Canadian provincial productivity differences, and for 9.92% and 6.95% of within-province productivity growth. Evaluated at the sample mean, Canadian productivity gained 0.74% as a result of trade variety growth: export variety contributed 0.41% and import variety contributed 0.33%. While the USA is the single most important source of export-led Canadian productivity growth, its relative importance is much less on the import side. Emerging markets in Asia, especially China, contributed significantly to Canadian productivity growth by increasing import variety for Canadian producers.

1. Introduction

As documented in Broda and Weinstein (2006) and many other sources, trade variety (extensive margin) has grown rapidly in the past two decades. The usual explanation for the growth in trade variety is the wave of globalization which started in mid-1980s. Reductions in transportation costs, a sharp fall in tariff barriers, better and more symmetric information flows across markets, the proliferation of global production networks, etc., are all part of the explanation for a rise in trade variety.

Using monopolistic competition models (MC), economists can examine how trade variety affects productivity through the effects of input and output variety.

The input variety effect is similar to that found in endogenous growth models (Romer, 1990; Grossman and Helpman, 1991), where a greater variety of inputs leads to higher productivity. This effect is based on the assumption of diminishing marginal productivity of factors of production. Under the assumption that imports are used as intermediate inputs in production, an expansion in import variety will boost productivity growth.[1] Broda et al. (2006) find that new imported varieties on average account for 10% of productivity growth.

The output variety effect predicts that the expansion of export variety (as final output variety) can boost the exporting country's productivity. This hypothesis is based on the assumption of diminishing technical rate of substitution or economies of scope (Panzar and Willig, 1981). More export varieties (final output varieties) may improve productivity because of the effect of "economies of scope". Empirically, the link between export variety and productivity has been found by Feenstra et al. (1999) for South Korea and Taiwan; by Funke and Ruhwedel (2001) for East Asian coun-

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tries; by Chen (2011) for China; and by Feenstra and Kee (2008) for a sample of 48 countries (both developed and developing).

The existing literature on productivity gains from trade variety, however, has two limitations. First, most studies focus on either export variety or import variety. The total effect of both export and import variety and their interaction (gross substitute or complementary effects) has not yet been investigated in a unified framework. In this respect, Tybout (2003) points out that simple aggregation of individual (export or import) effects may result in a serious bias on their joint effects on productivity. Second, studies using multi-country panel data have had to assume that the key parameters (price elasticities of supply and demand) are identical across countries in the panel. This assumption, however, is too strong given the large variation in technology and taste across countries, which will have an effect on price elasticities.

By extending Feenstra and Kee's (2004) model to include both export and import variety,[2] this paper uses Canadian international trade data at the provincial level to analyze the effects of trade variety on productivity. This paper differs from Feenstra and Kee (2004) and other related studies in the following three ways: First, the paper looks at the effects of import and export variety on productivity based on a unified framework; second, by using Canadian provincial data, this paper is able to estimate the country-specific effect of trade variety and productivity based on within-country data without relying on the strong assumption of common elasticities across countries; third, following the method in Chen and Jacks (2012), I calculate the contributions of specific trading partners' export and import variety to Canadian productivity growth between 1988 and 2006. By determining the productivity contributions of specific markets, this paper provides an insight to the benefits of more expanded trade with countries from fast growing regions such as Asia, and especially with China. My results show that the USA is still the single most important source of Canadian productivity enhancement on the export side. Emerging economies such as China, however, have contributed significantly on the import side. This finding provides a fresh argument for trade liberalization that has so far received very little attention in the international trade and development economics literature.

The rest of the paper is organized as follows: section 2 summarizes the danymics of Canadian trade margins from 1988 to 2006. Section 3 introduces the mechanism through which import/export variety affects productivity and a system of equations relating sectoral shares and import shares as well as total factor productivity (TFP) to trade variety. The estimation results are reported in section 4. Section 5 presents the impact on Canadian provincial productivity differences and productivity growth, broken down by export and import variety. The productivity contributions of specific trading partners are also presented. Section 6 concludes.

2. The Trade Margins: An Overview of Canadian Trade 1988–2006

Researchers typically adopt Armington's (1969) definition of a trade variety as a country-good pair, i.e. a harmonized system (HS) category. This paper defines export/import varieties based on the trade data provided by Trade Analyser, which provides data at the HS 10-digit level for imports and at the 8-digit level for exports (this dataset is the most disaggregated trade data available for Canada). Therefore, an import variety is defined as a country-specific good such as "live sheep from France," and an export variety is defined as a province-specific good such as "live sheep from Ontario, Canada." The concept of "country" for the USA is "abused"a little bit by treating each US state as an independent "country" as Chen and Jacks (2012).

