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Outsourcing and International Fragmentation of Production: Implications for Developing Countries

Lecture 2: International Fragmentation and Trade Across Time and Space

Vertical Specialization and the Border Effect Puzzle

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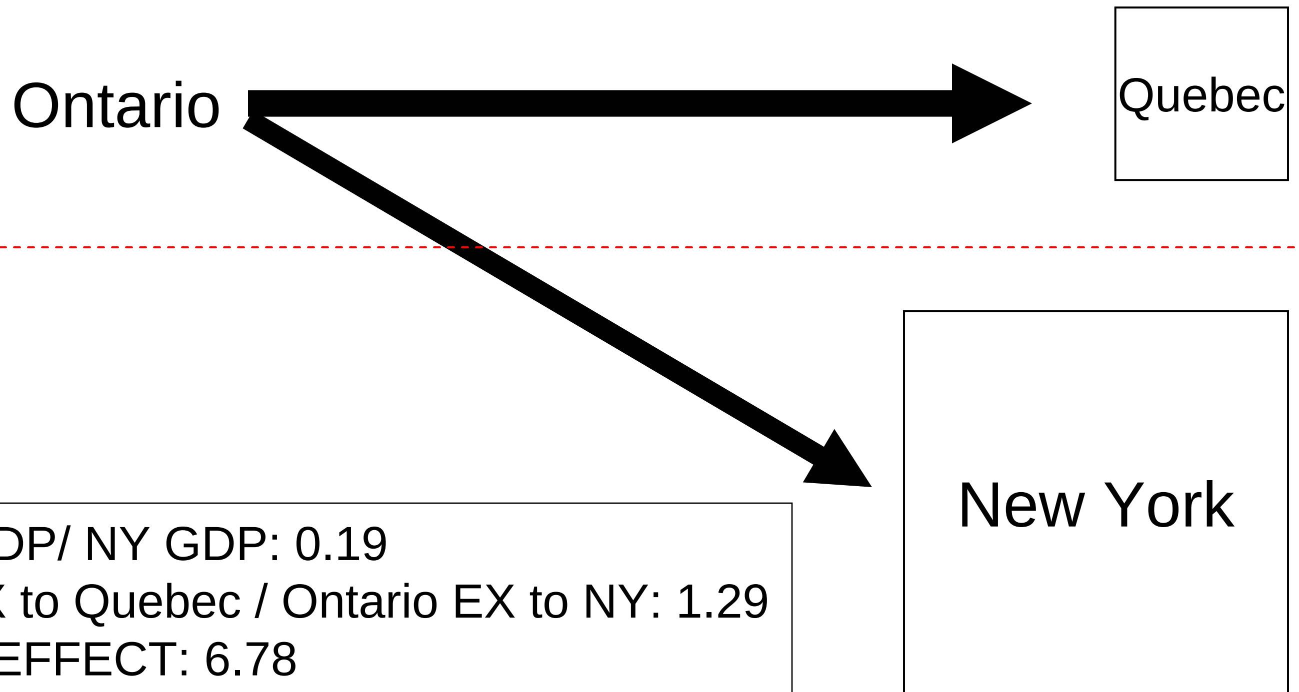
Simple Illustration of Border Effect



Quebec GDP/ NY GDP: 0.19
Ontario EX to Quebec / Ontario EX to NY: 1.29
BORDER EFFECT: 6.78
Data are from 1999

Formal Evidence of Border Effect

- McCallum (1995): “gravity equation” regression involving trade between Canadian provinces and between Canadian provinces and U.S. states
    - $bilateraltrade_{ij} = \beta_0 + \beta_1 GDP_i + \beta_2 GDP_j + \beta_3 dist_{ij} + \beta_4 DUMMY_{ij} + u_{ij}$
    - Main Result: A Canadian province trades **22** times as much with another province as it does with a U.S. state, all else equal.
- Subsequent research on different regions, countries and time periods consistent with McCallum’s results
    - Obstfeld and Rogoff (2000): “Home bias in trade” is one of the six major puzzles of international economics.

Formal Evidence of Border Effect

- Anderson and van Wincoop (2003) add two theoretical insights
    - The right framework to address questions like “what happens when barriers between New York and Quebec, or between New York and Ontario, decrease?” is a general equilibrium framework: bilateral trade depends on “multilateral” barriers that each country has with all other countries, in addition to bilateral barriers
        - Eliminating the barrier between New York and Ontario affects trade between Quebec and Ontario, because it affects each province’s “multilateral” barrier
    - If there is less international trade, there is more intra-national trade, all else equal
    - However, their theoretically-consistent estimate for Canada’s border effect is still large: 10.5!

Relationship between border effect, border barriers, and elasticity of substitution

• Log of border effect is approximately the product of a (proportional) border barrier and the elasticity of substitution between goods

• Anderson and van Wincoop (2003) border effect of 10.5 for Canada can be generated by:

- Border barrier = 120%, elasticity of substitution = 3
- Border barrier = 48%, elasticity of substitution = 5
- Border barrier = 19%, elasticity of substitution = 10
- Border barrier = 12%, elasticity of substitution = 15

• Puzzle: most existing measures of observed U.S.-Canada border barriers are about 5% or less.

- Relatively low border barriers can generate observed border effects only with **high** elasticities of substitution**.**
- Relatively low elasticities of substitution are consistent with border effect only with **high** border barriers**.**
- Too much **intra-**national trade, too little **inter**national trade

One resolution to puzzle: Vertical Specialization

• **International trade increasingly involves "back-and-forth" vertical trading chains:**

1] U.S. produces and exports engine parts to Mexico
2] Mexico produces engines and exports all of it to the U.S.
3] U.S. produces automobiles with these engines, and some of the autos are exported.

• Intra-national vertical trading chains even more prevalent

• Specialization occurs in different stages of production.
• Countries and regions link sequentially to produce a good.

• Hummels, Ishii, Rapoport and I call this phenomenon **VERTICAL SPECIALIZATION**
  • Many other names and terms – disintegration of production, fragmentation, outsourcing, intra-product specialization, multi-stage production, etc.

Vertical Specialization Magnifies Effects of Border Barriers

- Core idea: Multiple border crossings
    - For goods with multiple stages of production occurring in different countries, trade costs are incurred each time there is a border crossing; consequently, the effects of border barriers are magnified.

- This leads to magnified:
    - <u>reduction</u> in international trade via decreased purchases of vertically specialized goods (internal margin) and decrease in internationally vertically specialized goods (external margin)
    - <u>increase</u> in intra-national trade because of the Anderson-van Wincoop insight that lower *inter*-national trade implies higher *intra*-national trade, and because there is increased intra-national vertical specialization

Goals and Related Literature

- Define and present evidence on vertical specialization.
- Develop Ricardian model of intra-national and international trade with vertical specialization.
  - Generate analytical expressions for border effects in special cases of model
  - Calibrate model to U.S.-Canada and back out implied border barrier and border effect:
    - Border barrier and border effect implied by model are **half** of most existing estimates
- Highlight three key points on the role of vertical specialization

- Other explanations of border effect
  - Evans (2003), Chaney (2005): Fixed costs of exporting and/or heterogeneity in firm productivity can explain large share of border effect
  - Rossi-Hansberg (2005): Labor mobility across locations and production externalities can also generate magnification effect

Relevant Readings (Models of Fragmentation)

1. Amiti, Mary. “Location of Vertically Linked Industries: Agglomeration versus Comparative Advantage.” *European Economic Review*, 2005, 809-832.
2. Deardorff, Alan V. “Fragmentation in Simple Trade Models”, manuscript, University of Michigan, 1998.
3. Dornbusch, Rudiger, Stanley Fischer, and Paul A. Samuelson. “Comparative Advantage, Trade and Payments in a Ricardian Model with a Continuum of Goods”, *American Economic Review*, 1977 (67), 823-839.
4. Eaton, Jonathan, and Samuel Kortum. “Technology, Geography, and Trade”, *Econometrica*, 2002 (70), 1741-1779.
5. Jones, Ronald W., and Henryk Kierzkowski. “A Framework for Fragmentation”, in Arndt, Sven and Kierzkowski (eds.) *Fragmentation: New Production Patterns in the World Economy*. Oxford University Press, 2001, 17-34.
6. Markusen, James and Anthony Venables. “A Multi-Country Approach to Factor Proportions and Trade Costs” NBER WP 11051, 2005.
7. Strauss-Kahn, Vanessa. “Firms’ Location Decision across Asymmetric Countries and Employment Inequality”, *European Economic Review*, 2005 (49), 299-320.
8. Venables, Anthony. “Fragmentation and Multinational Production.” *European Economic Review*, 1999, (43), 935-945.
9. Yi, Kei-Mu. “Can Vertical Specialization Explain the Growth of World Trade?” *Journal of Political Economy*, February 2003, 52-102.
10. Yi, Kei-Mu. “Vertical Specialization and the Border Effect Puzzle”, Federal Reserve Bank of Philadelphia Working Paper #05-24, October 2005.

Relevant Readings (Border Effect)

1. Anderson, James E. and Eric van Wincoop. "Gravity with Gravitas: A Solution to the Border Puzzle." *American Economic Review*, March 2003, 93 (1), 170-192.
2. Anderson, James E. and Eric van Wincoop. "Trade Costs." *Journal of Economic Literature*, September 2004, 42, 691-751.
3. Chaney, Thomas. "Distorted gravity: Heterogeneous Firms, Market Structure, and the Geography of International Trade." Manuscript, University of Chicago, 2005.
4. Chen, Natalie. "Intra-national versus International trade in the European Union: Why Do National Borders Matter?" *Journal of International Economics*, 2004, 63, 93-118.
5. Combes, Pierre-Philippe, Miren Lafourcade, and Thierry Mayer. "The Trade-Creating effects of Business and Social Networks: Evidence from France." *Journal of International Economics*, 2005, 66, 1-29.
6. Evans, Carolyn. "The Economic Significance of National Border Effects." *American Economic Review*, 2003, 93 (4), 1291-1312.
7. Head, Keith and Thierry Mayer. "Illusory Border Effects: Distance Mis-measurement Inflates Estimates of Home Bias in Trade." Manuscript. CEPII. January 2002.
8. Helliwell, John. *How Much do National Borders Matter?* Washington D.C.: Brookings Institution Press, 1998.
9. Hillberry, Russell H. "Aggregation bias, Compositional Change, and the Border Effect." *Canadian Journal of Economics*, August 2002, 517-530.
10. Hillberry, Russell H. and David Hummels. "Trade Responses to Geographic Frictions: A Decomposition Using Micro-Data". NBER WP 11339, May 2005.

Relevant Readings (Border Effect)

11. McCallum, John. “National Borders Matter: Canada-U.S. Regional Trade Patterns.” *American Economic Review*, June 1995, 85, 615-623.
12. Nitsch, Volker. “National Borders and International Trade: Evidence from the European Union.” *Canadian Journal of Economics*, November 2000, 33 (4), 1091-1105.
13. Rossi-Hansberg, Esteban. “A Spatial Theory of Trade.” *American Economic Review*, December 2005 (?).

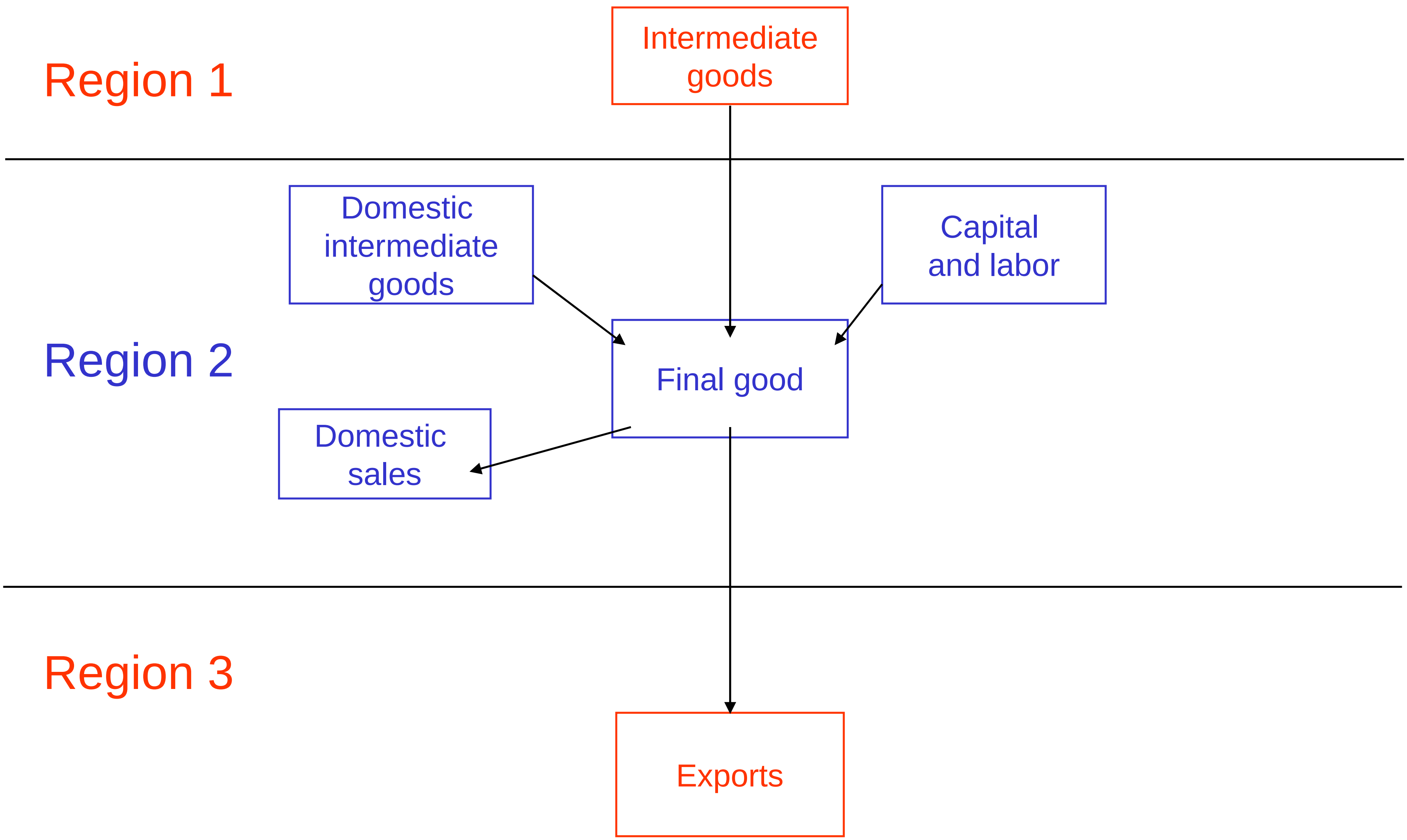
Vertical Specialization: Concepts

- **VERTICAL SPECIALIZATION**:
  - Goods are produced in multiple sequential stages
  - Two or more regions provide value-added in the good's production process
  - *At least one region must use imported inputs in its stage of the production process, and some of the resulting output must be exported.*

- The third part is key: Vertical specialization is related to, but not the same as, intermediate goods trade, which is consistent with the first two parts, but not necessarily with the third.

