The Border Puzzle Revisited: A View from Regional Specialization

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Abstract

(This paper is preliminary. Comments are welcome.)

This paper revisits the influential work of Anderson and van Wincoop (AER, 2003) on the border puzzle. We find that regional specialization plays an important in determining international and intranational trade. Because manufacturing activities are not evenly distributed in space, regional specialization has interesting implications for production sharing across regions, thus having further implications for trade within and across countries. Therefore, the Anderson and van Wincoop model suffers from the omitted variable problem, and their account of the border effect may be incomplete.

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The border puzzle is one of the six puzzles of open economy macroeconomics (Obstfeld and Rogoff). Anderson and van Wincoop solve the puzzle by applying the theory of gravity equation both to estimation and to the general-equilibrium comparative statics of border effects. This theory of gravity equation predicts that bilateral trade flows, after controlling for size, depends on bilateral trade costs relative to the product of multilateral resistance indices. These multilateral resistance indices are a complex function of trade costs and income shares of *all* regions. So these indices incorporate the effects of third-country trade costs on bilateral trade flows. Because multilateral resistance indices are larger for smaller regions, trade is larger between smaller regions. They use this property of multilateral resistance indices to explain why the border effect is stronger for Canada than for the United States.

In this paper we revisit the Anderson and van Wincoop solution to the border puzzle. We find strong evidence that regional specialization plays an important role in determining international and intranational trade. Our empirical work is inspired by the theoretical work by Rossi-Hansberg on the spatial theory of trade. He argues that unlike transport costs, tariffs imply a discontinuity in relative prices at borders. This changes specialization patterns. Agglomeration effects and transport costs amplify this effect of tariffs on specialization in equilibrium and delivers a high elasticity of trade with respect to trade barriers. Thus, even with very low trade barriers, the border can have large impacts on trade flows.

We construct two measures of regional specialization. One measures the concentration of manufacturing activities. The other measures the extent of specialization between region pairs. We find that in addition to bilateral trade costs and multilateral resistance indices, both measures of regional specialization have significant effects on bilateral trade flows. Specifically, for trade between US states and trade between US states and Canadian provinces, regions with a higher concentration of manufacturing activities have significantly higher export shares. And trade shares are higher between regions that are less specialized. These results suggest that regional production sharing associated with regional specialization plays an important role in shaping international and intranational trade. However, trade between Canadian provinces exhibit a different pattern. We find no evidence that provinces with a higher concentration of manufacturing activities have higher export shares to other provinces. And trade shares are higher between provinces that are more specialized. This different trade pattern may be related to the fact that manufacturing activities are concentrated in a few large provinces and Canadian provinces are more specialized than US states.

As the spatial theory of trade suggests, regional specialization is affected by international trade barriers to a large extent. Thus, when tariffs are reduced, regional specialization patterns may change. This has further implications for trade within and across countries. Therefore, our empirical study also implies that the Anderson and van Wincoop simulation of the border effect is likely to be incomplete. How regional specialization is shaped by international trade barriers deserves further investigations.

This paper is organized as follows. In section 1, we review the Anderson and van Wincoop model and the Rossi-Hansberg spatial theory of trade, and present the estimating equation of bilateral trade. In section 2, we provide empirical evidence that the Anderson and van Wincoop model is not adequate in explaining bilateral trade flows. In particular, their exporter multilateral resistance indices fail to capture the key factors affecting exports. In section 3, we present strong empirical evidence that regional specialization plays an important role in determining the trade between and within the US and Canada. Section 4 concludes the paper.

1 Bilateral Trade Equation

1.1 The Anderson-van Wincoop Gravity Model

To derive the gravity equation of bilateral trade, Anderson and van Wincoop (2003) make three key assumptions. First, all goods are differentiated by place of origin. Each region is specialized in only one good. Second, preferences are identical and homothetic, which can be approximated by a CES utility function. Third, goods market is clear, which imposes a general equilibrium structure onto the model. Under these assumptions, it is straightforward to derive the bilateral trade equation as a function of trade costs, regional income shares, price indices, and the elasticity of substitution between goods produced in different regions.

Let i and j index regions. Let x_{ij} be the value of exports from i to j. Let y_i and y_j be the nominal income for i and j, respectively. Let y^w be the world nominal income. Let θ_i be i's share of world nominal income. Let t_{ij} be the cost of exporting goods from i to j. The gravity equation of bilateral trade can be written as

$$x_{ij} = \frac{y_i y_j}{y^w} \left(\frac{t_{ij}}{\Pi_i P_j} \right)^{1-\sigma} \tag{1}$$

where

$$\Pi_i^{1-\sigma} = \Sigma_j t_{ij}^{1-\sigma} P_j^{\sigma-1} \theta_j, \tag{2}$$

$$P_j^{1-\sigma} = \Sigma_i t_{ij}^{1-\sigma} \Pi_i^{\sigma-1} \theta_i. \tag{3}$$

As implied by equations (2) and (3), both $P_j^{\sigma-1}$ and $\Pi_i^{\sigma-1}$ are an implicit function of trade costs and income shares of all regions. In Anderson and van Wincoop, $P_j^{\sigma-1}$ and $\Pi_i^{\sigma-1}$ are referred to as multilateral resistance indices, respectively, for importers and exporters. Thus, equation (1) says that bilateral trade between i and j, after controlling for their income shares, depends on bilateral trade costs between i and j, relative to the product of multilateral resistance indices.

Some variants of this gravity equation can be generated by other models with different assumptions on the production side. For example, Eaton and Kortum provide a stochastic version of the Ricardian model, Redding and Venables extend the standard monopolistic competition model of trade by adding intermediate inputs, Lai and Zhu develop a monopolistic competition model that allows for asymmetric tariffs, distance, and production costs, and Helpman, Melitz and Rubinstein's model adds firm-level heterogeneity and allows for zero trade and sample selection.