Trade growth can be broken down into two components: the intensive margin and the extensive margin. Expansion in the intensive margin refers to the growth in value as a result of surviving (existing) varieties, while expansion of the extensive margin refers to the growth caused by newly added varieties.

In the following I provide only a sketch of the descriptive statistics. Details can be found in the working version of this paper (Chen, 2010). During 1988–2006 Canadian exports more than tripled in nominal terms, with the contribution from extensive margin around 20%. In contrast, imports increased by almost 180%, with 65% of that growth coming from the extensive margin. The USA is the single most important trade partner for Canada. Over 80% of Canadian varieties were exported to the USA in 2006 (and 81% of total Canadian export revenue). It also accounted for about 54% of import varieties (and 54% of total Canadian import value). During that period, Canada has seen a significant diversification in its sources of imports. For example, China's import value and variety increased by 1500% and 150% respectively between 1988 and 2006. As a result, the share of China in total import value and variety rose to 8.82% and 3.25% in 2006 respectively, from 1.61% and 2.22% in 1988.

3. The Empirical Model

Effect of New Varieties in Price Indices

Feenstra (1994) derives an exact price index from a constant elasticity of substitution (CES) aggregate allowing both variety and quality/taste changes in existing varieties. This index can also apply to different regions as long as they are CES aggregates. As in Feenstra and Kee (2004), if region *a* belongs to *b* (i.e. *a* is a province of *b*), then the price index ratio of two regions is:

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

where P_t^c is the aggregate price level, and $\lambda_t^c(I_t)$ is the revenue share of common varieties ($j \in I_t$) to total varieties $(j \in I_t^c)$:

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

Equation (1) reflects changes in variety given that the quality of the same variety is unchanged. In fact, λ is a variety variable since it can be deemed as a weighted variety ratio where the weight is determined by the revenue of each variety. A new variety with sales revenue of one million is 100 times as important as a new variety with sales revenue of only ten thousand. Given equation (1), we can see that a new output variety produced in region *a* will also be counted as a new but common variety in *b* (since *a* belongs to *b*) and thus increase the price ratio by increasing λ^b since the coefficient of the lambda ratio for output, $1/(1-\sigma)$, is positive. In contrast, introducing a new variety in region *a* will decrease since $1/(1-\sigma)$ is negative for input.

An Empirical GDP Function with both Export and Import Variety

A widely applied variable profit gross domestic product (GDP) function is the translog functional form proposed by Diewert (1973). In this paper, I use a translog

GDP model similar to Kohli (2004) and assume there are N differentiated tradable output/export sectors, M import sectors (treated as negative outputs in these types of GDP models), a homogenous nontraded output sector $(N+M+1)$, and K types of productive factors:

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

Notice that in a panel data regression setting, α_0^c and β_0^t refer to section and time fixed effects respectively. Homogeneity in prices and endowments as well as symmetry is conventionally assumed:

$$\begin{aligned} & \sum_{m=1}^{M} \alpha_m + \sum_{n=N+1}^{N+M+1} \alpha_n = 1, \quad \sum_{k=1}^{K} \beta_k = 1, \\ & \sum_{j=1}^{M} \delta_{mj} + \sum_{n=M+1}^{N+M+1} \delta_{mn} = \sum_{k=1}^{K} \rho_{mk} = 0, \quad m = 1, \ldots, M, \\ & \sum_{j=M+1}^{N+M+1} \delta_{jn} + \sum_{m=1}^{M} \delta_{mn} = \sum_{k=1}^{K} \rho_{kn} = 0, \quad n = M+1, \ldots, M+N+1, \\ & \sum_{m=1}^{M} \rho_{mk} + \sum_{n=M+1}^{N+M+1} \omega_{nk} = \sum_{j=1}^{K} \tau_{nj} = 0, \quad k = 1, \ldots, K, \\ & \delta_{ij} = \delta_{ji}, \quad i, j = 1, \ldots, M+N+1; \quad \text{and} \quad \tau_{ij} = \tau_{ji}, \quad i, j = 1, \ldots, K. \end{aligned} \quad (3)$$