Figure 1

Vertical Specialization



Vertical Specialization: Measurement

- **Vertical Specialization Exports (VS)**

For region k and good i:

$$VS_{ki} = \left(\frac{\text{imported intermediates}}{\text{gross output}}\right) \times \text{exports}$$

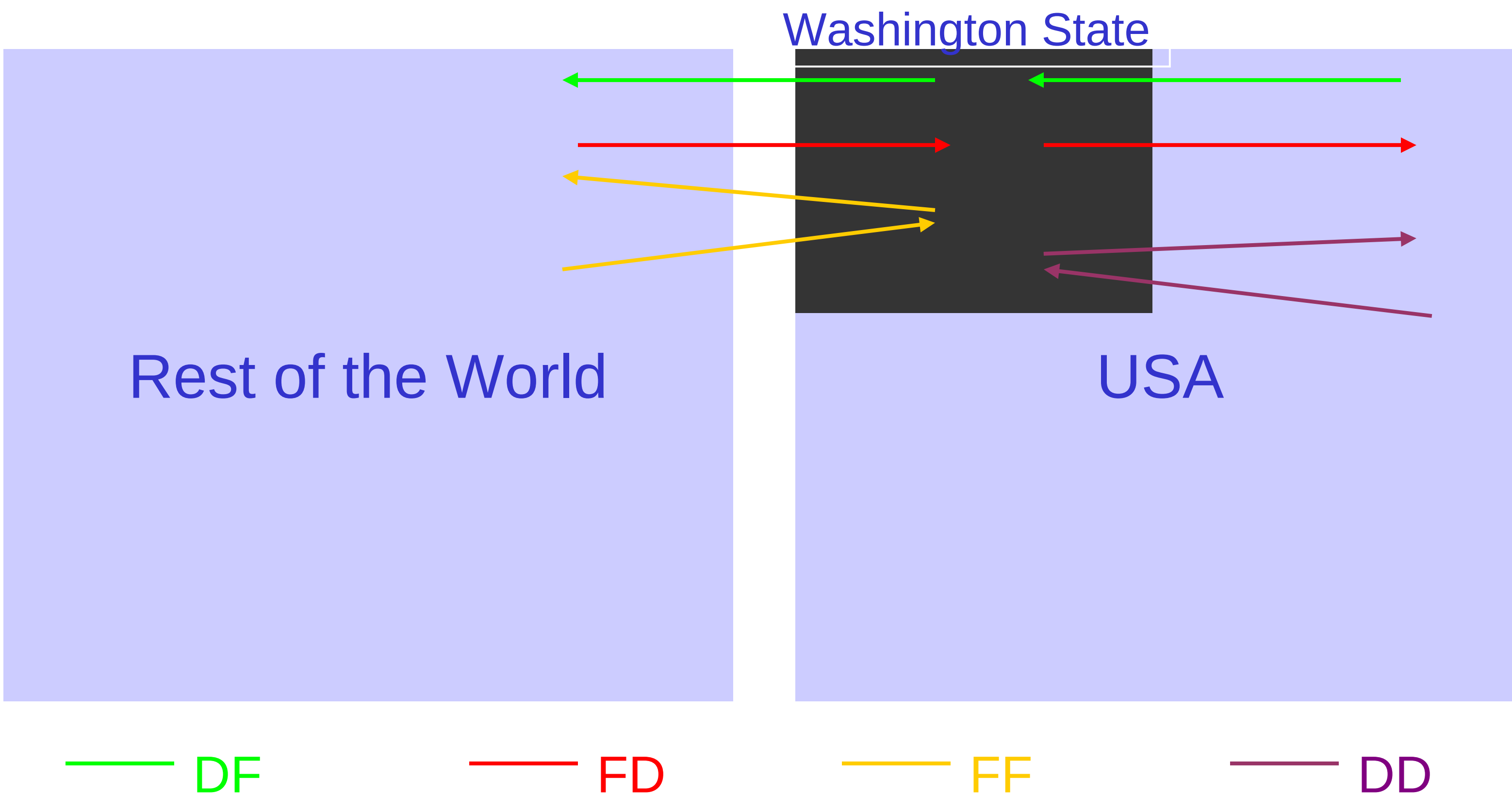
- VS_{ki} is imported input content of region k's exports of good i.

- Region-level VS: $$\frac{\sum_i VS_{ki}}{\sum_i X_{ki}} = \frac{VS_k}{X_k}$$

TABLE 1
VERTICAL SPECIALIZATION AT THE STATE LEVEL

STATE	Year	Vertical Specialization (percent of total merchandise exports)
Hawaii	1987	36.3%
Hawaii	1992	43.4%
Hawaii	1997	43.0%
Washington	1963	33.3%
Washington	1967	42.3%
Washington	1972	36.9%
Washington	1982	47.9%
Washington	1987	47.3%
U.S.	1972	6.0%
U.S.	1997	12.3%
Canada	1971	20.0%
Canada	1990	27.0%

4 Possible Directions for Regional Vertical Specialization



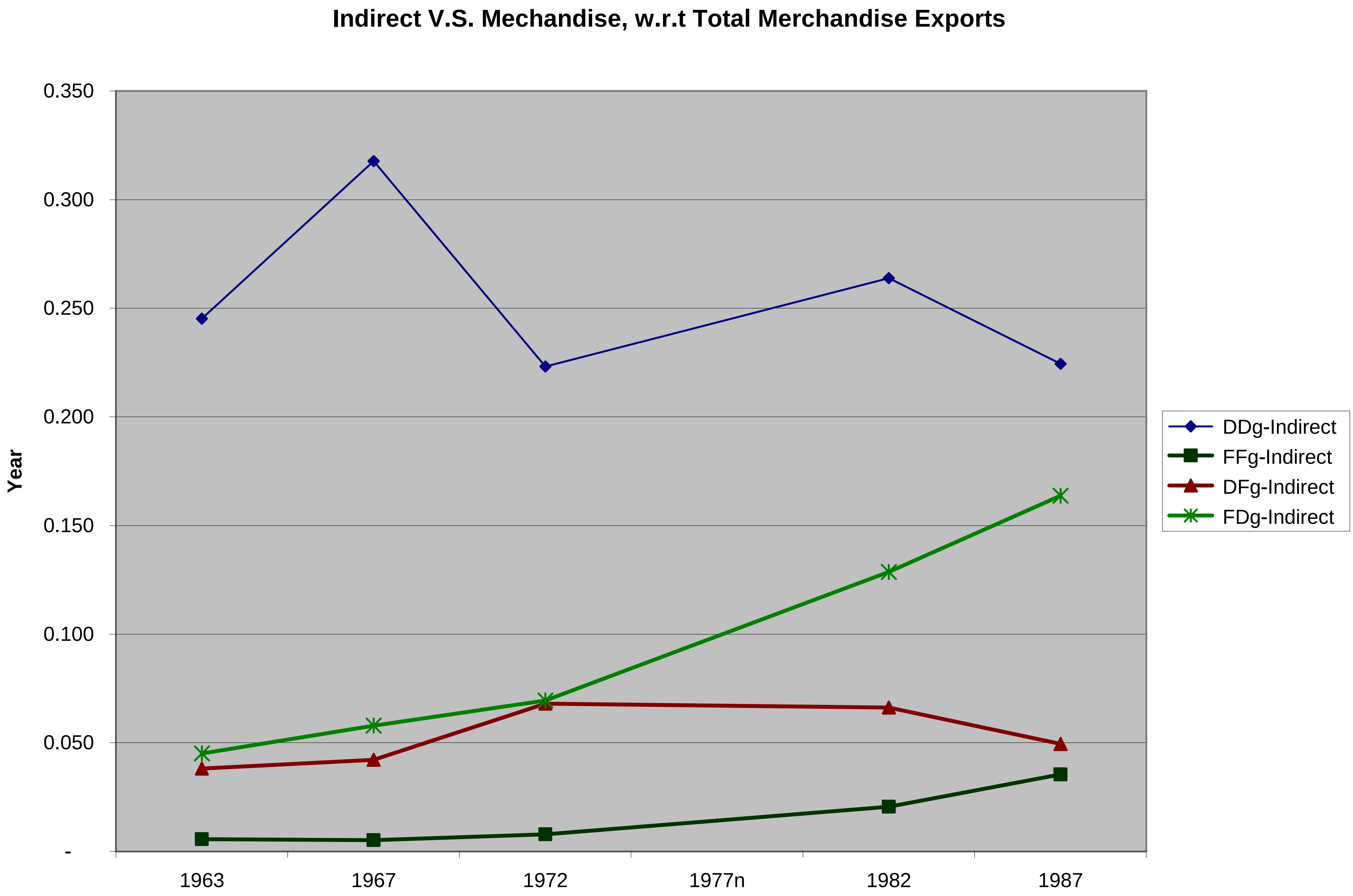
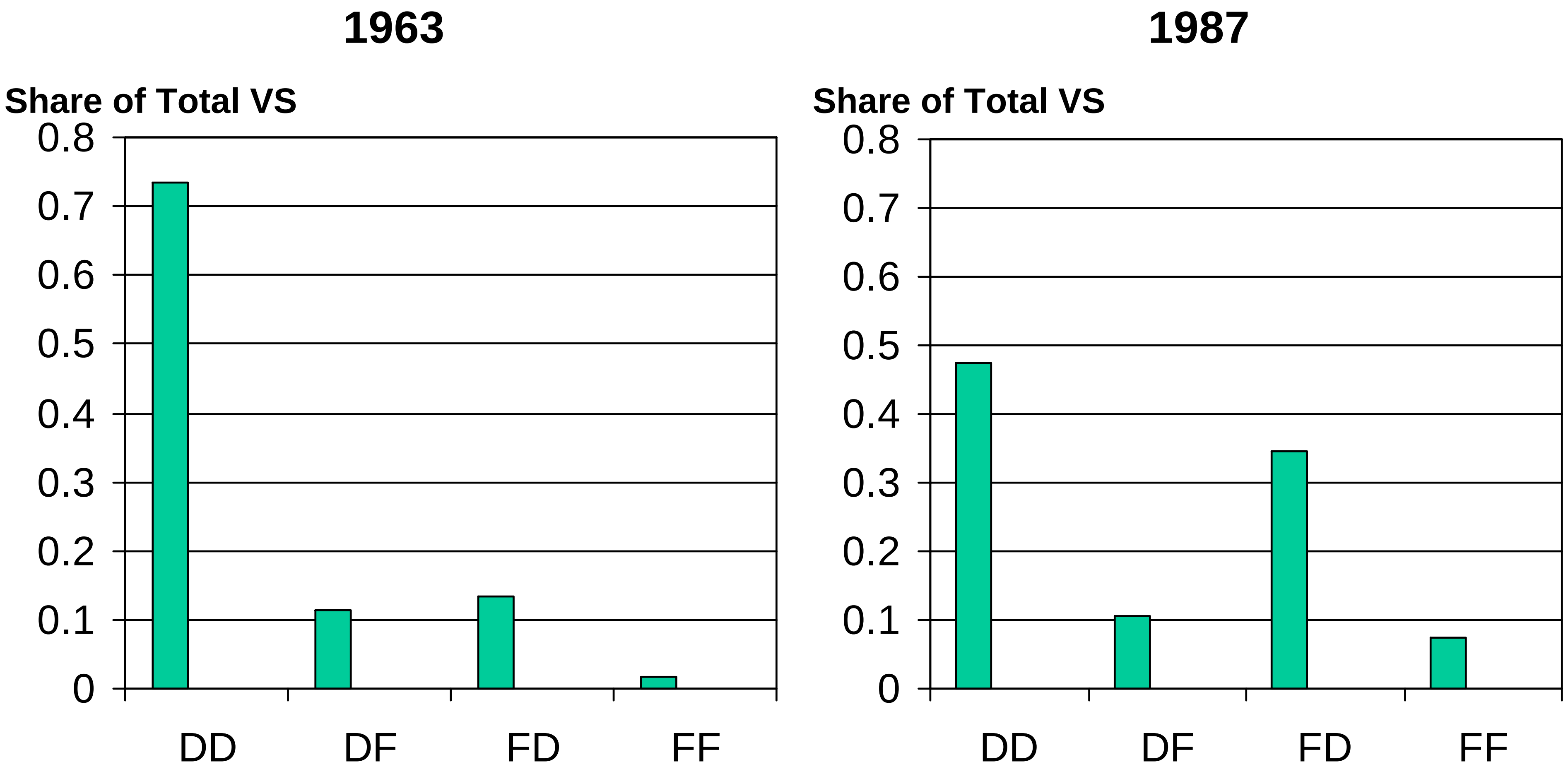

Indirect V.S. Mechandise, w.r.t Total Merchandise Exports
0.350
0.300
0.250
0.200
0.150
0.100
0.050
-
Year
1963
1967
1972
1977n
1982
1987
DDg-Indirect
FFg-Indirect
DFg-Indirect
FDg-Indirect

Figure 2

Decomposition of Washington's Vertical Specialization Exports



Note: VS exports = 33% (47%) of total merchandise exports in 1963 (1987)

DF: **D**omestic imported inputs; exports to **F**oreign destinations

Ricardian Vertical Specialization Model: Basic set up

- I regions, C countries
- One factor: labor
  - Mobile within a region
  - Immobile across regions
- Continuum of goods on unit interval (cf. Dornbusch-Fischer-Samuelson, (DFS) 1977)
- Each region possesses technologies for producing goods on [0,1] continuum

Model: Production and Technologies

- Each good is produced in two stages
  - Stage 1: $y_1^{\mathrm{i}}(z) = (A_1^i(z) l_1^i(z))^{1-\theta_1} m_1^i(z)^{\theta_1}$
  - Stage 2: $y_2^{\mathrm{i}}(z) = (A_2^i(z) l_2^i(z))^{1-\theta_2} x_1^i(z)^{\theta_2}$ $\qquad z \in [0,1]$

- Stage 1 goods are used as input in the production of itself and of stage 2 goods
- Stage 2 goods are consumed (and possibly exported).
- Productivities (for each stage of each good) differ across regions

Model: Production and Technologies

- Distribution of $A_1^i(z)$ and $A_2^i(z)$ is Frechet (Eaton and Kortum, (EK) 2002)
  - $F(A) = e^{-TA^{-n}}$
  - T governs the "average" productivity
  - *n* governs the heterogeneity or variance of productivities
    - Higher *n* means less variance.
    - EK: $n = \sigma - 1$ (σ is the elasticity of substitution in a monopolistic competition model)

Model: Barriers to Trade

- Ad valorem or “iceberg” border barriers:
  - $(1+b_{ij})$ > 1 if regions are in different countries:
  - $(1+b_{ij})$ = 1 if regions are in same country
  - b_{ij} represents real resource cost (tariff revenue w/ no production or consumption value, border costs associated with regulations and time, etc.)

- Iceberg transport costs:
  - If 1 unit is shipped from region i to region j, $1/(1+d_{ij}) < 1$ units arrive in region j.
  - Ad valorem equivalent is: $1 + d_{ij}$

- Total trade costs: $(1+\tau)=(1+b)(1+d)$

Model: Firm Maximization

- Stage 1 firms and stage 2 firms in region *i* maximize profits taking prices as given:

  - Stage 1 firms maximize: $p_1^i(z)y_1^i(z) - w^i l_1^i(z) - p_1^i(z)m_1^i(z)$

  - Stage 2 firms maximize: $p_2^i(z)y_2^i(z) - w^i l_2^i(z) - (1 + d_{ji})(1 + b_{ji})p_1^j(z)x_1^i(z)$
    (assuming stage 1 input originates from region *j)*

  - $p_1^i(z)$ and $p_2^i(z)$ are factory gate prices

Model: Consumer Preferences and Prices

- Standard static consumer maximization problem
  - Logarithmic preferences over [0,1] continuum

$$\int_0^1 \ln(c^i(z))dz$$

- If good z is produced in region j, final price paid by consumer in region i, $p^i(z)$, $= p_2^j(z)(1+d_{ji})(1+b_{ji})$

Model: Equilibrium

An equilibrium of this model is a set of production levels (of each stage of each good on the continuum), consumption levels, and goods and factor prices, such that all consumer and firm first order conditions are satisfied, and all goods and factor markets clear.