With distance and tariffs as trade barriers, the bilateral trade cost t_{ij} can be expressed as $d_{ij}^{\rho}\tau_{ij}$, where d_{ij} is the bilateral distance between region i and region j; τ_{ij} equals 1 plus the tariff rate imposed by j on imports from i; and ρ measures the elasticity of trade to distance. The stochastic form of the bilateral trade equation may be written as

$$\ln\left(\frac{x_{ij}}{y_i y_j}\right) = k + (1-\sigma)\,\rho\ln d_{ij} + (1-\sigma)\ln\tau_{ij} + \ln P_j^{\sigma-1} + \ln\Pi_i^{\sigma-1} + \varepsilon_{ij} \qquad (4)$$

where k is a constant term, and ε_{ij} is the error term which captures all the unobserved factors that may affect bilateral trade flows. The inclusion of tariffs allows me to estimate the elasticity of substitution between goods produced in different regions (σ), which is a key parameter in the counterfactual analysis of the effect of trade liberalization on trade flows.

Anderson and van Wincoop (2003) consider a case in which bilateral trade barriers include distance and costs associated with the international border. In their case, bilateral trade barriers are symmetric. So a simplified solution to constraints (2) and (3) is $\Pi_i = P_i$, which reduces those constraints to $P_j^{1-\sigma} = \Sigma_i t_{ij}^{1-\sigma} P_i^{\sigma-1}\theta_i$. However, when asymmetric tariffs are included, their symmetric solution cannot be applied. To solve for $P_i^{\sigma-1}$, plugging equation (2) into (3) yields

$$P_j^{1-\sigma} = \Sigma_i \frac{t_{ij}^{1-\sigma}\theta_i}{\Sigma_{j'} t_{ij'}^{1-\sigma}\theta_{j'} P_{j'}^{\sigma-1}} \text{ for } j = 1, \ldots, N \qquad (5)$$

where N is the number of regions in the model. It is straightforward to show that among the N equations there is one redundant condition. Without loss of generality, any region can be chosen as the numeraire. That is, for the numeraire region, $P^{\sigma-1}$ can be set to be 1. In addition, $P_i^{\sigma-1}$ are meaningful only in relative terms. For example, if $P^{\sigma-1}$ is 0.30 for Arizona and 0.06 for California, then the gravity equation (1) implies that controlling for distance, tariffs and exporters, the import share ($x_{ij}/y_i y_j$) would be five times (i.e., 0.30/0.06) higher for Arizona than that for California on average. Like $P_i^{\sigma-1}$, $\Pi_i^{\sigma-1}$ is meaningful only in relative terms. $\Pi_i^{\sigma-1}$ can be obtained by plugging the solved $P_i^{\sigma-1}$ into equation (2). For the numeraire region, $\Pi^{\sigma-1}$can be normalized as 1.

Anderson and van Wincoop show that $P^{\sigma-1}$ and $\Pi^{\sigma-1}$ tend to be larger for smaller regions. They use this property of multilateral resistance indices to explain why the border effect is stronger for Canadian provinces than for US states. Their simulation of the border effect takes into account the effect of removing the international border on multilateral resistance indices. Thus, their simulation is based on the proposition that their structural model fully captures all factors that affect bilateral trade flows. However, if additional factors affect bilateral trade and are affected by the existence of tariffs, then the omission of those factors may lead to biased estimates. And the account of the border effect in Anderson and van Wincoop may be incomplete.

1.2 The Economic Geography and Trade Model

In the economic geography and trade literature, manufacturing activities are not evenly distributed in space. Some regions are the core of manufacturing production while other regions serve as peripheries that may specialize in agricultural production or supply intermediate inputs. This uneven distribution of manufacturing production may not sit well with the first two assumptions in the Anderson and van Wincoop model. The distribution of manufacturing activities in space also determines the pattern of trade across and within countries.

The recent theoretical work by Rossi-Hansberg (2005) uses a spatial theory of trade to explain the effect of national borders on trade. He argues that unlike transport costs, tariffs imply a discontinuity in relative prices at borders. This changes specialization patterns. Agglomeration effects and transport costs amplify this effect of tariffs on specialization in equilibrium and delivers a high elasticity of trade with respect to trade barriers. Thus, even with very low trade barriers, the border can have large impacts on trade flows.

Inspired by the economic geography and trade literature, we augment the gravity equation (4) by adding measures of regional specialization. Let S_{ij} be a vector of regional specialization measures. Then the gravity equation can be augmented as

$$\ln\left(\frac{x_{ij}}{y_i y_j}\right) = k + (1-\sigma)\,\rho \ln d_{ij} + (1-\sigma)\ln \tau_{ij} + \ln P_j^{\sigma-1} + \ln \Pi_i^{\sigma-1} + S_{ij}\gamma + v_{ij} \qquad (6)$$

where v_{ij} is the error term that subsumes all unobserved factors that may affect bilateral trade flows between i and j. If S_{ij} enters the estimating equation significantly, then the simulation of the border effect should not only pay attention to $P^{\sigma-1}$ and $\Pi^{\sigma-1}$, but also to the effect through the evolution of regional specialization. It implies that the Anderson and van Wincoop model would give us an incomplete account of the border effect on bilateral trade.