Given (3), 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 $\ln P_{mt}^c$

$$s_{mt}^c = \alpha_m + \sum_{j=1}^{M+N+1} \delta_{mj} \ln P_{mt}^c + \sum_{k=1}^{K} \rho_{mk} \ln v_{kt}^c, \quad m = 1, \ldots, M. \quad (4a)$$

and

$$s_{nt}^c = \alpha_n + \sum_{j=1}^{M+N+1} \delta_{nj} \ln P_{nt}^c + \sum_{k=1}^{K} \rho_{nk} \ln v_{kt}^c, \quad n = M+1, \ldots, N+M+1. \quad (4b)$$

where $s_{mt}^c \equiv -\frac{P_{mt}^c Q_{mt}^c}{GDP_n^c}$ and $s_{nt}^c \equiv \frac{P_{nt}^c Q_{nt}^c}{GDP_n^c}$ are the negative GDP shares of import m and the GDP shares of sector n, respectively.

Data and Estimating Equations

The data covers all the 10 provinces in Canada (excluding three 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 taken from the Canadian socioeconomic database CANSIM.

There are three factors of production: labor (L), capital (K), and (arable) land (T). Labor and land (as well as real GDP (chained in 1997 Canadian dollars)) are provided 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 by the 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.

I aggregate all the tradable industries into four sectors: agriculture and forestry (AF), mining and basic metals (MB), light manufacturing (LM), and heavy and electronic manufacturing (HE).[3] I then compare the provincial value-added and import value of these four sectors with the corresponding regional GDP to construct the sectoral and import shares respectively. The nontraded 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^c_{Lt}, is constructed by comparing the labor income with the corresponding regional GDP.

I use each of the 10 provinces as a specific "region", i.e. $c = , \dots , 10$, and Canada as a whole as the comparison region (*). Since the prices of the same types of varieties sold by any Canadian province and Canada (as a whole) are the same, we can take the difference of equation (2) and equations (4a,4b) of any province (c) with that of the Canada (*), replace the difference of traded sector prices by equation (1), and thus map trade variety into the empirical GDP function as well as the share equations:

$$
\begin{aligned}
Rs^c_{nt} = s^c_{it} - s^*_{it} &= \phi_{Ln}(\ln \ell^c_t - \ln \ell^*_t) + \phi_{Kn}(\ln k^c_t - \ln k^*_t) \\
&+ \sum_{m=1}^{8} \delta_{mn}\left(\frac{\ln \lambda^{c*}_{mt}}{(1-\sigma_m)} - (\ln P^c_{9t} - \ln P^*_{9t})\right) + \varepsilon_{nt}, \quad n = 1, \dots, 8. \qquad (5)
\end{aligned}
$$

$$
\begin{aligned}
\text{Adj.}TFP^c_t &\equiv \ln G^c_t(P^c_t, V^c_t) - \ln G(P^*_t, V^*_t) \\
&\quad - \frac{1}{2}(s^c_{Lt} + s^*_{Lt})(\ln \ell^c_t - \ln \ell^*_t) - \frac{1}{2}(1 - (s^c_{kt} + s^*_{kt}))(\ln k^c_t - \ln k^*_t) \\
&\quad - \frac{1}{2}(\ln T^c_t - \ln T^*_t) - \sum_{n=1}^{8} \frac{1}{2}(s^c_{nt} + s^*_{nt})(\ln P^c_{9t} - \ln P^*_{9t}) \\
&= \alpha^*_t + \alpha^c_0 + \beta_k(\ln k^c_t - \ln k^*_t) + \beta_9(\ln P^c_{9t} - \ln P^*_{9t}) \\
&\quad + \sum_{n=1}^{8} \frac{1}{2}(s^c_{nt} + s^*_{nt}) \frac{\ln \lambda^*_{nt}}{(1-\sigma_n)} + \zeta_t \qquad (6)
\end{aligned}
$$

where $\ln(\ell_t) = \ln\left(\frac{L_t}{T_t}\right)$ and $\ln(k_t) = \ln\left(\frac{K_t}{T_t}\right)$, ε_{nt} and ζ_t are the residuals of (5) and (6) respectively. If homogeneity in prices of nontraded sector is not violated, β_9 in (6) should be unity, whereas β_k in (6) represents the negative value of the share of land in GDP.[4] $Rs^c_{nt} \equiv s^c_{nt} - s^*_{nt}$ is the residual sector share (n = 1, 2, 3, 4) or the negative residual import share (n = 5, 6, 7, 8). Adj.TFP^c_t 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.