Model: Specialization and Trade

- I^2 possible production methods for each good (I regions, 2 stages per good)
  - For each good consumed in each region, model delivers the lowest cost production method
  - Vertical specialization occurs if two different regions involved in production and some of the final good is exported
- Relative cost differences (comparative advantage) is determined by relative technology (TFP) differences.
- Under frictionless trade, there is complete specialization (up to some "borderline" stages) in the production of each stage
  - If there is vertical specialization for a good z' and involving regions i and j, then:

$$\frac{A_1^i(z')}{A_1^j(z')} > \frac{w^i}{w^j} > \frac{A_2^i(z')}{A_2^j(z')}$$ if region i (j) produces stage 1 (2)

Border Effect in Standard Ricardian trade model

- Special case: Goods are produced in just one stage
- Special case: 2 countries, 2 regions per country
- Special case: Each region's productivities are drawn from same Frechet distribution, (and regions are same size and there are no barriers within and between regions other than border barrier)
    - Wages and GDP are equalized across regions and countries
    - This is a special case of EK model (i.e., standard 2-country DFS model), with each country's productivity equal to the max of each region's productivity

Border Effect in Standard Ricardian trade model

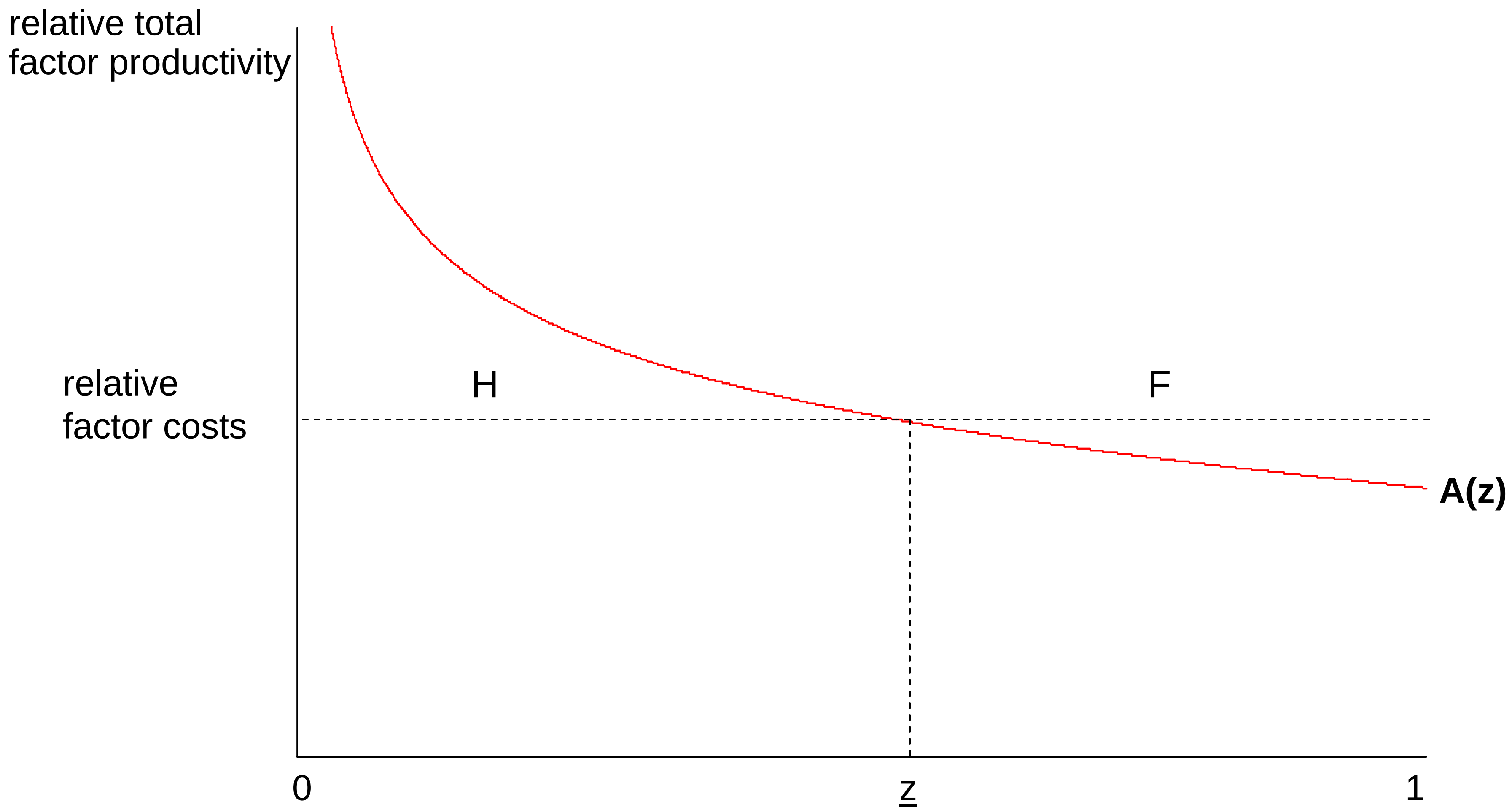
- Border effect = $\dfrac{Intra_b / Inter_b}{Intra_0 / Inter_0} = \dfrac{Intra_b / Intra_0}{Inter_b / Inter_0}$

Border Effect in Standard Ricardian trade model

- Order goods according to declining home country comparative advantage
- International imports (by home) is given by $(1-\underline{z})wL$, where $\underline{z}$ is the cutoff z between home and foreign production
- Intra-national imports (by home) is given by $\underline{z}wL/2$.
- Under free trade $\underline{z} = 0.5$.

Figure 3

Standard DFS Model



Border Effect in Standard Ricardian trade model

•Plugging in previous expressions, denominator of border effect is: $\frac{(1-\underline{z}_b)}{(1-\underline{z}_0)}$

•Numerator of border effect is: $\frac{\underline{z}_b}{\underline{z}_0}$

•Frechet distribution implies that relative total factor productivities (home to foreign) equals:

- $$A^r(z) = \left(\frac{1-z}{z}\right)^{1/n}$$
- The larger is n (elasticity – 1), the flatter is A(z)

•In this example, the solution for $\underline{z}$ is: $\underline{z}_b = \frac{(1+b)^n}{1+(1+b)^n}$

Border Effect in Standard Ricardian trade model

• Denominator of border effect (international trade under border barriers divided by international trade under free trade)

$$= \frac{1}{1+(1+b)^n} \bigg/ \frac{1}{2} = \frac{2}{1+(1+b)^n}$$

• This is clearly <u>decreasing</u> in the border barrier.

• Numerator of border effect (intra-national under border barriers divided by intra-national trade under free trade)

$$= \frac{(1+b)^n}{1+(1+b)^n} \bigg/ \frac{1}{2} = \frac{2(1+b)^n}{1+(1+b)^n}$$

• This is <u>increasing</u> in the border barrier.

• So, in both numerator and denominator, border effect is increasing in the border barrier.

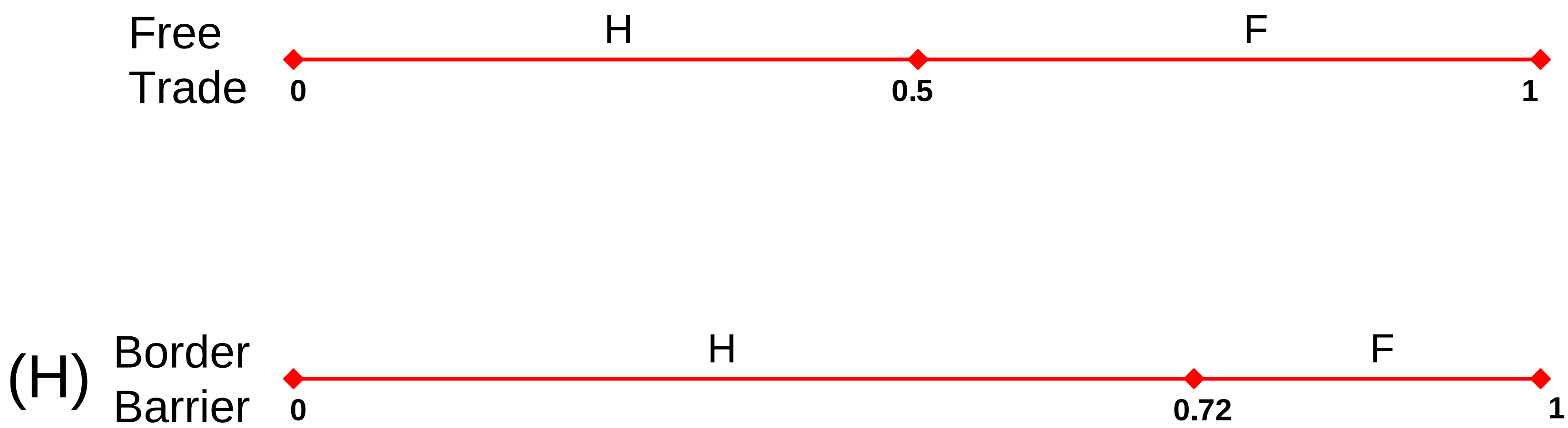
Border Effect in Standard Ricardian trade model

• Overall border effect $$= \frac{\dfrac{2(1+b)^n}{1+(1+b)^n}}{\dfrac{2}{1+(1+b)^n}} = (1+b)^n$$

• Log of border effect is approximately the elasticity multiplied by the border barrier

Figure 4

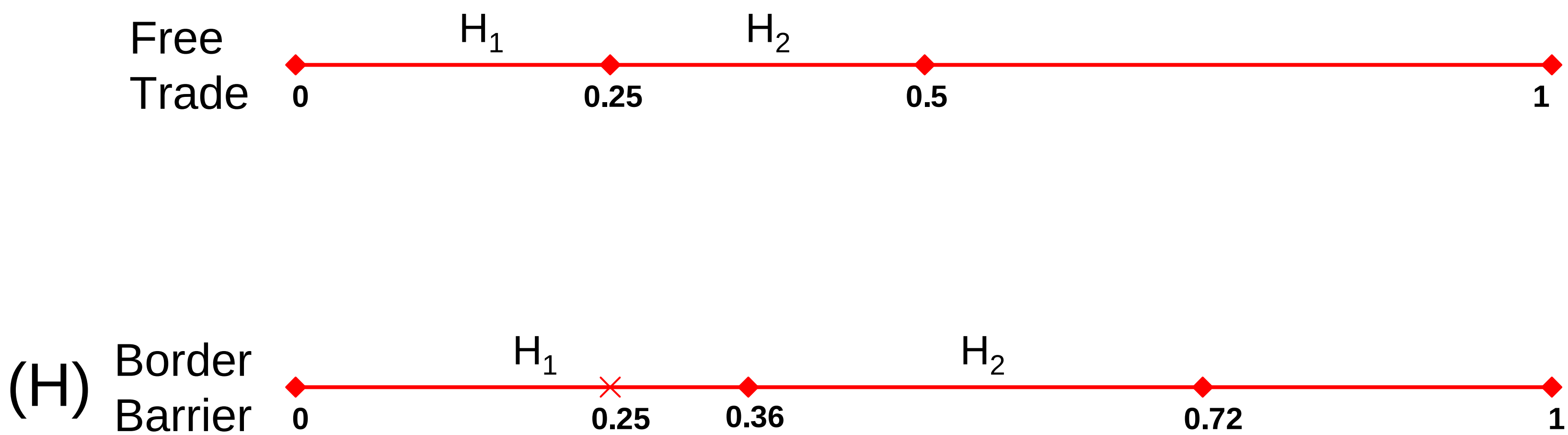
International Production Specialization: Standard model



Note: Symmetric case (identical productivity distributions and labor); border barrier = 10%; elasticity = 11; (H) is for consumer in H

Figure 5

Intra-national Production Specialization: Standard model



Note: Symmetric case (identical productivity distributions and labor); border barrier = 10%; elasticity = 11; (H) is for consumer in H

Border Effect in Vertical Specialization Special Case

- For each good a country consumes, stage 1 production must occur in that country.
  - e.g. If motor vehicle is going to be purchased by U.S. consumer, parts and components must be made in U.S.
  - Only location of stage 2 production is determined by the model, e.g., final assembly can be in U.S. or Canada
  - Most of preceding analysis can be applied
- As before, symmetrically sized regions, and each region's productivities are drawn from same Frechet distribution (for stage 1 and stage 2 production)
- Input share of production is same across stages: $\theta_1 = \theta_2 = \theta$

Border Effect in Vertical Specialization
Special Case

• Denominator of border effect (international trade under border barriers divided by international trade under free trade)

$$= \frac{\dfrac{1}{1+(1+b)^{n\left(\frac{1+\vartheta}{1-\theta}\right)}}}{\dfrac{1}{2}} = \frac{2}{1+(1+b)^{n\left(\frac{1+\vartheta}{1-\theta}\right)}}$$

•Numerator of border effect (intra-national under border barriers divided by intra-national trade under free trade)

$$= \frac{\dfrac{(1+b)^{n\left(\frac{1+\theta}{1-\theta}\right)}}{1+(1+b)^{n\left(\frac{1+\theta}{1-\theta}\right)}}}{\dfrac{1}{2}} = \frac{2(1+b)^{n\left(\frac{1+\theta}{1-\theta}\right)}}{1+(1+b)^{n\left(\frac{1+\theta}{1-\theta}\right)}}$$

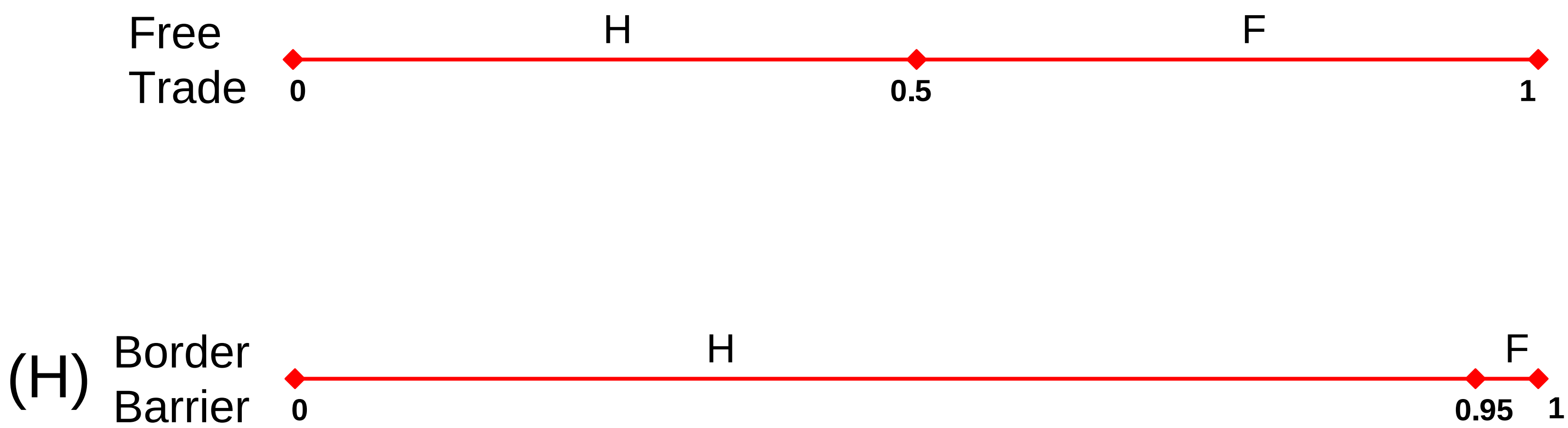
Border Effect in Vertical Specialization Special Case

•Overall border effect $= (1+b)^{n\left(\frac{1+\theta}{1-\theta}\right)}$

• Log of border effect is approximately the product of three terms: the border barrier, the elasticity, and a term that is increasing in the share of inputs in production. The latter term delivers the magnification effect.

Figure 6

International Production Specialization: Vertical specialization special case



Note: Symmetric case (identical productivity distributions and labor); border barrier = 10%; elasticity = 11; share of 1st stage inputs in 2nd stage production = 0.5; (H) is for consumer in H

Intuition for Border Effect in Vertical Specialization Special Case

- Two forces underlie the magnified effect:
  - "Back-and-forth" trade leads to at least some stages bearing multiple border costs → (1+θ) in numerator
  - "Marginal" production process is stage-2 production. Relevant border cost is cost relative to cost of producing marginal stage → (1-θ) in denominator (Point #1)
    - Note: even if barriers are imposed only on value-added (e.g. value-added tariffs), magnification still exists

- Alternative intuition:
  - Effective cost of sending stage-1 input to F $= (1+b)^{\frac{\theta}{1-\theta}}$
  - Effective cost of sending stage-2 good back to H $= (1+b)^{\frac{1}{1-\theta}}$

Model Solution

• No analytical solution

• Divide [0,1] continuum into 1,000,000 intervals (goods).