In the following we will examine international trade between US states and Canadian provinces and intranational trade for US and Canada. All regressions use data for 1993 unless specified otherwise. In 1993, the United States imposed an average tariff of 2% on Canadian goods, while Canada imposed an average tariff of 4% on imports from the United States. So the tariff variable τ_{ij} equals 1.04 if i is a US state and j is a Canadian province, $\tau_{ij} = 1.02$ if i in a Canadian province and j is a US state, and $\tau_{ij} = 1$ if i and j are in the same country. Note that in this paper we will not deal with the issue of zero trade because it is not a serious concern in our current setting: less than 1% of region pairs have zero trade.

2 $P^{\sigma-1}$ & $\Pi^{\sigma-1}$

In Anderson and van Wincoop, multilateral resistance indices play an important role in the counterfactual analysis of the border effect. In this section we provide evidence that the exporter multilateral resistance indices $\Pi_i^{\sigma-1}$ are not a major factor affecting exports. This leads to a systematic bias in the prediction of the Anderson and van Wincoop structural model for bilateral trade flows.

Following Anderson and van Wincoop, we estimate the structural equation (4) subject to constraints (2) and (3). In this approach $P_j^{\sigma-1}$ and $\Pi_i^{\sigma-1}$ are treated as unknown variables which can be solved from equations (2) and (3). Because both $\ln P_j^{\sigma-1}$ and $\ln \Pi_i^{\sigma-1}$ are nonlinear functions of σ and ρ as implied by equations (2) and (3), the bilateral trade equation (4) is nonlinear in parameters σ and ρ and thus must be estimated using nonlinear estimation techniques. The structural estimation yields estimates of $1-\sigma = -55.78$ and $(1-\sigma)\rho = -0.79$. See column 1 of Table 2. A high elasticity of substitution σ may indicate that goods made in the different regions are highly substitutable. A high σ also supports Rossi-Hansberg.

To illustrate the pattern of which the prediction of the Anderson and van Wincoop structural model deviates from the bilateral trade data, we regress the residuals $\widehat{\varepsilon}_{ij}$ on importer and exporter dummy variables. The estimates represent the unexplained importer and exporter effects that affect imports and exports, respectively. The results are shown in Table 1. In the table regions are sorted by the estimated exporter effects in a descending order. Saskatchewan is excluded from the regression. So its estimates are zero. Because the residual is the gap between the actual and predicted trade flows, a large estimated exporter effect indicates that the Anderson and van Wincoop model tends to underpredict the actual exports. As shown in Table 1, the Anderson and van Wincoop model tends to underpredict exports by Midwest manufacturing states (e.g., Ohio, Illinois, Kentucky, Tennessee, Indiana, Minnesota, Wisconsin, Michigan) and large Canadian provinces (e.g., Ontario, Quebec). On the other hand, a small estimated exporter effects indicates that the Anderson and van Wincoop model tends to overpredict the actual exports. As displayed in Table 1, the Anderson and van Wincoop model tends to overpredict exports by small Canadian provinces and US states, e.g., Newfoundland, Prince Edward Island, New Brunswick, Montana, Arizona, and North Dakota.

If $P_j^{\sigma-1}$ and $\Pi_i^{\sigma-1}$ fail to fully capture importer and exporter characteristics, and some omitted importer and exporter effects are correlated with any explanatory variables in (4), then the Anderson and van Wincoop structural estimates may be inconsistent. To fully control for importer and exporter effects, we replace $\ln P_j^{\sigma-1}$ and $\ln \Pi_i^{\sigma-1}$ with importer and exporter dummy variables D_j and D_i. The estimating equation (4) is then transformed into a linear specification

$$\ln\left(\frac{x_{ij}}{y_i y_j}\right) = k + (1-\sigma)\,\rho \ln d_{ij} + (1-\sigma)\ln \tau_{ij} + D_j + D_i + u_{ij}. \tag{7}$$

Equation (7) can be estimated using simple OLS. This method is adopted by Eaton and Korum, Redding and Venables, and Helpman, Melitz and Rubinstein. Compared to the Anderson and van Wincoop approach, OLS is easier to implement. More importantly, a linear specification is more robust. This is because Anderson and van Wincoop's nonlinear estimates may be inconsistent if some omitted importer or exporter characteristics are correlated with any of the explanatory variables in equation (4). On the other hand, because the linear estimation does not fully incorporate the theoretical constraints (2) and (3), the linear estimates may be less efficient. In addition, the Anderson and van Wincoop model offers an interesting economic interpretation of the importer and exporter effects. That is, they represent the multilateral resistance indices $P_j^{\sigma-1}$ and $\Pi_i^{\sigma-1}$.

The OLS estimate of (4) is shown in column 2 of Table 2. The estimates of $\sigma = 53.54$ and $\rho = 0.024$. Based on these estimates, we then use equation (5) to solve for $P^{\sigma-1}$ and use equation (2) to solve for $\Pi^{\sigma-1}$. If no omitted variables are correlated with d_{ij} and τ_{ij}, the OLS estimation of equation (4) yields consistent estimates of σ and ρ. Then the inferred $P^{\sigma-1}$ and $\Pi^{\sigma-1}$ are also consistent estimates of multilateral resistance indices. Without loss of generality, Saskatchewan is chosen as the numeraire and excluded from the OLS regressions. The inferred $\ln P^{\sigma-1}$ and $\ln \Pi^{\sigma-1}$ are set to be zero for Saskatchewan. Thus, multilateral resistance indices for other regions are expressed relative to those for Saskatchewan.

Column 3 of Table 2 reports estimates of equation (4) in which $P_j^{1-\sigma}$ and $\Pi_i^{1-\sigma}$ are the consistent estimates of multilateral resistance indices. Although the coefficient on $\ln \Pi_i^{1-\sigma}$ is statistically significant, its magnitude is far below one as implied by the theoretical constraint.