Because of 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 (5) and for the TFP equation (6). 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

Two problems in estimation may emerge. First, a seemingly unrelated regression problem may exist in (5). For instance, the Rybczynksi effect states that, *ceteris paribus*, an increase in a factor endowment will benefit the sectors (industries) using that factor intensively but will hurt the other sectors. Second, endogeneity might arise since productivity may also affect export variety. That is, in equation (6) TFP can also affect the export variety, given that productivity growth may help some products gain competitive advantages over their international counterparts and boost exports. The endogeneity problem can be corrected by instrumental variables (IVs) which are correlated with export variety but not with productivity.[5] Thus I conduct a three-stage nonlinear least squares regression (N3SLS) which is a commonly used remedy for both the seemingly unrelated regression (SUR) problem and the endogeneity problem.

It should be noted that IV estimates are always biased (though they are consistent asymptotically), and that the bias is determined by three factors: the correlation of the IVs and the error term, that of the (excluded) IVs and the endogenous variables, and the R^2 from the first stage regression. Good 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 nontrivial number (i.e. the IVs should not be too "weak"). Furthermore, the variance of the endogenous variables should be explained by the IVs as much as possible (the R^2 should be large). The effectiveness of the excluded IVs (the nontrivial correlation with endogenous variables) and the overall fitness of IVs (R^2) are shown in in the next subsection, and the overall validity of excluded IVs (unrelated with error terms) is shown in the subsection following by an overidentifying test statistic.

The Selected Instrumental Variables

"Classic" IVs include items such as tariff, transport costs and distance, which can only affect productivity through export variety. Since all Canadian provinces face the same tariffs, only IVs concerning transportation costs and distance will be useful here. To find enough IVs, I also consider six additional IVs that are identified along four dimensions: (i) transportation—weighted distance and railway density for transportation; (ii) demography—international resident ratio; (iii) market demand—effective sales tax and lagged consumer price index (CPI); (iv) factor supply—the log difference in land. Data are available in CANSIM.

For the transportation IVs, I use a weighted distance to approximate the real trade distance facing each province. As the majority of Canadian goods are exported to North America, Western Europe, and East Asia, I assume all 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 assign the weights of 40%, 40%, 10%, 10% respectively[6] in calculating distance between the capital city of each province to the four destinations. These weights roughly reflect the export shares of those regions represented by the four destinations.

Since most Canadian cities (and population) are located near the Canada–US border, the density of railway is calculated by dividing total provincial mileage of railway by the corresponding Canada–US border length.[7] The international resident ratio is defined as a temporary visitor or an immigrant who has been in Canada since 1948. Of course, an immigrant who has taken on Canadian citizenship is technically no longer an international resident. For the purposes of this study, however, I treat this person as an "international" since he/she is likely to still have links with the country of origin and hence have better access to market opportunities in that country. It is believed that "international" residents have informational advantages with respect to their countries of origin as well as with the host countries (Rauch and Trindade, 1999). The ratios of urban residents and international residents are obtained by comparing their numbers with the total provincial population.[8]

Finally, the effective sales tax rate is calculated as the ratio of the total tax revenues on product sales to their corresponding provincial GDP. All the IV values in ordinary least squares (OLS) are logarithm values, with the exception of "effective sales tax", which is transformed to be the logarithm of one plus the initial value.[9]

Table 1 shows the OLS of the four export varieties on all the included and excluded IVs.[10] Most of IVs have significant effects on each export variety. For example, trade distance has a negative effect on LM and HE, while having a positive effect on AF and MB. These results may be explained by the fact that Asia has been a rapidly growing market for AF and MB varieties since 1990. Also, more than half of such varieties are produced in inland provinces which are farther from the destination markets. In contrast, industries in LM and HE have gone through vertical and horizontal integration with US counterparts as a result of the bilateral free trade agreement (FTA), and subsequently the North American Free Trade Agreement (NAFTA).

Not surprisingly, railway density benefits all export sectors because of it reducing transportation costs. The results of OLS reveal that the international resident ratio plays a (significantly) negative role on AF and MB but has a positive effect in LM and HE. One interpretation is that international residents (especially those from developing countries) are more likely to boost the exports of manufacturing sectors (LM and HE) since these are the more technology-intensive sectors, while hurting resource processing sectors (AF and MB) because varieties of these sectors may be substituted by imports from developing countries (the residents' native countries).