• For each region, draw Frechet productivities for stage 1 and stage 2 for each good

• Given wages, calculate cheapest production process for each good

• Adjust wages until trade balance is achieved

Quantitative Assessment of U.S.-Canada Border Barrier and Border Effect

- In each of three successively more detailed model-fitting exercises, solve for the U.S.-Canada trade cost and Canada's relative productivities to match data on relative wages, trade, and/or vertical specialization between U.S. and Canada in 1990.

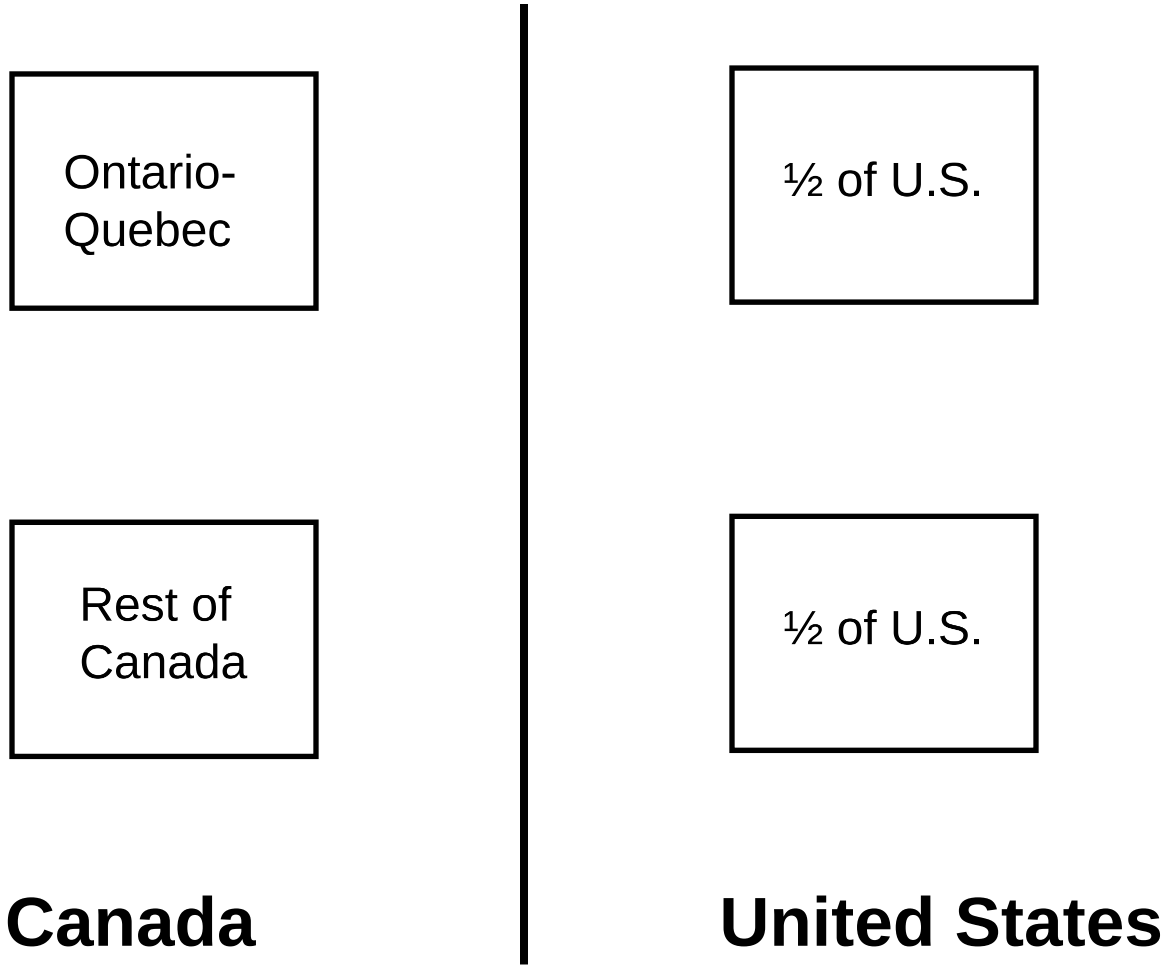
- Once an assumption is made on the relative transport (distance) costs:

    - Infer size of border barrier
    - Solve model under zero border barriers
    - Calculate border effect from model solutions under positive border barrier and under zero border barrier

Calibration of Key Parameters and Variables

- 2 countries (United States and Canada)
  - Canada's labor endowment = 9% of U.S. labor endowment
- 2 regions per country
  - In third simulation, Canada is divided into Ontario-Quebec and Rest of Canada. Labor endowments are 5.67% and 3.33%, respectively, of U.S. labor endowment.
- Distribution of total factor productivities:
  - Frechet parameter on heterogeneity of technology across goods: ("elasticity"): 5
- Share of 1^{st} stage output in 1^{st}-stage production: 0.62
- Share of 1^{st} stage output in 2^{nd}-stage production: 0.62
- Intra-national distance costs: 0
- International distance costs: 5%
- Fraction of goods facing low trade costs: 1/3 (will explain later)

Regions


Ontario-
Quebec
Rest of
Canada
½ of U.S.
½ of U.S.
Canada
United States

Data to be Matched by Model

	SIMULATION 1	2	3
Values of Variables Used to Calibrate Productivity and Trade Costs			
Wage			
Canada wage relative to United States (manufacturing)	0.88	0.88	
Ontario-Quebec relative wage			0.88
Rest of Canada relative wage			0.88
Trade (merchandise export share of merchandise GDP)			
Canada	0.910	0.910	
Ontario-Quebec			0.962
Rest of Canada			0.796
Vertical Specialization (share of merchandise exports)			
Canada		0.270	
Ontario-Quebec			0.333
Rest of Canada			0.144

TABLE 3
Simulation One:
Symmetric Regions, Homogeneous Trade Costs

Mean Productivity (relative to U.S.)		1.08
International trade cost		**15.3%**
Border Effects:		
5 percent distance cost		**2.70**
	Increase in U.S.-Canada trade if border barrier was eliminated	36.3%
10 percent distance cost		**1.57**
	Increase in U.S.-Canada trade if border barrier was eliminated	16.0%
Elasticity =10 (2.5 percent distance costs)		2.58
EK model (5 percent distance costs)		9.40

Note: Productivity and trade cost solved to fit Canada export share of GDP and relative wage. Productivity is size-adjusted.
International trade cost is relative to intra-national trade cost

TABLE 4
Simulation Two:
Symmetric Regions, Heterogeneous Trade Costs

Mean Productivity (relative to U.S.)	0.99
Low International trade cost	1.21%
High International trade cost	56.18%
Import-weighted trade cost	**22.52%**
Border Effects:	
5 percent distance cost	**5.03**
Increase in U.S.-Canada trade if border barrier was eliminated	44.2%
10 percent distance cost	**3.62**
Increase in U.S.-Canada trade if border barrier was eliminated	33.6%

Note: Productivity and trade costs solved to match Canada's vertical specialization share, trade share, and relative wage. Productivity is size-adjusted. International trade costs are relative to intra-national costs.

TABLE 5
Simulation Three:
Heterogeneous Regions, Heterogeneous Trade Costs

OQ Productivity (relative to U.S.)	0.88
OQ: Low international trade cost	-1.61%
OQ: High international trade cost	63.29%
OQ: Import-weighted trade cost	**17.29%**
ROC Productivity (relative to U.S.)	1.17
ROC: Low international trade cost	7.99%
ROC: High international trade cost	55.10%
ROC: Import-weighted trade cost	**33.47%**

Border Effects:

5 percent distance cost	**5.22**
Increase in U.S.-Canada trade if border barrier was eliminated	45.7%
10 percent distance cost	**3.72**
Increase in U.S.-Canada trade if border barrier was eliminated	35.6%

Summary of Quantitative Assessment

• (Import-weighted) trade costs between United States and Canada are about 23 percent (based on elasticity of 5 and relative to intra-national trade costs).

• Border barrier between U.S. and Canada is about 19 percent (when international distance costs are 5 percent).

• Canada's border effect is about 5

• Both estimates are less than half of Anderson and van Wincoop and other estimates – but consistent with estimates that allow for heterogeneity in border barriers across industries

• Elimination of border barriers between U.S. and Canada will lead to increase in trade of about 45 percent.

Importance of Vertical Specialization for Results

- Because vertical specialization magnifies the cost of border barriers, presence of significant international vertical specialization in the Canadian data implies that at least some goods face small international trade costs (relative to intra-national trade costs). (Point #2)
- Data indicate that one-third of goods production faces small international trade barriers.
- For these goods, model implies border barrier is effectively zero.
- Consequently, elimination of border barriers will not lead to a large increase in international trade, which implies a relatively small border effect

Conclusion

- Canada and United States are already fairly highly integrated economies
- Vertical specialization breaks tight link between elasticity of trade with respect to (iceberg-type) trade barriers, and the elasticity of substitution between goods.
    - Chaney (2005) also has model that breaks this link
- Vertical specialization and trade costs in a broader context:
    - Goods are produced in sequential, tradable stages; regions vary in their efficiency in producing them: vertical specialization is endogenous
    - In usual trade models, production occurs in just one stage; it's a black box. Maintained assumption is that the nature of production is invariant to trade costs. This is fine for many research questions.
    - But, this paper shows the assumption leaves out quantitatively important forces for understanding border effect puzzle. "Reduced form" production function *does respond* to changes in trade costs. This is the source of the magnification effect (Point #3).
    - More generally, changes in the distribution of productivities, the technology of production, etc., can generate magnified impacts to the extent that vertical specialization responds to these changes.

CAN VERTICAL SPECIALIZATION EXPLAIN

THE GROWTH OF WORLD TRADE?

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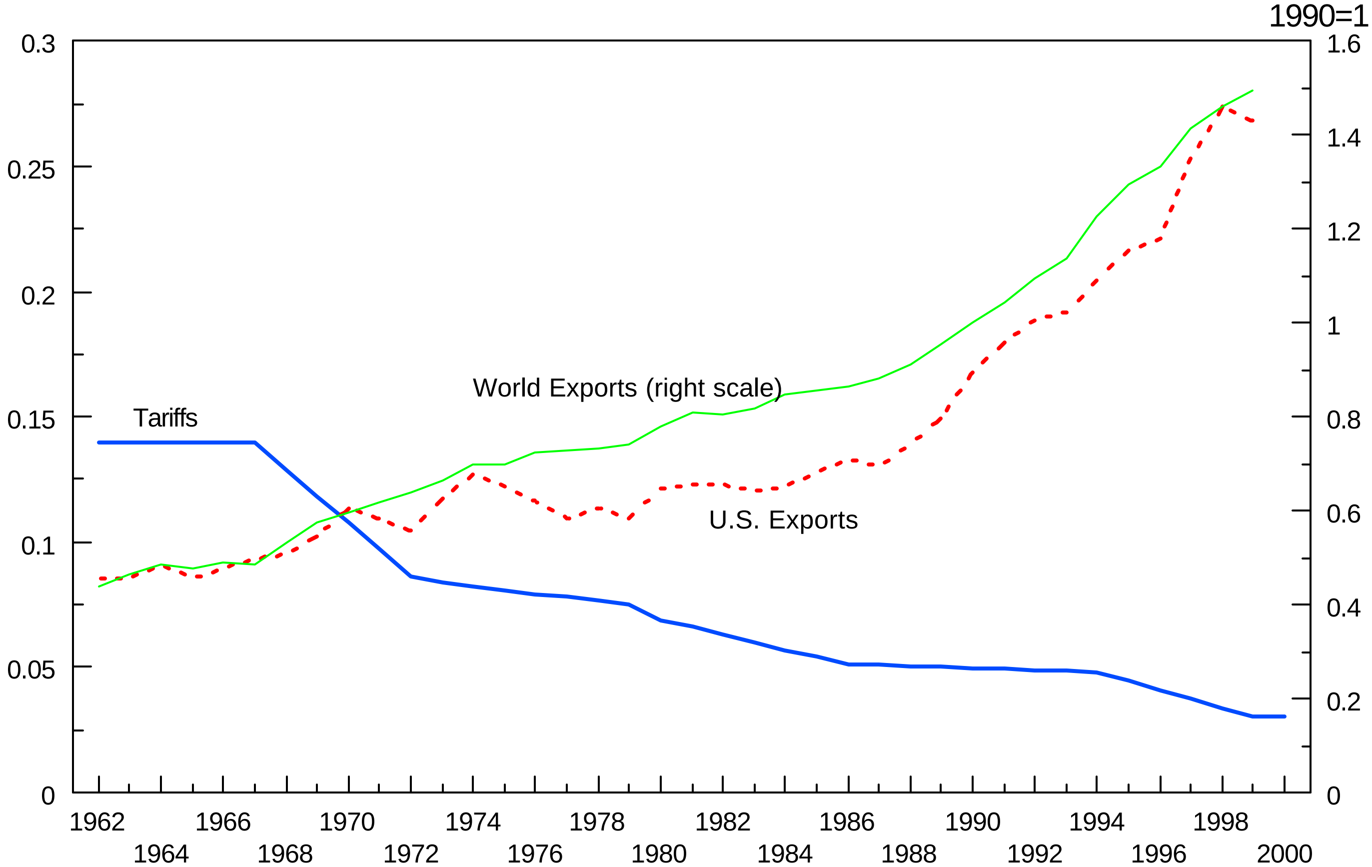
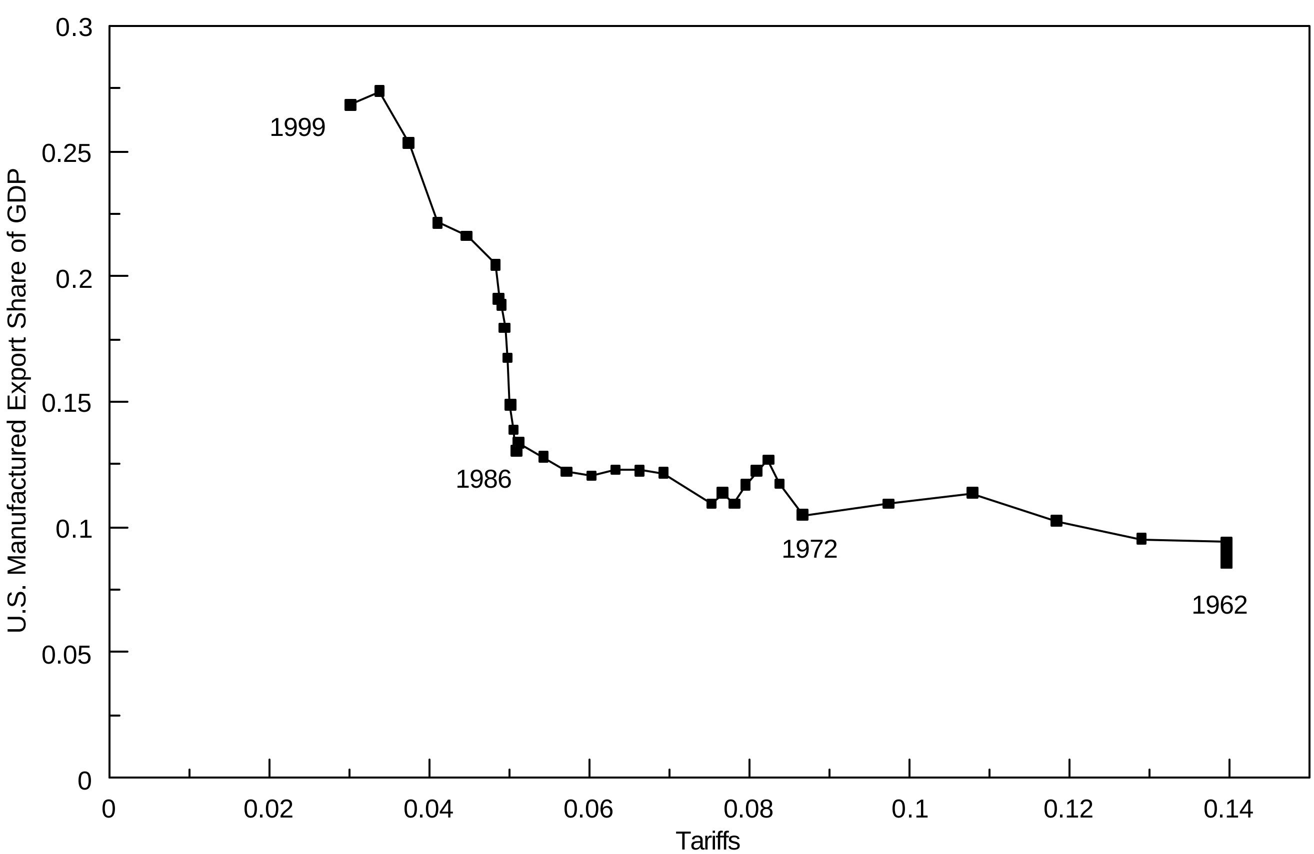
FIGURE 1
Manufacturing Export Share of GDP and Manufacturing Tariff Rates





Source: WTO and author's calculations (see Appendix A and Section 5)

INTRODUCTION

Enormous Expansion in World Trade During the Past Half-Century

World merchandise export share of output has almost **tripled**.