To investigate further the deviation pattern of the Anderson and van Wincoop model, we compare the inferred $\ln P_j^{\sigma-1}$ and $\ln \Pi_i^{\sigma-1}$ with the importer and exporter effects estimated from (7). Panel A of Figure 1 plots the inferred $\ln P_j^{\sigma-1}$ against the estimated importer effects. It displays a strong correlation between the inferred $\ln P_j^{\sigma-1}$ and the estimated importer effects. The slope is a high 0.94 (with a standard deviation of 0.09), which is not statistically different from 1. The $R^2 = 0.75$.

In contrast, panel B of Figure 1 shows a weak relationship between the inferred $\ln \Pi_i^{\sigma-1}$ and the estimated exporter effects. Even after excluding Newfoundland and Prince Edward Island, the slope is just 0.38 with a standard deviation of 0.20. The $R^2 = 0.1$, which suggests that $\ln \Pi_i^{\sigma-1}$ fail to capture key factors that influence exporting. In addition, this figure reveals an interesting pattern. Large regions (e.g., Ontario, Quebec, Alberta, California, and Midwestern states) have much larger exporter effects than Saskatchewan (i.e., positive estimates of exporter effects) while having smaller inferred $\ln \Pi_i^{\sigma-1}$ than Saskatchewan (i.e., negative inferred $\ln \Pi_i^{\sigma-1}$). In contrast, small regions (e.g., Newfoundland, Prince Edward Island, Montana and North Dakota) have much lower estimated exporter effects while having much larger inferred $\ln \Pi_i^{\sigma-1}$. Note that if the estimated $\ln \Pi_i^{\sigma-1}$ are higher than the estimated exporter effects for region i, then the Anderson and van Wincoop model overpredicts actual exports by i on average. On the other hand, if the estimated $\ln \Pi_i^{\sigma-1}$ are lower than the estimated exporter effects for region i, then the Anderson and van Wincoop model underpredicts actual exports by i on average. Thus, the pattern revealed by panel B of Figure 1 is consistent with Table 1. That is, the Anderson and van Wincoop model tends to overpredict exports by small regions while underpredicting exports by large regions.

Why is $\ln P_j^{\sigma-1}$ strongly correlated with the estimated importer effects, but $\ln \Pi_i^{\sigma-1}$ weakly related with the estimated exporter effects? Table 3 provides us one possible explanation. The table shows that $\ln \theta$ is strongly and negatively correlated with both $\log P_j^{\sigma-1}$ (-0.80 with $p < 0.01$) and the estimated importer effects (-0.52 with $p < 0.01$). It means that larger regions tend to have a lower import share, as revealed by the data.

This is consistent with the usual observation that a large region trades more with itself than with other regions. At the same time, as dictated by constraints (2) and (3) in the Anderson and van Wincoop structural model, large regions tend to have lower $P^{\sigma-1}$. Thus, the strong correlation between the inferred $\ln P^{\sigma-1}$ and estimated importer effects works through regional economic size $\ln \theta$.

In contrast, as reported in Table 3, there is nearly no correlation between $\ln \theta$ and the estimated exporter effects. The trade flows data suggest that some large regions with abundant natural resources and/or a high manufacturing concentration (e.g., Alberta, Ontario, Midwestern states) have substantially higher exporter effects, which means that those regions have higher export shares on average after controlling for distance, tariffs, and importers. On the other hand, $\ln \theta$ is strongly correlated with $\ln \Pi_i^{\sigma-1}$ (-0.83 with $p < 0.01$) as dictated by constraints (2) and (3). This explains why $\ln \Pi_i^{\sigma-1}$ is weakly related with the estimated exporter effects.

Note that in the Anderson and van Wincoop model the negative correlation of $\ln \theta$ with $\ln \Pi^{\sigma-1}$ and $\ln P^{\sigma-1}$ is the key to explain why the border effect is stronger for a small country (Canada) than for a big country (US). However, the above results suggest that exporting is likely driven by factors other than the $\ln \theta$-related $\ln \Pi^{\sigma-1}$. This raises some doubt about the Anderson and van Wincoop simulation of the border effect. If factors other than $\ln \Pi^{\sigma-1}$ affect exports and may change when tariffs are reduced, then the account of the border effect by Anderson and van Wincoop may be incorrect.

To summarize, $\ln \Pi^{\sigma-1}$ fail to capture key factors affecting exporting. In particular, the data reveal that some large regions in fact have bigger exporter shares rather than smaller export shares as predicted by the Anderson and van Wincoop model. These large regions are abundant in natural resources (e.g., Alberta) and have high manufacturing concentration (e.g., Midwestern states). In the next section we will investigate the role of regional specialization in determining the patterns of international and intranational trade.

3 Regional Specialization

There are two related measures of regional specialization. One measures the localization of manufacturing activities across regions. For region i the index of localization of manufacturing activities is defined as

$$Localization_i = \frac{Q_i^M/Q_i}{Q^M/Q}$$

where Q_i^M is the manufacturing value added for region i, Q_i is i's GDP, Q^M is the manufacturing value added aggregated over all regions, and Q is the sum of all regions' GDP. This localization index of manufacturing activities can be interpreted as a weighted average of localization indices for detailed manufacturing industries with the share of industry value added as the weight.[1] To match with other data, this index is calculated for the year 1993. Panel A of Figure 2 shows that unlike $\ln \Pi_i^{\sigma-1}$, $Localization_i$ is strongly correlated with the exporter effects estimated from equation (7). The simple correlation between them is 0.50 with $p < 0.01$. In contrast, panel B shows that $Localization_i$ has no relationship with the estimated importer effects. The simple correlation between $Localization_i$ and the estimated importer effects is -0.18 with $p = 0.20$.