All four R^2 are all above 0.96, showing that the IV regression can preserve most of the variation of the four export varieties. Overall, the six excluded IVs significantly affect the endogenous variables. These results reveal the overall fitness and effectiveness of all the IVs in explaining the endogenous variables.[11]

The Three-Stage Nonlinear Least Squared System Estimation

Table 2 presents the results of the nonlinear system of share equations (5) with the TFP equation (6). All the homogeneity properties on prices and endowments as well as the symmetric property on cross-price effects are implemented in the share equations. The last column shows the estimated coefficients of the regional productivity equation.

The upper part of Table 2 reports δ_{mn}, which are the partial price effects on the share of traded sectors and corresponding import sectors in columns (1)–(8) owing to

Table 1. The Stage Ordinary Least Squares Estimation

Independent variables		*(1) Agriculture & forestry*	*(2) Mining & basic metals*	*(3) Light manufacturing*	*(4) Heavy & electronic manufacturing*
Market sales & demand	Effective sales tax	0.1016	5.6866***	–6.8517***	0.2039
		(0.8871)	(1.5300)	(2.3755)	(1.3043)
	(Lag) CPI	0.4618	–7.1790***	–1.0810	4.4652***
		(1.0781)	(1.8594)	(2.8869)	(1.5851)
Factor supply	Capital/land ratio	–0.2562**	1.6168***	–2.5345***	–0.1802
		(0.1200)	0.2069)	(0.3213)	(0.1764)
	Labor/land ratio	1.0280***	–1.5045***	4.8273***	1.5778***
		(0.1281)	(0.2209)	(0.3430)	(0.1884)
	Difference in land	1.1883***	0.0091	1.8203***	1.1431***
		(0.0929)	(0.1603)	(0.2489)	(0.1366)
Import variety	Agriculture & forestry	1.0300***	0.8082***	–1.6405***	–0.9881***
		(0.1028)	(0.1772)	(0.2752)	(0.1511)
	Mining & basic metals	0.0191	0.9934***	0.4373*	0.0341
		(0.0978)	(0.1687)	(0.2620)	(0.1438)
	Light manufacturing	–0.2038***	0.0841	0.5793***	0.6027***
		(0.0627)	(0.1081)	(0.1678)	(0.0921)
	Heavy & electronic manufacturing	–0.4218***	–0.4647***	–0.1011	–0.4296***
		(0.0725)	(0.1250)	(0.1941)	(0.1066)
Demography	International residents ratio	–3.0551***	–3.1578***	5.4625***	5.2730***
		(0.4228)	(0.7292)	(1.1321)	(0.6216)
Transportation	Trade distance	6.7183***	7.3077***	–13.5105***	–11.7075***
		(0.6479)	(1.1174)	(1.7348)	(0.9526)
	Railway density	0.0451***	0.0676***	0.0189**	0.0168***
		(0.0034)	(0.0059)	(0.0091)	(0.0050)
Fixed effect	Years	YES	YES	YES	YES
Observations		190	190	190	190
R^2		0.9799	0.9801	0.9698	0.9884