World manufactured export share of output has almost **quadrupled**.

In the United States, trade growth has been even faster:

Merchandise export share growth:	3.3% per year (since 1962).
Manufactured export share growth:	4.2% per year (since 1962).

INTRODUCTION (con't)

What Explains this Trade Growth?

Standard Story:

Worldwide Reductions in Tariffs (and Transportation Costs)

Two Problems with Standard Story:

1. **Tariffs (and transportation costs) have declined by only about 15 percentage points since the early 1960s.**

   The workhorse trade (monopolistic competition, Ricardian) and international real business cycle models can only explain the trade growth by assuming *very high* elasticities of substitution across goods (12 or higher).

INTRODUCTION (con't)

2. **Trade has grown more in the 1980s and 1990s than in the 1960s and 1970s, even though tariffs fell by more in the earlier period.**
   a. Between 1962 and 1976, tariffs fell 6 percentage points. U.S. manufacturing trade (adjusted) grew by 36 percent.
   b. Between 1976 and 1997, tariffs fell 5 percentage points. U.S. manufacturing trade grew by 130 percent.

So we have 2 dynamic puzzles:

1. Reconciling the large trade growth with relatively small reductions in tariffs (Magnitude)
2. Explaining the greater "potency" of tariff reductions in the last two decades (Non-linearity)

INTRODUCTION (con't)

To resolve these puzzles, I argue that we need to go beyond the growth of trade, broadly speaking, because it is masking important changes occurring in the **NATURE** of trade:

International trade increasingly involves interconnected vertical trading chains:

1] U.S. produces and exports engine parts to Mexico

2] Mexico produces engines and exports all of it to the U.S.

3] U.S. produces automobiles with these engines, and some of the autos are exported.

Specialization increasingly occurs in different stages of production.

Countries increasingly link sequentially to produce a good.

I (and co-authors) call this phenomenon **VERTICAL SPECIALIZATION**

- Many other names and terms – disintegration of production, fragmentation, outsourcing, intra-product specialization, multi-stage production, etc.

INTRODUCTION (con't)

How can vertical specialization help us understand the growth of world trade?

Intuitive story to explain the increase in world trade and vertical specialization:

1. World-wide tariffs (and transportation costs) decline.

2. The cost of producing goods whose production processes involve multiple stages in multiple countries falls by more than the cost of producing "regular" goods, because the vertically specialized goods are "tariff-ed" multiple times while in-process.

3. Vertical specialization trade increases by more than "regular" trade because:

   a. Magnified decline in costs for vertically specialized trade (internal margin)
   b. Some "regular" goods now become vertically specialized (external margin)

4. Total trade increases – because both regular trade and vertical specialization trade increase – by more than standard models predict.

5. Moreover, the effect is non-linear, because, if tariffs are high enough, so that there is no vertical specialization, then tariff reductions have only the standard effects on trade. Once vertical specialization kicks in, then the magnification effect kicks in.

Hence: There is the possibility of "rescuing" the standard story by modifying existing trade models to include for vertical specialization.

OUTLINE

A. Summarize Evidence on Growth of Vertical Specialization

cf. Ishii and Yi (1997)
Hummels, Rapoport, and Yi (1998)
Hummels, Ishii, and Yi (2001)

B. Show that Standard Trade Models have Difficulty Explaining the Magnitude and Non-linearity of Trade Growth.

C. Assess Whether Quantitative Dynamic Trade Model w/ Vertical Specialization can Better Explain Trade Growth.

VERTICAL SPECIALIZATION: CONCEPTS

VERTICAL SPECIALIZATION:

1. A good is produced in two or more sequential stages.

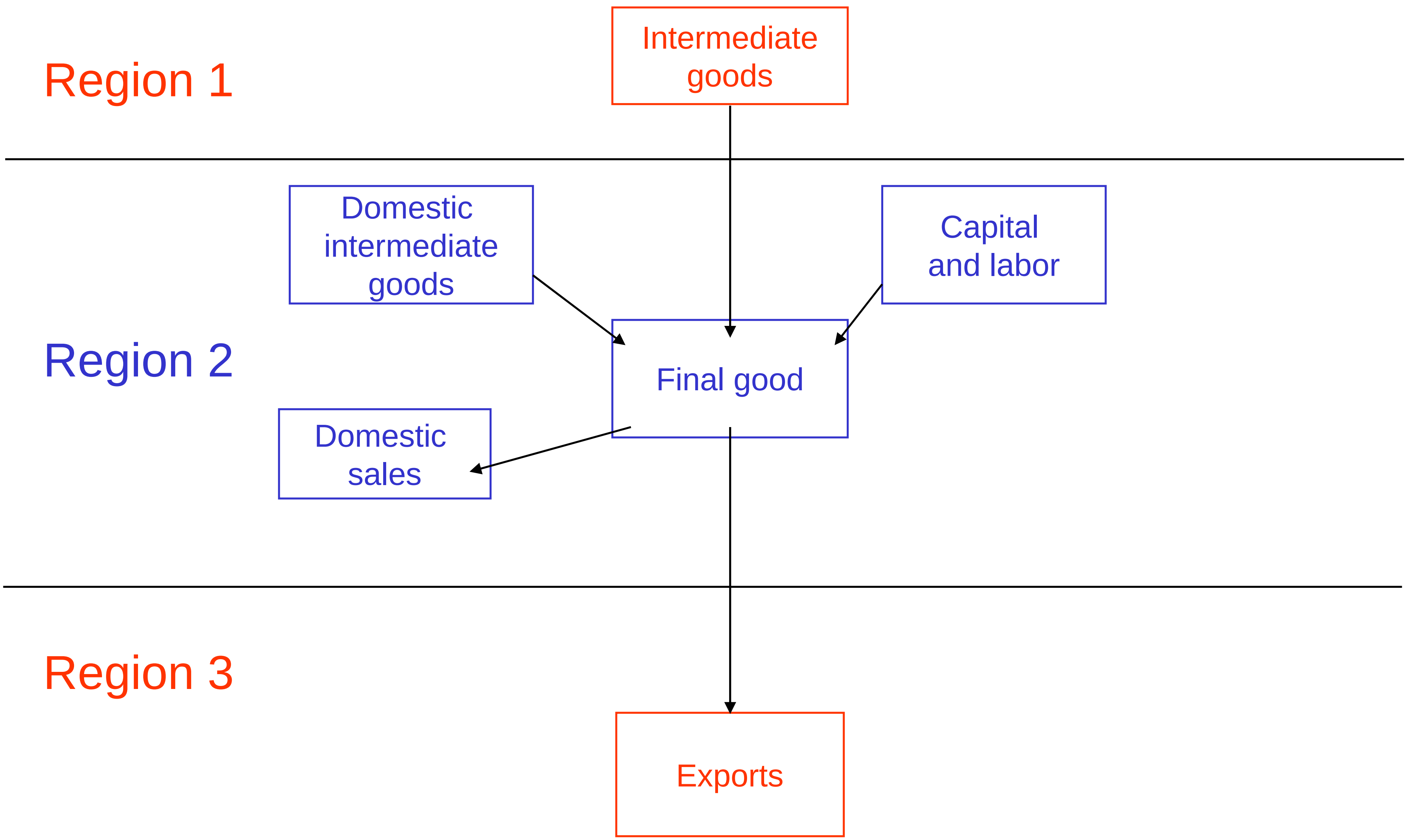
2. Two or more countries provide value-added during the production of the good.

3. *At least one country must use imported inputs in its stage of the production process, and some of the resulting output must be exported.*

Part 3 is key: Vertical Specialization is related to but not the same as intermediate goods trade, which is consistent with 1 and 2, but not necessarily with 3.

Figure 1

Vertical Specialization



VERTICAL SPECIALIZATION: CONCEPTS

Three reasons why vertical specialization is a better characterization of the changing nature of trade:

- Intermediate goods trade as a share of total trade has **fallen** in recent decades.

- Empirical classifications of intermediate and final goods are often arbitrary. Our concept is based primarily on an input-output framework and does not depend on such classifications.

- Theoretical distinctions between intermediate goods models and final goods models sometimes do not have much bite. Our concept leads to a useful categorization of trade models: those in which only one stage of production is traded and those in which two or more stages are traded.

VERTICAL SPECIALIZATION: MEASUREMENT

1. Vertical Specialization Exports (VS)

For country k and good i:

$$VS_{ki} = \left(\frac{\text{imported intermediates}}{\text{gross output}}\right) \times \text{exports}$$

$$= \left(\frac{\text{exports}}{\text{gross output}}\right) \times \text{imported intermediates}$$

VS is imported input content of country k's exports of good i.

Country-level VS: $\frac{VS_k}{X_k} = \frac{\sum_i VS_{ki}}{\sum_i X_{ki}}$

VERTICAL SPECIALIZATION: MEASUREMENT

3 extensions of basic measure:

1. Accurate measures of VS require data at the level of individual goods, but this is not feasible other than for case studies. Input-output tables can help us obtain country-wide numbers. These tables provide industry-level data on:
   - imported inputs
   - gross production
   - exports

   $VS_k/X_k = \mathbf{uA^M X}/X_k$

   where **u** is a 1xn vector of 1's, $\mathbf{A^M}$ is the nxn imported coefficient matrix, **X** is an nx1 vector of exports, and n is the number of sectors.

   Moreover, we can calculate the value of imported inputs used indirectly in producing an export good. The revised formula below allows for imported inputs to "circulate" through domestic economy through multiple stages before "exiting" embodied in an exported good:

   $VS_k = \mathbf{uA^M[I - A^D]^{-1}X}$

   where **I** is the identity matrix and $\mathbf{A^D}$ is the nxn domestic coefficient matrix.

   The above is our primary measure of vertical specialization exports (VS)

MEASURING VERTICAL SPECIALIZATION IN INTERNATIONAL TRADE

3 extensions of basic measure:

2. Imported Capital Goods: used to produce goods that are exported. So imported capital services are used as inputs to produce export goods.

3. VS1: Country k can also participate in vertical specialization by exporting goods to countries that use them as inputs into producing those countries' export goods.

   VS1 is country k's export content of other countries' exports of good i.

   For country k and good i:

   $$VS1_{ki} = \sum_{j=1}^{n} \text{(exported intermediates to country j)*[(j's exports}_i\text{)/(gross production}_i\text{)]}$$

   VS1 is much harder to measure than VS because we would need:

   - I-O tables for all trading partners of the country for which VS1 is calculated.
   - Bilateral imported inputs data.

VERTICAL SPECIALIZATION EXPORTS: RESULTS

CASE STUDIES of VS:

Cf. Ishii and Yi (1997) FRBNY Research Paper #9718
Hummels, Rapoport, and Yi (1998), FRBNY Economic Policy Review, June 1998

Case Studies

a] 1965 U.S.-Canada Auto Agreement
b] U.S.- Mexico Maquiladora Trade
c] Japan – S.E. Asia Electronics Trade
d] Opel-España Auto Trade

In these case studies, 1/3-1/2 of relevant exports is VS, and VS growth accounts for 1/3-1/2 of relevant export growth.

VERTICAL SPECIALIZATION EXPORTS: RESULTS

Data:

a] OECD Input-Output database: 10 countries, selected years between 1968 and 1990

b] Korea, Ireland, Taiwan Input-Output tables, selected years between 1960s and 1995

c] Mexico’s maquiladora and non-maquiladora trade w/ U.S.

These 14 countries account for more than 60% of world exports.

Results Summary:

1. **As of 1990, the VS share of total exports in our sample was 21% and had grown 30% since 1970. Under plausible assumptions for the rest-of-the-world and for the 1990s, we estimate the VS share of exports to be about 30% as of 1995, an increase of 40% since 1970.**
2. **VS export growth accounts for about 1/3 of overall export growth.**
3. VS exports range from 10% to 40% of total exports in our 14 countries, with smaller countries having larger VS shares of exports.
4. Chemicals and machinery industries account for most of the VS export growth
5. Vertical specialization has been primarily a North-North phenomenon, with the exception of the U.S.

VERTICAL SPECIALIZATION EXPORTS: RESULTS
Focus on U.S. evidence: VS and VS1

Relative to other countries, U.S. VS share of exports is lower, but growth rate of VS share is higher.

We can use trade data w/ Mexico and Canada to estimate a lower bound on VS1.

VS as a share of total (merchandise) exports: (from the OECD I-O Database)

1972	.059
1977	.084
1982	.088
1985	.093
1990	.108

Between 1972 and 1990, VS as a share of exports grew 3.42% per year

Using that growth rate, we can extrapolate backwards and forwards and obtain the following VS estimates:

1962	.042
1997	.137

VERTICAL SPECIALIZATION EXPORTS: RESULTS

United States: VS and VS1

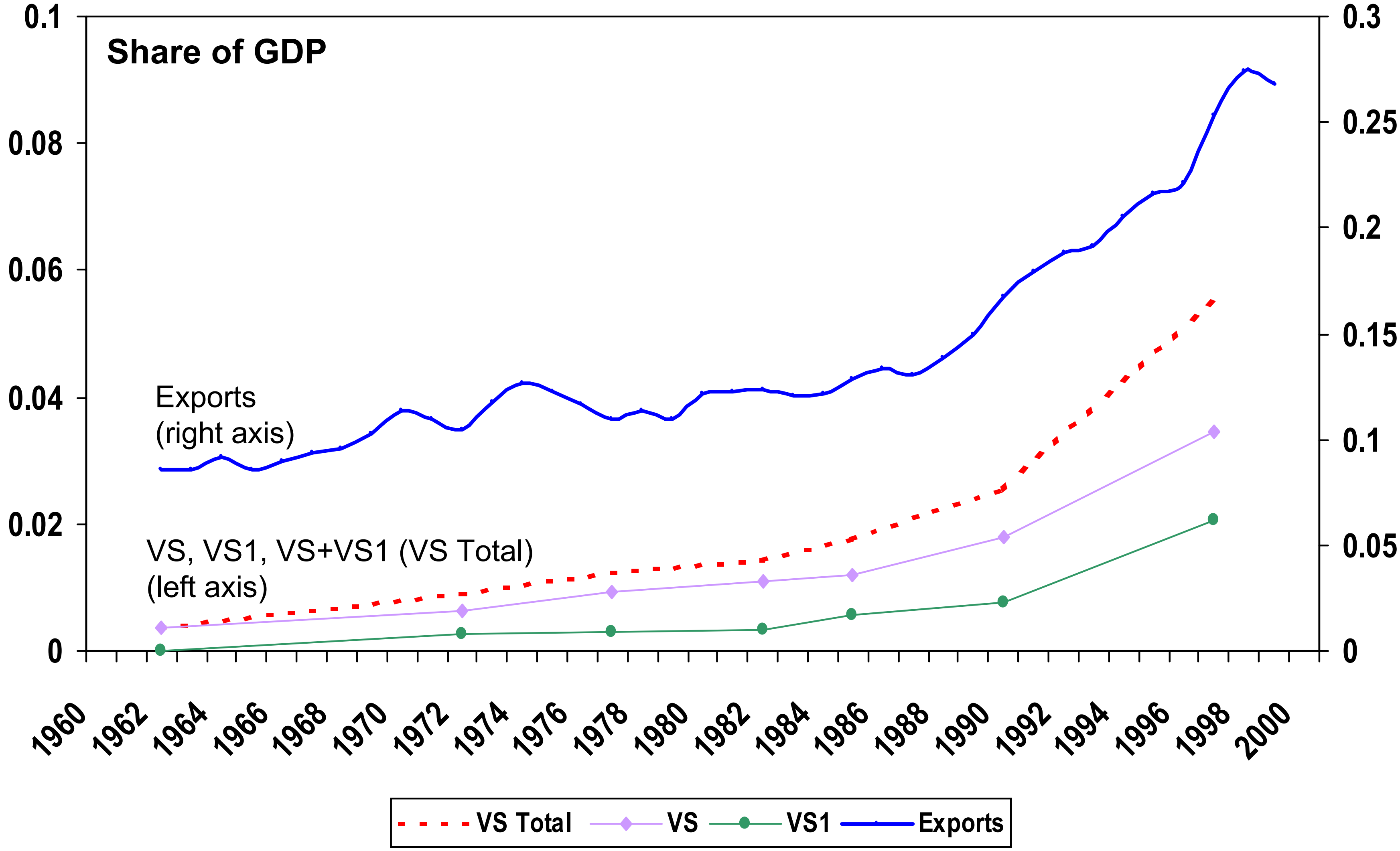
From Mexico's maquiladora data we know that in 1997 about $35 billion of U.S. exports to Mexico are themselves exported back to U.S. embodied in Mexican goods. Also, USITC estimates an additional $6.5 billion of U.S. exports to Mexican non-maquiladoras return to U.S. embodied in Mexican goods.