Figure 2 also reveals that Midwestern states and large Canadian provinces have higher concentration of manufacturing activities. Clearly, there is a core-periphery pattern in manufacturing specialization. Because of agglomeration effects, the core has a higher exporter share (i.e., exports normalized by size) than peripheries. Thus, there is a strong correlation between $Localization_i$ and the estimated exporter effects. Below we will provide further evidence that $Localization_i$ is strongly related to trade patterns within and

[1] Let Q_{gi}^M be the value added of manufacturing good g in region i. Let Q_g^M be the total value added of manufacturing good g aggregated over all regions. Then

$$Localization_i = \Sigma_{g\in M}\left(\frac{Q_{gi}^M/Q_i}{Q_g^M/Q}\right)\left(\frac{Q_g^M}{Q^M}\right) = \frac{Q_i^M/Q_i}{Q^M/Q}.$$

between the US and Canada.

A related measure of regional specialization is to compare industrial composition differences between region pairs, which is constructed as

$$Specialization_{ij} = \Sigma_{g \in M} \left| \frac{Q_{gi}^M}{Q_i^M} - \frac{Q_{gj}^M}{Q_j^M} \right|$$

where Q_{gi} is the value added in manufacturing industry g for region i, and Q_i is the total value added for region i in the manufacturing sector. If the two regions i and j have exactly the same industrial distribution of output, then the index $Specialization_{ij}$ is equal to zero. On the other hand, if the two regions are completely specialized, then the index is equal to two. The index is related to Krugman's index regional specialization which the industrial distribution of employment rather than value added to construct the index. Unlike $Localization_i$, $Specialization_{ij}$ captures a bilateral relationship.

Next we examine to what extent regional specialization affects bilateral trade flows. Results are given in Table 4. For comparison, column 1 lists results for equation (7). In column 2, we add $Specialization_{ij}$. Its coefficient is -0.35, indicating that trade shares are higher between pairs that are less specialized (i.e., with a lower $Specialization_{ij}$). It may reflect that trade is driven by intra-industry production sharing. Based on the estimates of σ and ρ in column 2, we use constraints (2) and (3) to solve for $\ln P^{\sigma-1}$ and $\ln \Pi^{\sigma-1}$. If the OLS estimates of σ and ρ are consistent, the inferred $\ln P^{\sigma-1}$ and $\ln \Pi^{\sigma-1}$ are consistent estimates of multilateral resistance indices.

In column 3, we replace the exporter and importer dummy variables with multilateral resistance indices. The results are almost identical to those in column 3 of Table 2. This is because the inclusion $Specialization_{ij}$ leaves the estimates of $(1-\sigma)$ and $(1-\sigma)\,\rho$ almost unchanged and thus using estimates of σ and ρ from column 1 or column 2 gives almost identical estimates of $\ln P^{\sigma-1}$ and $\ln \Pi^{\sigma-1}$.

Column 4 presents results of equation (6) in which both measures of regional specialization are included. The coefficient on $Localization_i$ is positive and statistically significant, indicating that regions with higher concentration of manufacturing activities have significantly higher export shares. The coefficient on $Specialization_{ij}$ remains significantly negative. These results suggest that in addition to multilateral resistance indices, regional specialization is also important for determining international and intranational trade.

To examine whether regional specialization affects international and intranational trade in a different manner, we include interactions of $Localization_i$ and $Specialization_{ij}$ with dummy variables indicating the direction of trade flows. Results are shown in column 5 of Table 4. Now the coefficients on $Localization_i$ and $Specialization_{ij}$ represent the marginal effect of $Localization_i$ and $Specialization_{ij}$ on trade between US states. Similarly, interactions with $D_{US,CA}, D_{CA,CA}$ and $D_{CA,US}$ represent the differences in the marginal effect of $Localization_i$ and $Specialization_{ij}$ on US exports to Canada, trade between Canadian provinces, and Canadian exports to US states, respectively, from that for trade between US states. The estimate on $Localization_i$ remains significantly positive. The interactions of $Localization_i$ with $D_{US,CA}$ and $D_{CA,US}$ are not statistically different from zero, indicating that the marginal effect of $Localization_i$ on trade between US and Canada is not statistically different from that for trade between US states. This means that for trade among US states and trade between US states and Canadian provinces, regions with a higher concentration of manufacturing activities have significantly higher export shares. On the other hand, the interaction of $Localization_i$ with $D_{CA,CA}$ is significantly negative and its magnitude is not statistically different from that of the coefficient on $Localization_i$. Thus, for trade between Canadian provinces, the marginal effect of $Localization_i$ on trade is not statistically different from zero.

In addition, the coefficient on $Specialization_{ij}$ remains significantly negative and its magnitude becomes even larger. The interactions of $Specialization_{ij}$ with $D_{US,CA}$ and $D_{CA,US}$ are not statistically different from zero. Thus the marginal effect of $Specialization_{ij}$ on trade between US and Canada is not statistically different from that for trade between US states. So for trade between US and Canada and trade between US states, trade shares are higher between pairs that are less specialized. In contrast, the interaction of

$Specialization_{ij}$ with $D_{CA,CA}$ is statistically positive. The magnitude is twice as much as that of the coefficient on $Specialization_{ij}$. Thus, for trade between Canadian provinces, $Specialization_{ij}$ has a significantly positive effect, indicating that trade shares are higher for pairs that are more specialized. This result is consistent with the previous result that export shares are not significantly higher for provinces with a higher concentration of manufacturing activities. Compared to US states, Canadian provinces are more specialized and manufacturing activities are concentrated in a few large provinces.