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

Table 2. Three Stage Non-linear Least Squares Estimation

Independent variables	*(1) Agriculture & forestry*	*(2) Mining & basic metals*	*(3) Light manufacture*	*(4) Heavy & electronic manufacture*	*(5) Import in AF*	*(6) Import in MB*	*(7) Import in LM*	*(8) Import in H&E*	*(9) Adj.TFP*
AF	0.111***	–0.018	–0.023***	–0.053**	–0.006**	–0.004	0.003**	–0.046	0.231***
	(0.030)	(0.0149)	(0.004)	(0.022)	(0.003)	(0.005)	(0.001)	(0.038)	(0.056)
MB	–0.018	–0.033	0.020***	–0.017	0.001	0.001	–0.002	0.300***	0.164***
	(0.0149)	(0.0241)	(0.005)	(0.019)	(0.004)	(0.007)	(0.002)	(0.060)	(0.028)
LM	–0.023***	0.020***	0.000	0.018***	–0.001	–0.000	–0.001*	–0.062***	0.566***
	(0.004)	(0.005)	(0.001)	(0.005)	(0.001)	(0.001)	(0.0003)	(0.011)	(0.099)
HE	–0.053**	–0.017	0.018***	–1.257	–0.013***	–0.023***	–0.002*	1.278	0.692***
	(0.022)	(0.019)	(0.005)	(3.187)	(0.004)	(0.006)	(0.001)	(3.189)	(0.070)
Import in AF	–0.006**	0.001	–0.001	–0.013***	0.007***	0.003	–0.000	0.027***	–2.787***
	(0.003)	(0.004)	(0.001)	(0.004)	(0.002)	(0.002)	(0.000)	(0.008)	(0.604)
Import in MB	–0.004	0.001	–0.000	–0.023***	0.003	–0.031***	–0.007***	0.029**	1.329***
	(0.005)	(0.007)	(0.001)	(0.006)	(0.002)	(0.007)	(0.001)	(0.012)	(0.139)
Import in LM	0.003**	–0.002	–0.001*	–0.002*	–0.000	–0.007***	–0.000	0.007***	–3.753***
	(0.001)	(0.002)	(0.0003)	(0.001)	(0.000)	(0.001)	(0.000)	(0.003)	(0.897)
Import in H&E	–0.046	0.300***	–0.062***	1.278	0.027***	0.029**	0.007***	–1.595	0.007
	(0.038)	(0.060)	(0.011)	(3.189)	(0.008)	(0.012)	(0.003)	(3.192)	(0.017)
Capital–land ratio	–0.029***	0.228***	–0.015***	–0.023***	0.024***	0.060***	0.019***	0.063***	
	(0.006)	(0.015)	(0.002)	(0.006)	(0.003)	(0.011)	(0.003)	(0.015)	
Labor–land ratio	0.022***	–0.232***	0.014***	0.029***	–0.026***	–0.075***	–0.020***	–0.097***	–0.251***
	(0.006)	(0.0142)	(0.002)	(0.006)	(0.003)	(0.011)	(0.003)	(0.015)	(0.036)
Non-traded goods prices									0.422***
									(0.109)
Year fixed effects									YES
Prov. fixed effects									YES
No. of observations	190	190	190	190	190	190	190	190	190
R^2	0.5616	0.6214	0.6032	0.5050	0.7083	0.5391	0.5403	0.6249	0.6635

Notes: For column (9), each log of the relative export–import variety coefficient is the point estimate of $1/(1 - \sigma)$ of the industry in that row. *,**,*** indicate significance at 90%, 95%, and 99% confidence levels respectively, and White-robust standard errors are in parentheses.

export and import variety changes in the rows. Particularly, the diagonal of the upper-left quadrant 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 is mainly attributed to the multicollinearity problem between the export and import sectors.

The lower part of Table 2 of columns (1)–(4) presents the Rybczynksi effects of endowments on the traded sector shares. It shows 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. The lower part of columns (5)–(8) shows that a relative increase in capital benefits import demand; in contrast, a relative increase in labor hurts import demand. The results are surprising. As a capital abundant country, one would assume that Canada imports labor intensive goods and exports capital intensive goods. However, the results suggest that Canadian tradable output sectors (with the exception of MB) are mainly labor intensive while imports are mainly capital intensive. Two reasons may account for this "puzzle." First, Canadian trade is dominated by the USA. Compared with the USA, Canada is relatively a labor abundant country. Second, the Canadian nontraded sector (e.g. financial services and real estate) may be capital intensive. Nevertheless, the findings are counter-intuitive and warrant further investigation.

The upper part of column (9) presents the nonlinear seemingly unrelated regression 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 substitutable between varieties (as inputs or outputs) and the larger contribution in productivity growth a new variety will make. As shown in column (9), 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 moderately high in AF and MB. The results are quite intuitive: goods in AF and MB are in general more homogenous, 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: MB (0.25), LM (1.27), AF (1.35), and HE (–141.86). Both elasticities of substitution of MB and HE violate the "above unity" assumption. That is, the iso-cost curves for these two sectors are nonconcave. One possible reason is that imports in MB and HE may significantly "crowd out" domestic counterparts and thus hurt productivity via the output effect. These results deserve further investigation.