In addition, from U.S.-Canada Auto case study, we know that in 1997 about $15 billion of U.S. auto exports to Canada return to U.S. embodied in Canadian cars.

All together, in 1997, for these two cases alone, we estimate U.S. VS1 = $56.5 billion or 8.2% of U.S. merchandise exports. Doing a similar exercise for 1972, 1977, 1982, 1985, and 1990, and noting that maquiladora trade and vertical U.S.-Canada auto trade was non-existent prior to 1965, yield the following estimates for VS1 + VS:

1962	.042
1972	.085
1977	.111
1982	.116
1985	.138
1990	.153
1997	.219

FIGURE 3
United States VS, VS1, VS+VS1, and Exports



VERTICAL SPECIALIZATION EXPORTS: RESULTS

United States

Growth Decomposition: What fraction of the change in the U.S. merchandise export share of GDP can be accounted for by vertical specialization?

	Total VS (share of exports)		Export share of total GDP	Export share of Merchandise GDP
1962	**.042**		3.67%	7.46%
1997	**.219**		8.52%	23.38%
		Change:	4.85 percentage points	15.92 percentage points

VS+VS1 account for **35.3%** of increase in export share of total GDP
VS+VS1 account for **30.2%** of increase in export share of merchandise GDP

MODELING THE GROWTH OF TRADE AND VERTICAL SPECIALIZATION

Is vertical specialization an important propagation mechanism for trade growth?

I examine the effects of tariff reductions in three standard trade models:

Krugman monopolistic competition model
Dornbusch-Fischer-Samuelson (DFS) Ricardian model
Backus-Kehoe-Kydland International Real Business Cycle model

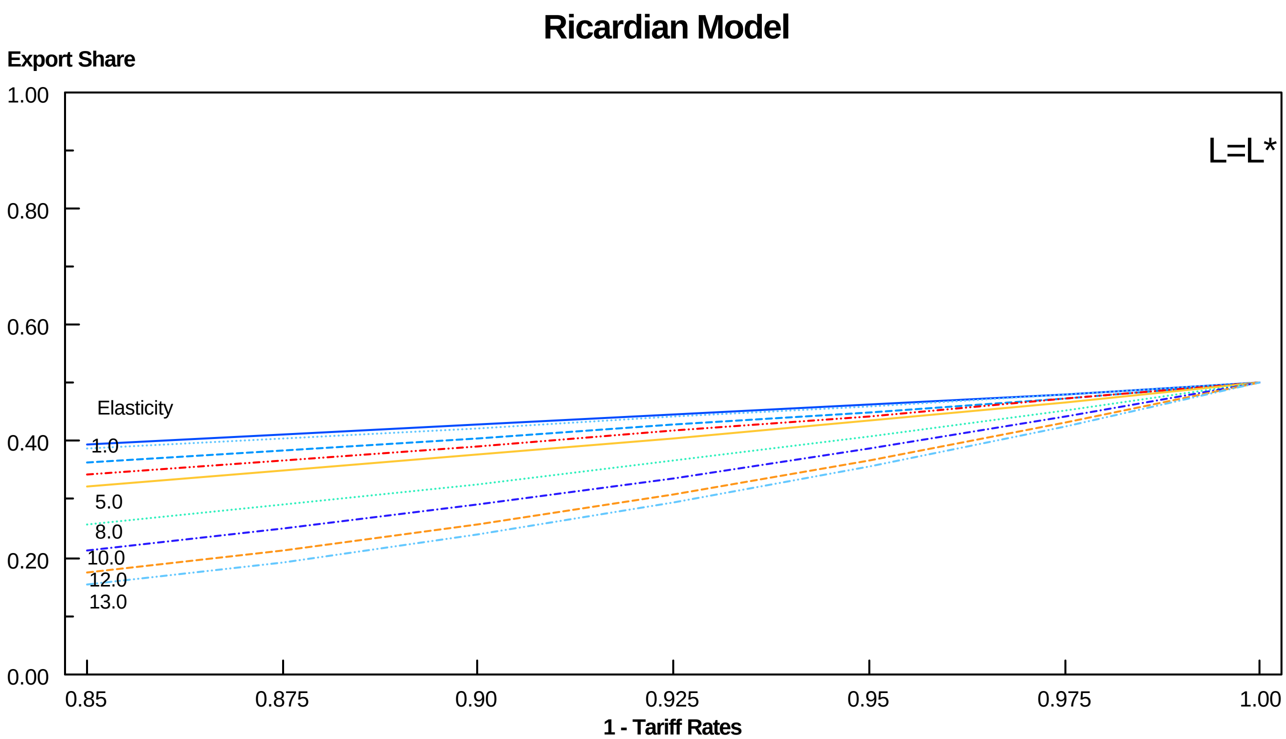
- In all 3 models, the effects of a tariff reduction from 15% to 0 are examined.

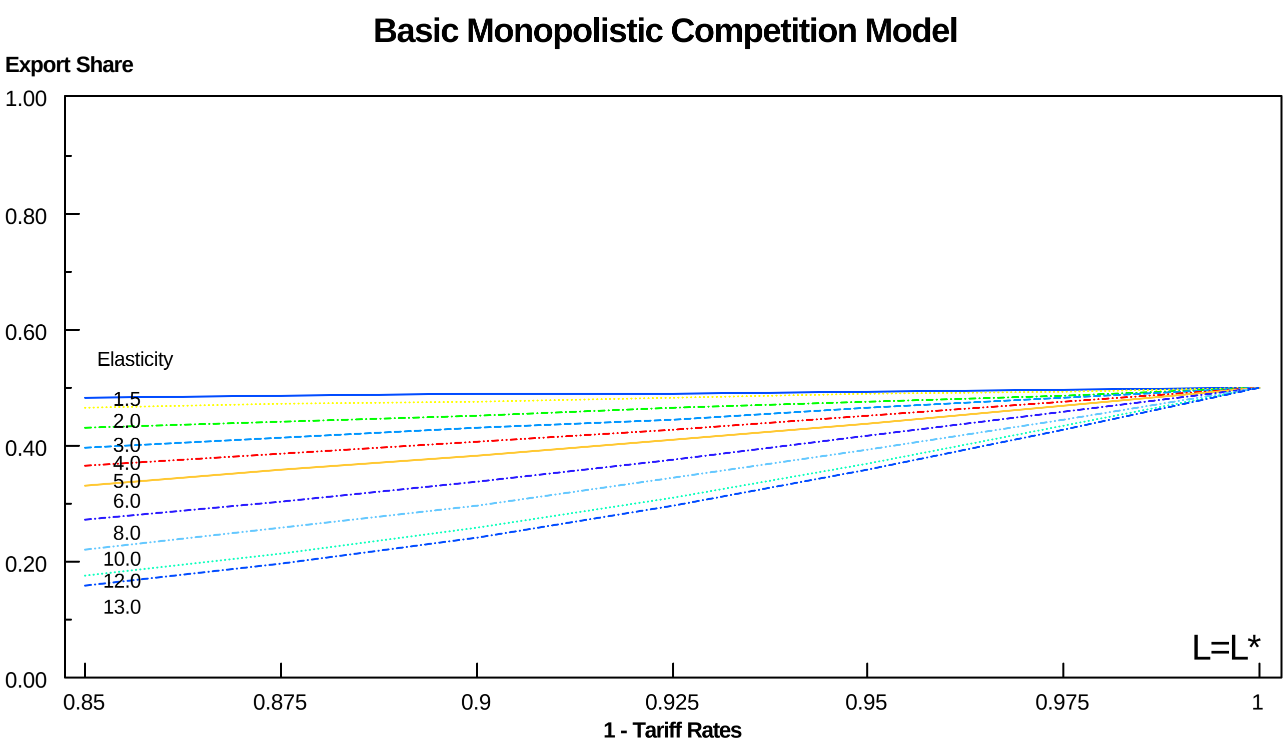
- If the elasticity of substitution between goods is 1, the models can explain only a small fraction of the growth of trade. Even with a 25 percentage point tariff reduction, the models explain only about 1/3-1/2 of the growth of trade.

- Elasticities of substitution of 12 or needed to generate the growth in the U.S. manufactured export share of GDP. These are high.

- Ishii and Yi (1997) show that a DFS Ricardian model modified to include for VS can generate high export share growth even w/ unitary elasticities of substitution

FIGURE 4
International Trade Models
Export Share of Output as a Function of Tariffs





CAN A CALIBRATED DYNAMIC MODEL OF VERTICAL SPECIALIZATION BETTER EXPLAIN THE GROWTH OF TRADE THAN STANDARD MODELS?

DYNAMIC RICARDIAN VERTICAL SPECIALIZATION MODEL

BASIC SETUP

2 countries

2 factors (homogenous capital and labor)

Continuum of goods indexed on unit interval

Infinite horizon

Capital accumulation, but no international capital flows (portfolio autarky)

Exogenous growth

DYNAMIC RICARDIAN VERTICAL SPECIALIZATION MODEL
BASIC SETUP

Production:

Each good is produced in three stages:

First stage produces intermediate good: $Y_1(z) = A_1(z)K_1(z)^{\alpha} L_1(z)^{1-\alpha}$

Second stage produces a second intermediate good:

$$Y_2(z) = Y_1(z)^{\theta}\left(A_2(z)K_2(z)^{\alpha} L_2(z)^{1-\alpha}\right)^{1-\theta}$$

Third stage produces a non-traded final good used for consumption and investment:

$$Y = \exp[\int_0^1 \ln[y_2(z)]dz] \text{ or, more generally, } Y = [\int_0^1 y_2(z)^{\frac{\sigma-1}{\sigma}} dz]^{\frac{\sigma}{\sigma-1}}$$

Above holds in autarky.

Market Structure:

Perfect competition at all stages.

Stage 1 firms, stage 2 firms, and stage 3 firms all maximize profits taking prices as given.

DYNAMIC RICARDIAN VERTICAL SPECIALIZATION MODEL
MODEL: FREE TRADE

Potentially, there are 4 production patterns for the first two stages of each good:

1] Home country produces stages 1 and 2 (HH)

2] Foreign country produces stages 1 and 2 (FF)

3] Home country produces stage 1, Foreign country produces stage 2 (HF)

4] Foreign country produces stage1, Home country produces stage 2 (FH)

e.g. if case 3, $Y_1{}^H(z) = A_1{}^H(z) K_1{}^H(z)^\alpha L_1{}^H(z)^{1-\alpha}$

$$Y_2{}^F(z) = X_1{}^F(z)^\theta \left(A_2{}^F(z) K_2{}^F(z)^\alpha L_2{}^F(z)^{1-\alpha}\right)^{1-\theta}$$

Ricardian Trade:

- Comparative advantage is determined by relative technology (TFP) differences. Relative cost differences are determined by relative technology differences.
- There is complete specialization (up to some “borderline” stages) in the production of each stage.

Cases 3 and 4 involve vertical specialization.

DYNAMIC RICARDIAN VERTICAL SPECIALIZATION MODEL

MODEL: FREE TRADE

Vertical specialization occurs under free trade as long as:

$$\frac{A_1^H(z')}{A_1^F(z')} > \left(\frac{r^H}{r^F}\right)^{\alpha}\left(\frac{w^H}{w^F}\right)^{1-\alpha} > \frac{A_2^H(z')}{A_2^F(z')} \quad \text{or} \quad \frac{A_1^H(z')}{A_1^F(z')} < \left(\frac{r^H}{r^F}\right)^{\alpha}\left(\frac{w^H}{w^F}\right)^{1-\alpha} < \frac{A_2^H(z')}{A_2^F(z')}$$

i.e., whenever it is cheaper to produce stage 1 in one country and stage two in the other country.

From the figure, the arbitrage condition that determines cutoff separating production pattern HH from production pattern HF:

$$\frac{\chi (r^H)^{\alpha} (w^H)^{1-\alpha}}{A_1^H(\underline{z}^h)^{\theta} A_2^H(\underline{z}^h)} = \frac{\chi \left((r^H)^{\alpha} (w^H)^{1-\alpha}\right)^{\theta} \left((r^F)^{\alpha} (w^F)^{1-\alpha}\right)^{1-\theta}}{A_1^H(\underline{z}^h)^{\theta} A_2^F(\underline{z}^h)}$$

i.e., the cost of producing the final good under HH equals the cost of producing the good under HF.