From the above regression results, we can draw the following observations. Regional specialization cannot be ignored in the analysis of international and intranational trade. Regional specialization implies that manufacturing activities are not evenly distributed in space. It has interesting implications for production sharing across regions and further implications for trade within and across the border. Thus, the Anderson and van Wincoop model suffers from the omitted variable problem. In addition, because regional specialization patterns may change when tariffs or other forms of trade barriers are reduced, the Anderson and van Wincoop simulation of the border effect may be incomplete.

Below we provide some evidence suggesting that although regional specialization exhibits persistence over time, the pattern of regional specialization evolves gradually over time. As shown in Table 5, $Localization_i$ for different years are highly correlated. The table also shows that the correlations become weaker when the year lag is longer. For example, $Localization_i$ for 1997 has the highest correlation with the localization index for 1993, and the lowest correlation with the localization index for 1984.

Figure 3 displays the evolution of $Specialization_{ij}$ over the period of 1984-1997. The CA_CA, US_CA and US_US series plot $Specialization_{ij}$ averaged across pairs of Canadian provinces, pairs of US states and Canadian provinces, and pairs of US states, respectively. Canadian provinces are more specialized, which is consistent with the fact that manufacturing activities are concentrated in several large Canadian provinces. In contrast, US states are less specialized. As expected, specialization is the least between Canadian provinces and US states. This pattern of specialization is persistent over time. However, the figure also shows that US states become less specialized over time. In contrast, for Canadian provinces, specialization declined until the early 90s and then increased gradually. This change over time largely drives the change of specialization between US states and Canadian provinces. The question on the extent to which these evolutions of regional specialization are driven by reductions in trade barriers deserves further investigation.

4 Conclusions

The border puzzle is one of the six puzzles of open economy macroeconomics. Anderson and van Wincoop solve the puzzle by applying the theory of gravity equation both to estimation and to the general-equilibrium comparative statics of border effects. This theory of gravity equation predicts that bilateral trade flows, after controlling for size, depends on bilateral trade costs relative to the product of multilateral resistance indices. Because multilateral resistance indices are larger for small regions, trade is larger between small regions. They use this property of multilateral resistance indices to explain why the border effect is stronger for Canada than for the United States.

In this paper we revisited the Anderson and van Wincoop solution to the border puzzle. Inspired by the Rossi-Hansberg spatial theory of trade, we included regional specialization into the analysis of trade between and within the United States and Canada. We constructed two measures of regional specialization. One measures the concentration of manufacturing activities. The other measures the extent of specialization between region pairs. We find that in addition to bilateral trade costs and multilateral resistance indices, both measures of regional specialization have significant effects on bilateral trade flows. Specifically, for trade between US states and trade between US states and Canadian provinces, regions with a higher concentration of manufacturing activities have significantly higher export shares. And trade shares are higher between regions that are less specialized. These results suggest that regional production sharing associated with regional specialization plays an important role in shaping international and intranational trade. However, trade between Canadian provinces exhibit a different pattern. We find no evidence that provinces with a higher concentration of manufacturing activities have higher export shares to other provinces. And trade shares are higher between provinces that are more specialized. This different trade pattern may be related to the fact that manufacturing activities are concentrated in a few large provinces and Canadian provinces are more specialized than US states.

Our empirical result also implies that the Anderson and van Wincoop simulation of the border effect is likely to be incomplete. This is because when tariffs are reduced, regional specialization patterns may change. This has further implications for trade within and across countries. Therefore, how regional specialization is shaped by international trade barriers deserves further investigations.

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```
(A)

log_P |
    1 +
      |
      |                                                                     Newfou *
      |
      |
      |
      |                                                            * Prince
    0 +                                                         Saskat * * Manito
      |                                                                      * Albert
      |                                                      * NovaSc     NewBru *
      |
      |
      |
      |                                                        Ontari Quebec
   -1 +                           * Montan                        *    *   * Britis
      |                   * Idaho
      |                NorthD * Arizon
      |
      |                Minnes * Maine
      |      Vermon * Loui*i
      |      Alabam NewH*m * Wiscon  * Texas
   -2 +      Miss*u ** * Tennes          * Washin
      |    NorthCF*oMic***K*ntuc
      |  Virgin *       Ind*aneo*gi
      |               Ohio Illino
      |     NewJer *    * Pennsy
      |    * NewYor    * Massac
      |     * Maryla                 * Califo
   -3 +
      ---+------------+------------+------------+------------+------------+------------+--
       -2.5         -2.0         -1.5         -1.0         -0.5          0.0          0.5

                                      FE_importer
```

```
(B)

log_Pie |
        |
    1.0 +
        |
        |      * Newfou
        |
    0.5 +
        |
        |
        |               * Prince
    0.0 +                   * Montan                      * Saskat
        |                     NorthD                  * Idaho    * Manito       Albert *
        |                       * *       * NewBru
        |                       Arizon              * NovaSc
   -0.5 +                          * Maine
        |
        |               * Vermon       Alabam    Wiscon    * Minnes
        |                 Louisi *    Tex*sM*chig  * Tennes
   -1.0 +              NewHam *     Washin *NorthC* Mi*sou *       * Quebec   * Britis
        |      * Florid             Indi*n **     * Kentuc Ontari
        |      * Virgin              Georgi Ohio *  * Illino
        |
   -1.5 +                NewJer * Pennsy
        |                      * Massac
        |* NewYor           * Maryla                       * Califo
        |
   -2.0 +
        |
        -+---------+---------+---------+---------+---------+---------+---------+---------+
      -1.25     -1.00     -0.75     -0.50     -0.25      0.00      0.25      0.50      0.75