One approach to assess the accuracy of these elasticities is by comparing them with priors. To my knowledge, there are no comparable studies for Canada. A second best approach is to compare similar studies for the USA or for a group of countries, for instance papers by Feenstra and Kee (2008) for 48 countries' exports (to USA) and Broda et al. (2006) for the imports of 73 countries. Feenstra and Kee divide exports into seven sectors, compared with four in my study. My elasticity estimate for AF lies between the Feenstra and Kee estimates for Agriculture (–3.85) and Wood & Papers (–0.50). In the case of LM, my estimate is also between the Feenstra and Kee elasticities for Textile & Garments (–2.00) and Petroleum & Plastics (–3.78). The estimated elasticities on MB and HE are larger (in absolute terms) than Feenstra and Kee's on MB (–0.27), Machinery & Transport (–0.38) and Electronics (–0.26), respectively. In summary, my estimated elasticities for AF and LM are in the range calculated by Feenstra and Kee; the elasticity for HE is quite close to Feenstra and Kee while the elasticity for MB is larger. Considering that Feenstra and Kee's estimates contain many developing countries such as India and Mexico whose exports could be seen as more important in boosting productivity than imports from developed economies, my estimates for Canada are plausible.

With respect to import elasticities, the Broda et al. (2006) study covers more than 200 industries (based on three-digit HS industry categorization) of 73 countries. They report a median elasticity of 5 for Canada. Simply comparing this median import elasticity with my results is not meaningful owing to the poorly estimated elasticities of MB and HE. However, Broda et al. (2006) 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 comparable with theirs (shown in the next subsection).

The lower part of column (9) presents the effects of the capital–land ratio and nontraded 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 estimated share of land in Canadian GDP is about 25.1%. However, the estimated coefficient of nontraded goods price is significantly less than unity which violates 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 including the nontradable price index. Thus, the system has nine overidentifying restrictions (one in each of the nine regressions). The overidentifying 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.

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 2. The estimated TFP as a result of trade variety and province fixed effects is thus shown by equation (7):

$$\begin{aligned}\text{Est.}TFP_t^c &= \text{Adj.}TFP_t^c - \hat{\alpha}_t^* - \hat{\beta}_k(\ln k_t^c - \ln k_t^*) + \hat{\beta}_9(\ln P_{9t}^c - \ln P_{9t}^*) \\ &= \hat{\alpha}_0^c + \sum_{n=1}^{8}\frac{1}{2}(s_{nt}^c + s_{nt}^*)\frac{\ln \lambda_{nt}^*}{(1-\hat{\sigma}_n)} + \hat{\varepsilon}_t. \qquad (7)\end{aligned}$$

With equation (7) in hand I further show the role played by import and export varieties in TFP variance and growth.[12] Table 3 shows the variance decomposition of country TFP in levels and growth rates. Province fixed effects explain 85.37% of the cross-province differences in the TFP levels while trade variety-induced provincial TFP accounts for about 7.06%. The variance of export variety induced TFP can account for 10.41% of the variation in provincial productivity levels. The equivalent figure on the import side is 1.57%. The impact of export and import variety is reduced slightly by 0.48% if the effects are taken jointly (i.e. accounting for the covariance

Table 3. 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 2.

between exports and imports). Furthermore, variety-induced TFP and province fixed effects are correlated, and taken together with province fixed effects, and 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. On the import side, however, the joint effect of province fixed effects with import variety is increased by 7.91%. The second column shows the growth decomposition of provincial TFP. 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%.

As indicated in equation (7) a 1% increase in the export variety of each sector n would increase provincial productivity by $0.5(s_{nt}^{i} + s_{nt}^{*})\big/(1-\hat{\sigma}_n)\%$. From 1988 to 2006 the weighted growth (as in equation (1)) in export and import varieties is about 7.14% and 9.89% (or 0.52% annually) respectively. This suggests that during the sample period Canadian productivity gained 0.74% as a result of trade variety growth, with export variety contributing 0.41% and import variety adding 0.33%. The annual productivity growth owing to import variety accounts for 0.017%, which is smaller than Broda et al.'s (2006) estimate of, 0.057%. The difference may be due to a difference in measurement of TFP. Whereas I calculate TFP for traded goods sectors only, Broda et al. (2006) includes nontraded sectors as well. Broda et al.'s (2006) TFP gain would be higher if new import varieties hurt export sectors by crowding out export varieties but benefit nontraded sectors.