FIGURE 5
Vertical Specialization Model
Free Trade

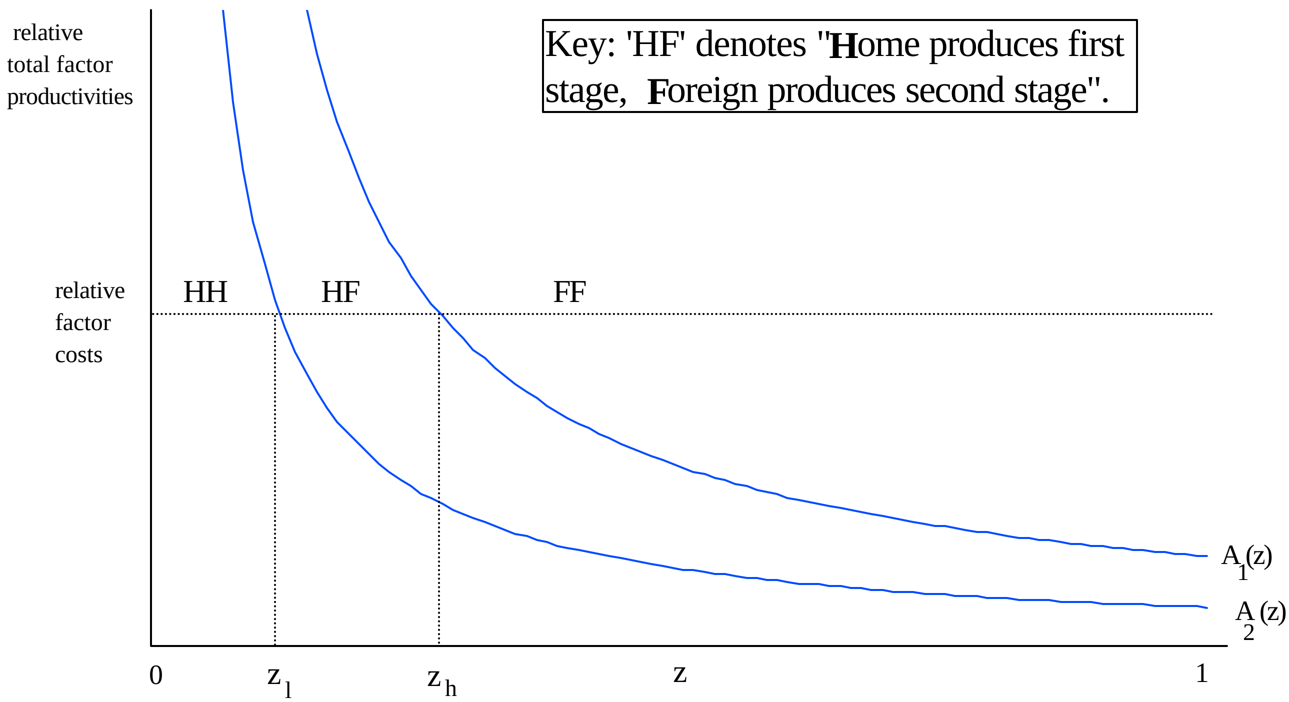
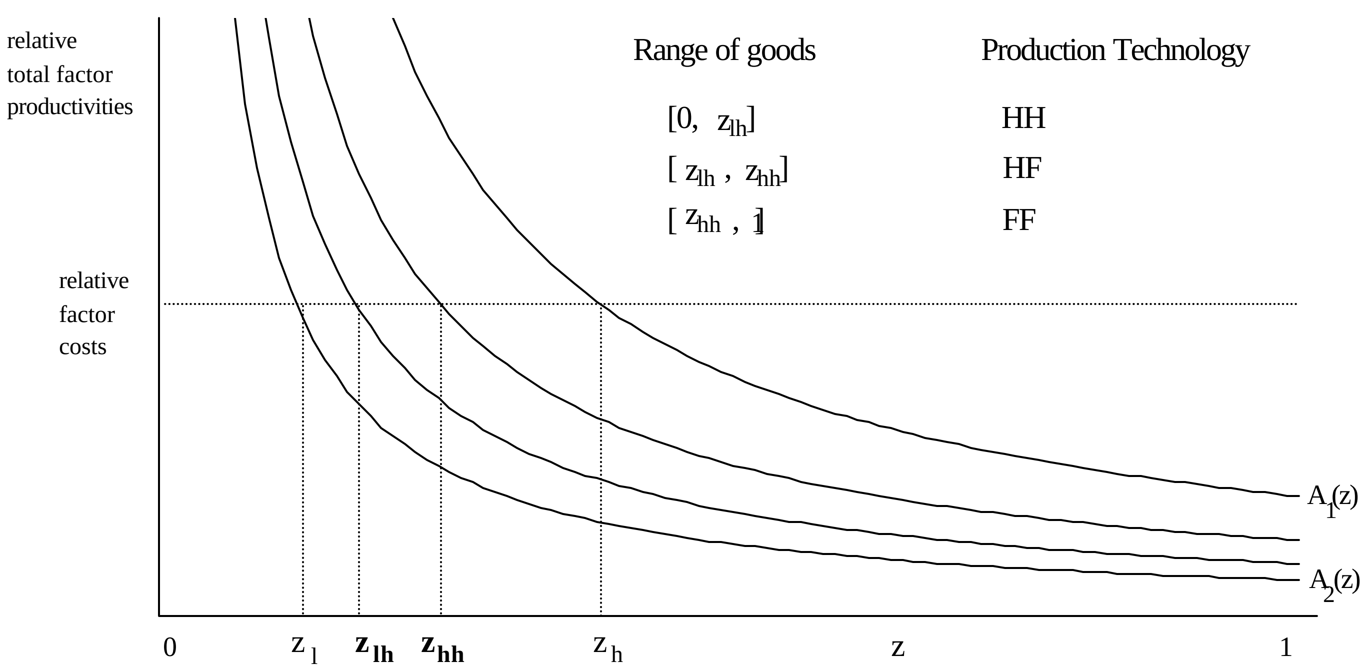


FIGURE 6
Vertical Specialization Model
Tariffs (Home Consumer's Perspective)



DYNAMIC RICARDIAN VERTICAL SPECIALIZATION MODEL
BASIC SETUP

Households:

Households maximize: $\sum_{t=0}^{\infty} \beta^t \ln(C_t)$

subject to a sequence of budget constraints: $C_t + K_{t+1} - (1-\delta)K_t = w_t L + r_t K_t \equiv Y_t$

Capital Accumulation: $K_{t+1} - (1-\delta)K_t = I_t$

Households own and accumulate capital. Firms rent capital period-by-period from households.

DYNAMIC RICARDIAN VERTICAL SPECIALIZATION MODEL
MODEL: INTRODUCING TARIFFS

Tariffs are ad valorem.

Tariffs are identical across stages of production and across countries.

Tariff revenue is returned to households as a lump sum transfer.

DYNAMIC RICARDIAN VERTICAL SPECIALIZATION MODEL

MODEL: EXTERNAL MARGIN

In a static framework with no capital, tariff revenue is thrown in ocean, and $A_2(z)$ is a proportional shift of $A_1(z)$, the elasticity of the export share of GDP with respect to tariffs under vertical specialization (holding the terms of trade constant) is:

$$\left(\frac{1+\theta}{1-\theta}\right)\left[\frac{z_l}{(1-z_l)\eta_{A_2}}\right]$$

where z_l is the cutoff good for which the costs of production patterns HH and HF are the same (for the home stage-3 firm), and η_{A_2} is the elasticity of stage 2 relative productivity, $A_2(z)$, with respect to z.

If there is no vertical specialization then the elasticity of the export share of GDP with respect to tariffs (holding the terms of trade constant) is:

$$\left[\frac{z_l}{(1-z_l)\eta_{A_2}}\right]$$

If $\theta = 5$, then the effect of tariff reductions is 5 times larger under vertical specialization.

DYNAMIC RICARDIAN VERTICAL SPECIALIZATION MODEL

MODEL: INTERNAL MARGIN

Along the internal margin, z is held fixed. Under the same assumptions as above, and under vertical specialization, the elasticity of the export share of GDP with respect to tariffs is given by:

$$(1-\sigma)\left[\left(1+\theta\left(\frac{HF(\omega^H,\omega^F)}{FF(\omega^H,\omega^F)+(1+\tau)^{\theta(1-\sigma)}HF(\omega^H,\omega^F)}\right)\right)\right]$$

The large expression in parentheses is roughly the share of vertical specialization in imports.

If there is no vertical specialization, then the elasticity of the export share of GDP with respect to tariffs (holding the terms of trade constant) is:

$$(1-\sigma)$$

Tariff reductions lower the cost of producing vertically specialized goods more than regular goods.

Note: the above two expressions have implications for estimation of gravity models.

Non-linear effect occurs because initially trade growth is governed by the standard mechanisms. Tariff reductions without vertical specialization behave like standard models. Once a critical tariff rate is exceeded then further reductions generate magnified effects along both the internal and external margin.

DYNAMIC RICARDIAN VERTICAL SPECIALIZATION MODEL

MODEL: SOLUTION METHOD

1. Calculate final steady-state and set initial capital stocks.

2. Assume dynamics settle down after T (125) periods.

3. Solve Euler equations, equilibrium conditions (n equations per period) $\forall$ T; nT total equations

DYNAMIC RICARDIAN VERTICAL SPECIALIZATION MODEL
MODEL: CALIBRATION

2 equal-sized countries: U.S. and R.O.W. (G7-U.S.)

Initial conditions: Each country is at steady-state governed by initial tariff rate.

Annual frequency; 1962+

Parameters:

- β (preference discount factor) = 0.96
- α (Cobb-Douglas coefficient on capital) = 0.36
- δ (depreciation rate on capital) = 0.13 (Jorgenson)
- θ (share of first stage output in second stage production) = 0.67
- τ (manufacturing tariffs, several sources) = .1395 in 1962, .0301 in 2000

DYNAMIC RICARDIAN VERTICAL SPECIALIZATION MODEL

MODEL CALIBRATION: RELATIVE PRODUCTIVITIES

Use Balassa's "Revealed Comparative Advantage" measure for industry j and stage k:

$$RCA_{u.s.,\, j,k.} = \frac{X_{u.s.,\, j,k.} \big/ X_{u.s.}}{X_{world,\, j,k} \big/ X_{world}}$$

as a proxy for $A_1(z)$ and $A_2(z)$. While RCA's do not reveal comparative advantage generally, they do reveal it in my model (as well as the classic 2 x 2 x 2 Heckscher-Ohlin model).

Caveat: RCA's are ordinal and I am using them to capture a cardinal relation

Measures of $X_{u.s.,j,k}$ and $X_{world,j,k}$ are not directly measurable and must be constructed.

DYNAMIC RICARDIAN VERTICAL SPECIALIZATION MODEL

MODEL CALIBRATION: RELATIVE PRODUCTIVITIES

3 steps to construct $A_1(z)$ and $A_2(z)$ using RCA measures:

1. Use OECD Input-Output tables (1985) to divide industries into stage 2 industries and stage 1 industries, based on whether demand for for industry output is intermediate demand or final demand:

   a. (Narrow) **Stage 1:** paper, industrial chemicals, drugs and medicines, petroleum and coal products, rubber and plastic products, non-metallic minerals, iron and steel, non-ferrous metals, and electrical apparatus. **Stage 2:** food, beverages and tobacco; textiles, apparel and leather; motor vehicles; shipbuilding; aircraft; office and computing machinery; radio and television; and non-electric machinery.
   b. (Broad) **Stage 1:** all of the above industries. **Stage 2:** same as Narrow

2. Each stage 2 industry has a stage 1 "counterpart", which is a weighted average of the stage 2 industry and the stage 1 industries, where the weights depend on the stage 2 industries use of inputs from the stage 1 industries and itself. Use the "proportionality" method to calculate the stage 1 counterpart's exports. Stage 2 exports are total exports by stage 2 industries minus the exports assigned to stage 1 counterpart.

3. Calculate RCAs. Then discretize the [0,1] continuum with the eight stage 2 industries and estimate a quadratic regression of $A_1(z)$ on z, and similarly for $A_2(z)$.

FIGURE 7
Stage 1 and Stage 2 Input-Output Relations

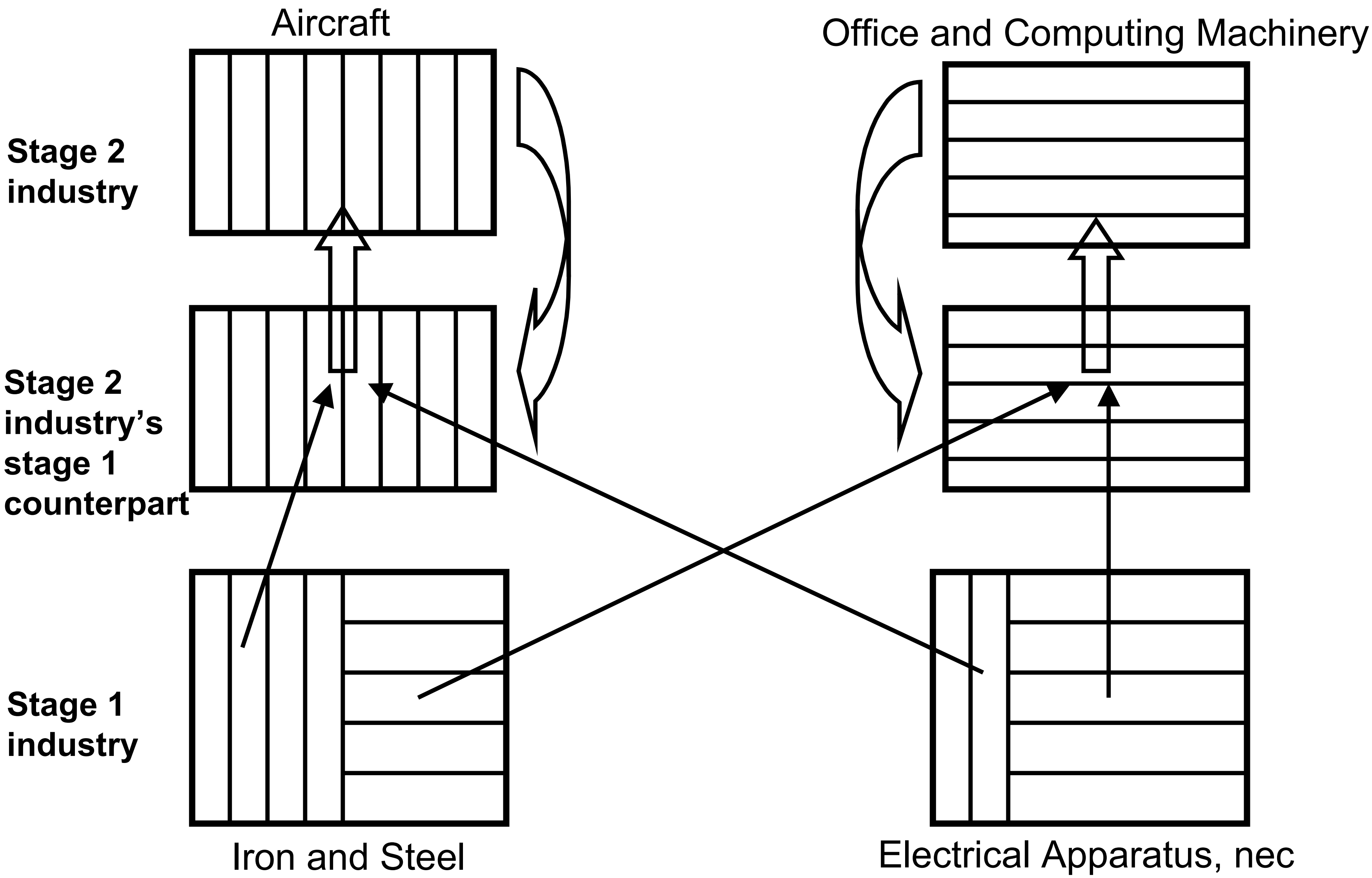


TABLE 1

PARAMETERS USED IN BENCHMARK CALIBRATIONS

b	Preference discount factor	0.96
a	Capital's share in production	0.36
d	Depreciation rate on capital	0.13
q	Share of first-stage output in second-stage production	0.67
s	Elasticity of substitution in stage-3 aggregator	1
Narrow benchmark case $A_1(z)$:	$1.26z^2 - 2.53z + 1.88$	
Narrow benchmark case $A_2(z)$:	$3.095z^2 - 3.38z + 1.63$	
Broad benchmark case $A_1(z)$:	$0.686z^2 - 1.478z + 1.63$	
Broad benchmark case $A_2(z)$:	$3.088z^2 - 3.401z + 1.567$	