                                       FE_exporter
```

Figure 1

```
(A)
localization1993 |
                 |
            1.50 +
                 |
                 |                                                      * Albert
                 |                        Indian Kentuc
                 |                     Michig *   ** Wiscon
            1.25 +                      NorthC *  * Ohio
                 |                    Alabam *       * Tennes
                 |                                      * Ontari
                 |                            Idaho *  * Saskat
                 |               Pennsy *  Missou *   Minnes * Quebec
            1.00 +           * Virgin   * Loui*iWas*iIll*no
                 |            VermoMaine *  * Georgi               * Britis
                 |             New*am***ontan
                 |       * NewYor  NewJ*rMassac Califo *   * Manito
                 |              NorthD *      * Texas
            0.75 +           * Newfou
                 |                Arizon *   * NewBru
                 |                   * Maryla
                 |           * Florid               * NovaSc
                 |
            0.50 +
                 |
                 |
                 |
                 |
            0.25 +                 * Prince
                 |
                 --+-----------+-----------+-----------+-----------+-----------+-
                 -1.5        -1.0        -0.5        0.0         0.5         1.0

                                          exporter effects
```

```
(B)

localization1993 |
                 |
            1.50 +
                 |
                 |                                                  Albert *
                 |           Indian Wiscon
                 |        Kentuc *  * Michig
            1.25 +    NorthC *   * Ohio
                 |   Alabam *    * Tennes
                 |                                               * Ontari
                 |            Penns* Idaho                           * Saskat
                 |      Missou *  *Minnes                           * Quebec
            1.00 +      *  Louisi *** Illino   * Washin
                 |  Virgin NewJer * Ge*rgi                              * Britis
                 |      NewHa* * VerMaine* Montan
                 |      * NewYor * Massac   * Califo                  * Manito
                 |             NorthD *     * Texas
            0.75 +                                                      Newfou *
                 |                     * Arizon                      NewBru *
                 |      * Maryla
                 |               * Florid                    * NovaSc
                 |
            0.50 +
                 |
                 |
                 |
                 |
            0.25 +                                                * Prince
                 |
                 --+---------+---------+---------+---------+---------+---------+-
                 -2.5      -2.0      -1.5      -1.0      -0.5       0.0       0.5