Country Contribution in Canadian Productivity Growth

As in Chen and Jacks (2012), I calculate the country-specific contribution to Canadian productivity growth. Table 4 reports the top 20 countries that contribute the most in

Table 4. Country Contribution to Canadian Productivity Growth via Variety Growth

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

Canadian productivity gain via export variety and import variety growth, respectively. Not surprisingly, the USA is the single most important export destination for Canada. Seventeen out of 20 top "countries" for Canadian exports are US states. The other NAFTA country, Mexico, is Canada's third most important export destination. Overall, NAFTA is the most important source for Canadian productivity growth via export variety. The import side, however, presents a very different picture. The USA is still very important to Canada, but its relative importance is much less than in the case of Canadian exports. Only nine states are in the top 20 list for imports. The country that contributes the most to Canadian productivity gain through imports is China, because of rapid growth in import value and variety. From 1988 to 2006, Canadian productivity reaped about 1.54% growth as a result of greater import variety from China, whereas the 14 next most important countries contributed a total of around 1.51% only.[13]

5. Conclusions

In this paper, I model and estimate the effects of both export and import variety on provincial productivity with multiple sectors in a unified framework. Estimating the eight share equations (four sectoral shares and four corresponding import shares) simultaneously with the TFP equation allows me to estimate the elasticity of substitution between trade varieties in each sector, and then infer the contribution of trade variety to provincial productivity. The resulting elasticity estimates of export variety range from a low of –0.45 in the HE sector, to a high of –5.10 in the MB sector. The findings are intuitive: goods in AF and MB are in general easy to substitute and have larger elasticities of substitution. However, the estimated elasticities of import variety seem not so consistent with the assumption in section 1. Both elasticities of substitution of MB and HE violate the "above unity" assumption. One possible reason is that imports in MB and HE may significantly "crowd out" the domestic competitors and thus hurt productivity via output effect.

Based on the N3SLS estimation, I also calculate 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 sum of trade variety-related effects account for 7.06% of the provincial productivity differences in level. Furthermore, they respectively account for 9.92% and 6.95% of within-province productivity growth, and if their joint effects are also included, the total effect accounts for 17.31%. Evaluated at the sample mean, Canadian productivity gained 0.74% owing to trade variety growth during the period 1998–2006: export variety contributed 0.41% and import variety contributed 0.33%. An analysis of country contributions shows that the US is the most important source of Canadian productivity growth on the export side and that China stands out for its contribution through imports.

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Notes

1. About two thirds of imports are intermediate inputs or capital goods, with the balance consumption goods. As noted by Romer (1994), however, the typical Dixit–Stiglitz structure can be applied for either consumption goods or as intermediate inputs with no fundamental change in the underlying economic analysis.
2. Although Feenstra and Kee (2008) is the revised version of Feenstra and Kee (2004), the 2008 version is in fact adding proof that the macro-level regressions in the 2004 version have a solid microfoundation. That is, the strictly concave transformation curve assumed in 2004 version can be derived from a "Melitz (2003)-type" model. Since the method in Feenstra and Kee (2004) is more convenient to apply in my paper I directly borrow Feenstra and Kee's method in 2004 without redoing the micro-analysis as in their 2008 version.
3. AF corresponds to HS 01–24 and 44–49; MB corresponds to HS 25–40 and 68–83; LM corresponds to HS 41–43, 50–67, and 94–96; HE corresponds to HS 84–93 and 97–99.
4. In fact, β_k should be $\beta^i_{kt} = 1 - \frac{1}{2}(s^i_{Lt} - s^*_{Lt}) - \frac{1}{2}(s^i_{Kt} - s^*_{Kt})$, 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.
5. Import varieties are not treated endogeneous since based on the ideas of monopolistic competition, a country will not invent a new variety that is identical to existing import varieties which implies perfect substitution is impossible.
6. The time-invariant weights are used to avoid possible correlation between distance and trade.
7. 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. The inclusion of railway as an IV is due to Atack et al. (2010).
8. A region with higher productivity may attract more international residents. However, such attraction should equally work on domestic residents as well. Thus the international resident ratio should be "productivity free." Furthermore, intuitively even if international residents were attracted more than domestic residents by regional productivity level, their migration decisions in general should base on the realized productivity level (i.e. the lagged productivity). Thus the international resident ratio should be exogenous to current productivity level.
9. In Canada sales taxes mainly consist of two parts: the federal tax which is the same across provinces and various provincial taxes. Provincial sales taxes are typically determined by the economic structure and social welfare goals of the provinces rather than local productivity level.
10. The OLS is slightly different from the first stage of N3SLS which regresses the derivatives of the unknown parameters on all the IVs.

11. Note that in the first stage of N3SLS, it actually projects the derivatives of the unknown parameters onto the IV space. However, we show the OLS results since they are straightforward and the results should not be very different from the first stage of N3SLS.
12. Readers can refer to Chen (2010) for the details of decomposition.
13. Note, there are countries making negative contributions as a result of either importing less Canadian variety or exporting less to Canada.