FIGURE 8
Narrow Case: Exports and VS+VS1 against Tariffs

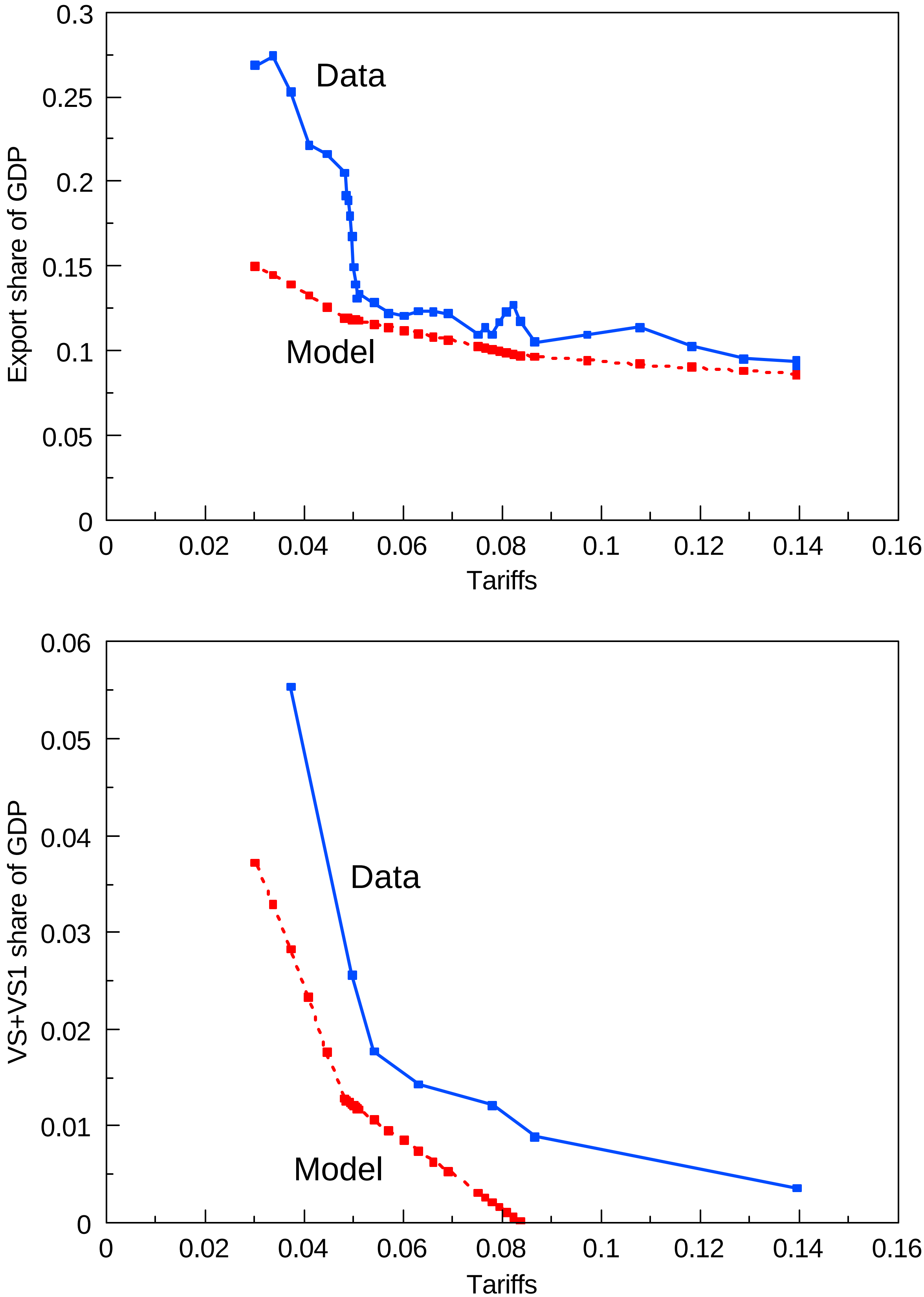


TABLE 2
RESULTS FROM BENCHMARK VERTICAL SPECIALIZATION MODEL

	Export Growth			Elasticity of Export Growth w.r.t Tariffs		
	(adjusted) U.S. Data	Narrow Case	Broad Case	(adjusted) U.S. Data	Narrow Case	Broad Case
1962-1999	213.0%	74.8%	113.0%	22.0	7.8	11.8
	Fraction Explained	**35.1%**	**53.0%**			
1962-1976	36.2%	16.2%	47.4%	6.9	3.1	9.0
1976-1999	130.0%	50.4%	44.6%	28.4	11.0	9.7
1962-1989	73.9%	37.9%	87.2%	9.4	4.8	11.1
1989-1999	80.1%	26.8%	13.8%	42.1	14.1	7.3

Export Share of GDP
Root Mean Square Error

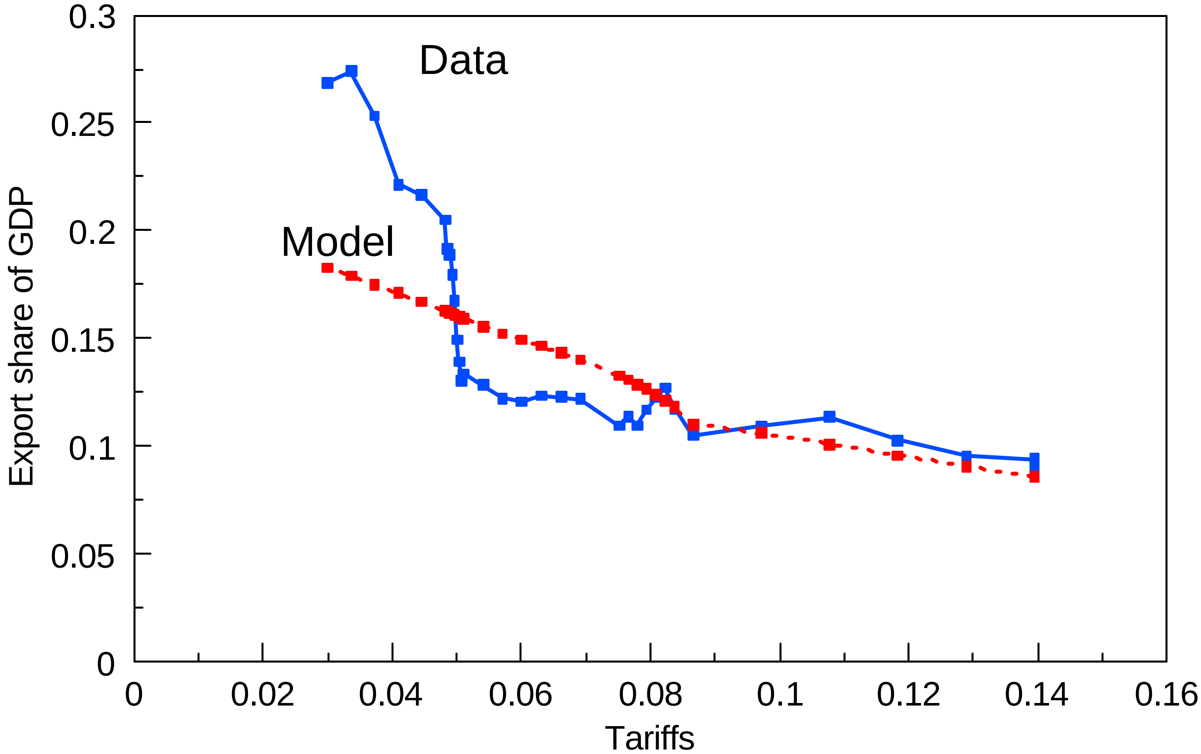
	Narrow Case	Broad Case
1962-1999	**0.049**	**0.032**
1962-1976	0.015	0.006
1976-1999	0.061	0.041
1962-1989	0.015	0.016
1989-1999	0.091	0.056

Vertical Specialization
(Percent of GDP)

	U.S. Data	Narrow Case	Broad Case
1962	0.36%	0.00%	0.00%
1977	1.21%	0.21%	1.50%
1990	2.56%	1.22%	4.25%
1997	**5.54%**	2.83%	5.46%

Source: Author's calculations

FIGURE 9
Broad Case: Exports and VS+VS1 against Tariffs



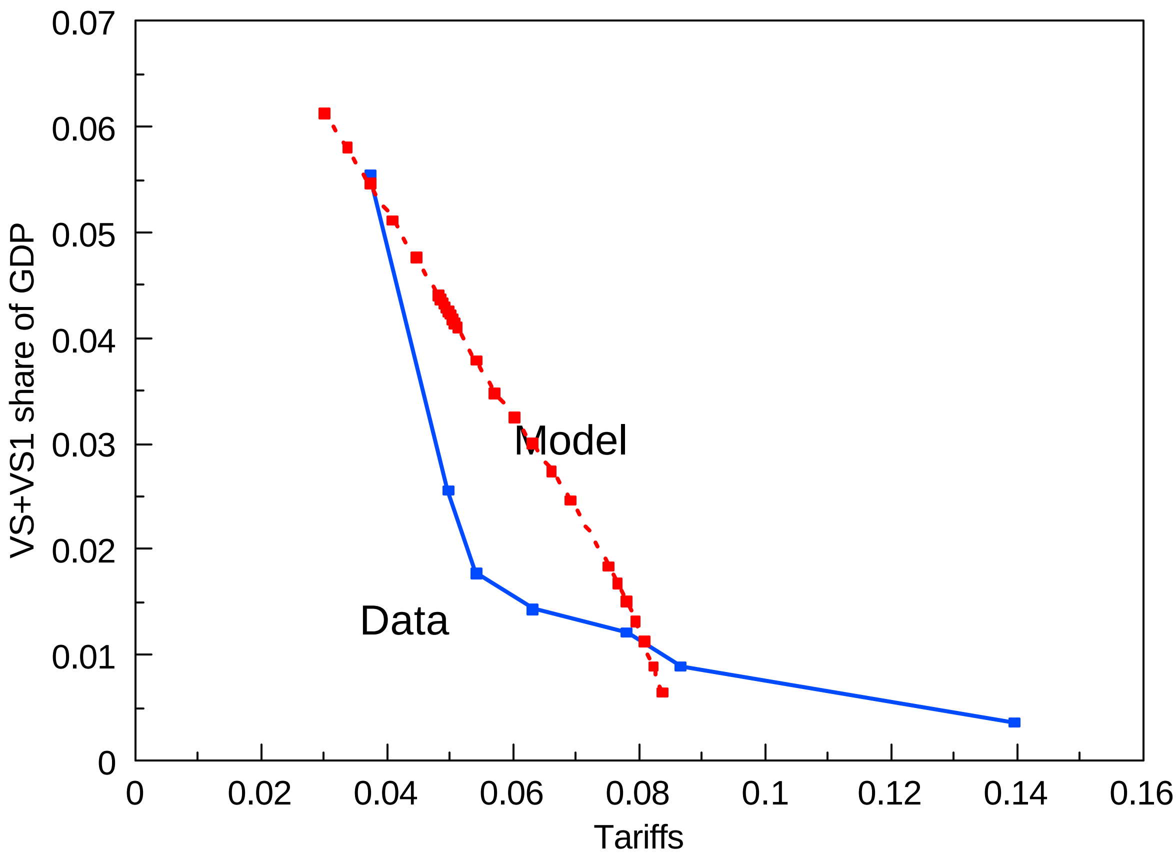


FIGURE 10
Narrow Case: VS Model vs. One-stage Model

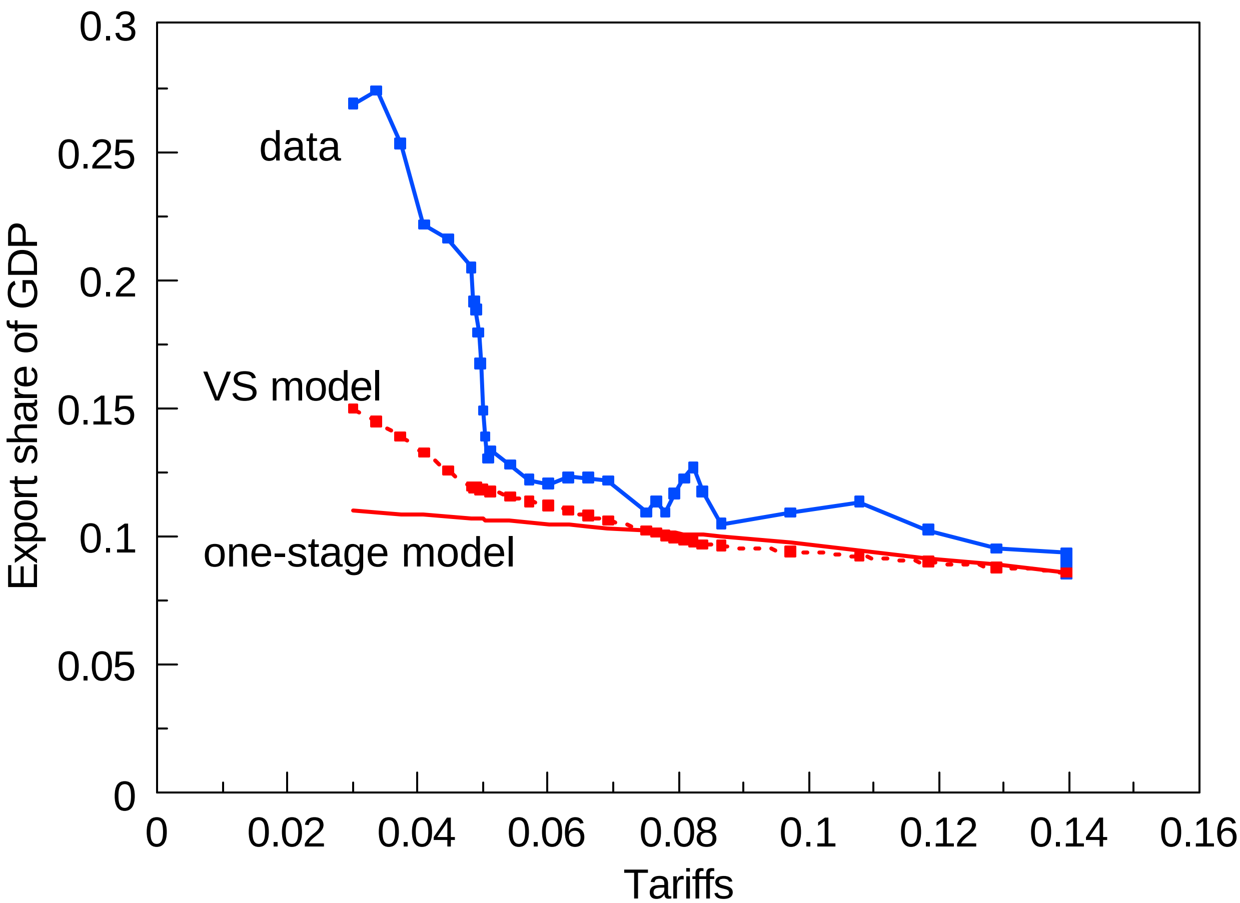


TABLE 3
COMPARISON OF VERTICAL SPECIALIZATION MODEL WITH STANDARD MODEL

Export Growth

	(adjusted) U.S. Data	Narrow Case: *VS Model*	Narrow Case: *One-Stage Model*	Broad Case: *VS Model*	Broad Case: *One-Stage Model*
1962-1999	213.0%	74.8%	28.3%	113.0%	62.7%
	Fraction Explained	**35.1%**	**13.3%**	**53.0%**	**29.4%**
1962-1976	36.2%	16.2%	18.1%	47.4%	32.9%
1976-1999	130.0%	50.4%	8.7%	44.6%	22.4%
1962-1989	73.9%	37.9%	24.3%	87.2%	50.3%
1989-1999	80.1%	26.8%	3.2%	13.8%	8.2%

Elasticity of Export Growth w.r.t Tariffs

	(adjusted) U.S. Data	Narrow Case: *VS Model*	Narrow Case: *One-Stage Model*	Broad Case: *VS Model*	Broad Case: *One-Stage Model*
1962-1999	22.0	7.8	2.9	11.8	6.5
1962-1976	6.9	3.1	3.4	9.0	6.2
1976-1999	28.4	11.0	1.9	9.7	4.9
1962-1989	9.4	4.8	3.1	11.1	6.4
1989-1999	42.1	14.1	1.7	7.3	4.3

Export Share of GDP Root Mean Square Error

	Narrow Case: *VS Model*	Narrow Case: *One-Stage Model*	Broad Case: *VS Model*	Broad Case: *One-Stage Model*
1962-1999	**0.049**	**0.061**	**0.032**	**0.047**
1962-1976	0.015	0.013	0.006	0.007
1977-1999	0.061	0.077	0.041	0.060
1962-1989	0.015	0.018	0.016	0.007
1990-1999	0.091	0.114	0.056	0.090

Source: Author's calculations

DYNAMIC RICARDIAN VERTICAL SPECIALIZATION MODEL

SIMULATION RESULTS (Welfare)

I computed welfare gains from tariff reductions by finding the proportion, ϕ, that the consumption path in the tariff-reduction simulation needed to be reduced to yield the same lifetime utility as the consumption path in a simulation with no changes in tariffs.

	Model w/ VS	Model w/o VS
	(average across 2 countries)	
Narrow (ϕ, (consumption proportion adjustment))	3.2%	0.95%
Broad	4.7%	2.2%

CONCLUSION AND EXTENSIONS

<u>Conclusions</u>

Vertical specialization matters in understanding the growth of trade, and in characterizing the changing nature of trade.

<u>Extensions</u>

Transport costs
Telecommunications revolution