                                           importer effects
```

Figure 2

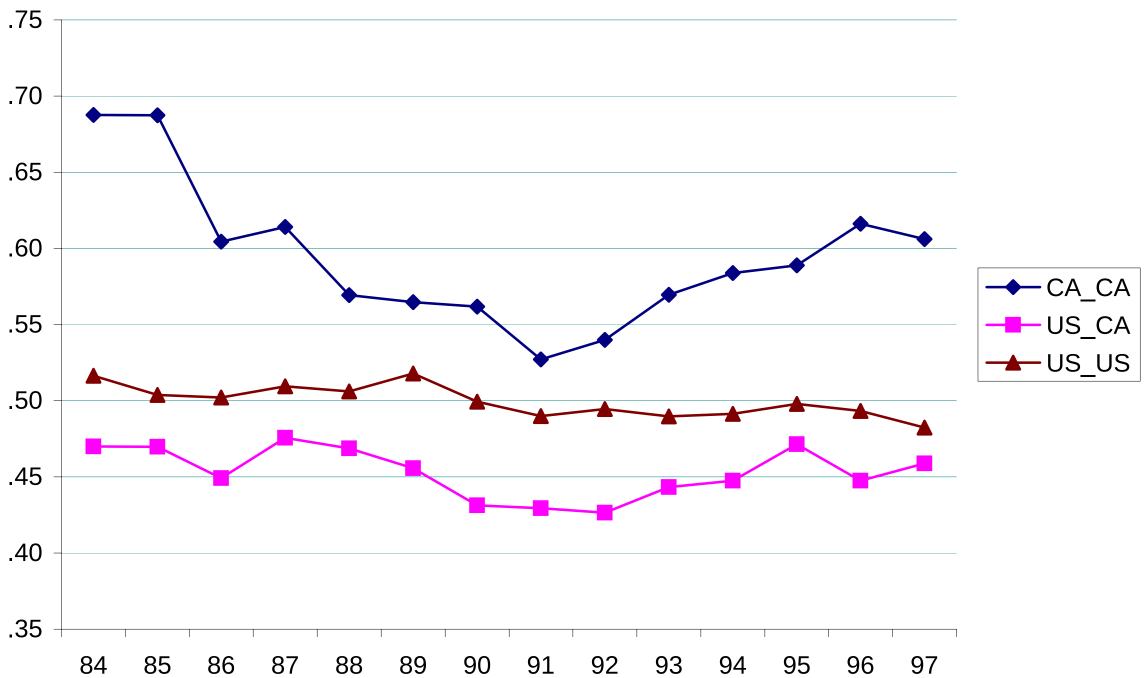

Figure 3 Specialization Indices for the Period 1984-97

Table 1. residual =exporter_dummy importer_dummy

region	residual_ exporter	region	residual_ importer
OHIO	1.030	ONTARIO	0.731
ILLINOIS	1.011	CALIFORNIA	0.722
QUEBEC	0.988	QUEBEC	0.711
ONTARIO	0.983	NEWBRUNSWICK	0.637
CALIFORNIA	0.962	PENNSYLVANIA	0.602
KENTUCKY	0.945	ILLINOIS	0.556
TENNESSEE	0.927	MASSACHUSETTS	0.472
BRITISHCOLUMBIA	0.832	BRITISHCOLUMBIA	0.471
INDIANA	0.807	OHIO	0.464
MINNESOTA	0.789	MICHIGAN	0.439
WISCONSIN	0.774	INDIANA	0.406
MISSOURI	0.759	TEXAS	0.385
MICHIGAN	0.713	KENTUCKY	0.377
PENNSYLVANIA	0.692	NEWJERSEY	0.329
NORTHCAROLINA	0.674	WISCONSIN	0.323
ALBERTA	0.662	WASHINGTON	0.305
MARYLAND	0.651	GEORGIA	0.304
NEWJERSEY	0.624	ALBERTA	0.253
GEORGIA	0.569	TENNESSEE	0.240
MASSACHUSETTS	0.567	MAINE	0.222
ALABAMA	0.456	NEWYORK	0.205
NEWHAMPSHIRE	0.300	MANITOBA	0.165
TEXAS	0.263	MARYLAND	0.162
MANITOBA	0.258	NEWHAMPSHIRE	0.133
MAINE	0.176	FLORIDA	0.119
NEWYORK	0.172	MINNESOTA	0.107
IDAHO	0.088	VERMONT	0.062
VIRGINIA	0.078	MISSOURI	0.058
VERMONT	0.066	NORTHCAROLINA	0.043
LOUISIANA	0.064	SASKATCHEWAN	0.000
NOVASCOTIA	0.041	LOUISIANA	-0.051
WASHINGTON	0.023	VIRGINIA	-0.052
SASKATCHEWAN	0.000	NEWFOUNDLAND	-0.065
NEWBRUNSWICK	-0.128	NORTHDAKOTA	-0.107
FLORIDA	-0.202	ALABAMA	-0.114
NORTHDAKOTA	-0.222	PRINCEEDWARDISLAND	-0.121
ARIZONA	-0.450	MONTANA	-0.171
MONTANA	-0.568	NOVASCOTIA	-0.221
PRINCEEDWARDISLAND	-0.809	ARIZONA	-0.368
NEWFOUNDLAND	-1.642	IDAHO	-0.468

Table 2. Anderson and van Wincoop Model

dependent variable = $\ln(x_{ij}/y_iy_j)$

	nonlinear (1)	linear (2)	(3)
ln_distance $(1-\sigma)\rho$	-0.79	-1.25	-1.18
t-statistics		-34	-32.57
ln_tariff $(1-\sigma)$	-55.78	-52.54	-39.64
t-statistics		-26.33	-19.58
ln_$P^{\sigma-1}$			0.67
t-statistics			18.92
ln_$\Pi^{\sigma-1}$			0.1
t-statistics			3.51
exporter dummy		x	
importer dummy		x	
R2		0.66	0.52

Table 3 Correlations

	$\ln\_P^{\sigma-1}$	$\ln\_\Pi^{\sigma-1}$	importer effects	exporter effects	$\ln\_\theta$
$\ln\_P^{\sigma-1}$	1	0.90774	0.86709	0.2645	-0.8004
p-value		<.0001	<.0001	0.0991	<.0001
$\ln\_\Pi^{\sigma-1}$	0.90774	1	0.61935	0.09209	-0.83432
p-value	<.0001		<.0001	0.572	<.0001
importer effects	0.86709	0.61935	1	0.46255	-0.52036
p-value	<.0001	<.0001		0.0027	0.0006
exporter effects	0.2645	0.09209	0.46255	1	0.06337
p-value	0.0991	0.572	0.0027		0.6977
$\ln\_\theta$	-0.8004	-0.83432	-0.52036	0.06337	1
p-value	<.0001	<.0001	0.0006	0.6977	

Table 4. The Effect of Regional Specialization on Bilateral Trade

dependent variable = $\ln(x_{ij}/y_i y_j)$

	(1)	(2)	(3)	(4)	(5)
ln_distance $(1-\sigma)\rho$	-1.25	-1.23	-1.18	-1.14	-1.13
t-statistics	-34	-31.68	-32.66	-31.61	-31.27
ln_tariff $(1-\sigma)$	-52.54	-53.72	-40.09	-42.3	-39.32
t-statistics	-26.33	-25.38	-19.75	-20.56	-18.64
ln_$P^{\sigma-1}$			0.68	0.69	0.63
t-statistics			19.1	19.96	17.64
ln_$\Pi^{\sigma-1}$			0.11	0.17	0.14
t-statistics			3.59	5.94	4.64
localization				1.13	1.08
t-statistics				10.33	6.21
Dus,ca * localization					-0.04
t-statistics					-0.12
Dca,ca * localization					-1.02
t-statistics					-2.8
Dca,us * localization					0.39
t-statistics					1.56
specialization		-0.35		-0.64	-1.1
t-statistics		-1.67		-3.37	-4.4
Dus,ca * specialization					0.87
t-statistics					1.53
Dca,ca * specialization					2.55
t-statistics					5.26
Dca,us * specialization					-0.03
t-statistics					-0.05
exporter dummy	x	x			
importer dummy	x	x			
R2	0.66	0.66	0.52	0.55	0.56

Table 5 Correlations between Localization Indices for Different Years

	localization1984	localization1987	localization1990	localization1993	localization1997
localization1984	1	0.96574	0.92897	0.92381	0.89293
p-value		<.0001	<.0001	<.0001	<.0001
localization1987	0.96574	1	0.97452	0.96704	0.92286
p-value	<.0001		<.0001	<.0001	<.0001
localization1990	0.92897	0.97452	1	0.97492	0.92335
p-value	<.0001	<.0001		<.0001	<.0001
localization1993	0.92381	0.96704	0.97492	1	0.93498
p-value	<.0001	<.0001	<.0001		<.0001
localization1997	0.89293	0.92286	0.92335	0.93498	1
p-value	<.0001	<.0001	<.0001	<.0001	