Fifth Summer School in Trade, Industrialization, and Development 2006

University of Milan, Palazzo Feltrinelli, Gargnano, Italy

June 11-14, 2006

Outsourcing and International Fragmentation of Production: Implications for Developing Countries

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Overview

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Focus on Measurement and on Implications of Fragmentation for Trade and for Growth

1. Measuring International Fragmentation: How widespread is it? How rapidly is it increasing?
2. International Fragmentation and Trade Across Time and Space Fragmentation helps us understand:
   - Growth in world trade
   - "Border Effect" puzzle
3. International Fragmentation, Trade and Growth: How important is it for growth "miracles" (e.g. South Korea, Taiwan, Ireland, China, etc.)?

Modeling Framework

- Ricardian: comparative advantage is based on productivity differences
- Fragmentation driven by changes in trade costs

Lectures will not cover:

- Implications of technology-based fragmentation
- Fragmentation in a Heckscher-Ohlin setting
- Implications of fragmentation and outsourcing for skill premium in wages and wage inequality
- Fragmentation and multinationals

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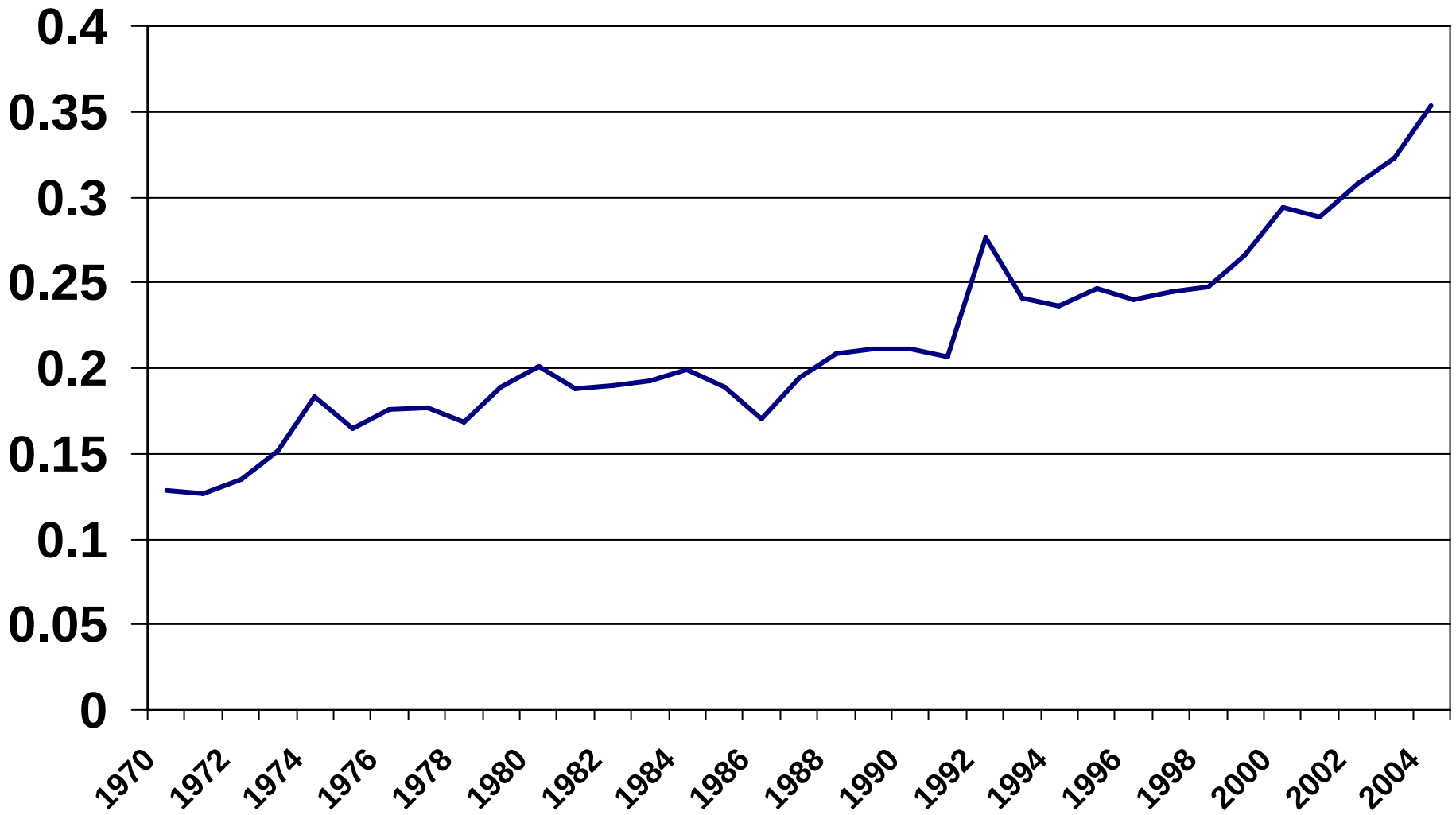
Lecture 1: Measuring International Fragmentation

Emerging Market Trade Increasing Rapidly

Export Share of GDP in Emerging Markets



Source: World Bank WDI database Note: Countries are World Bank's definition of lower and upper middle income countries ($825-$10,000 p.c. GDP in 2004) plus India

OUTLINE

- Examples of international fragmentation
- Measuring international fragmentation: vertical specialization
- Vertical specialization from three case studies
- Vertical specialization from input-output tables

Relevant Readings

1. Chen, Hogan, Matthew Kondratowicz, and Kei-Mu Yi. "Vertical Specialization and Three Facts about U.S. International Trade", *North American Journal of Economics and Finance*, 2005 (16), 35-59.

2. Hummels, David, Jun Ishii, and Kei-Mu Yi. "The Nature and Growth of Vertical Specialization in World Trade", *Journal of International Economics*, June 2001, 75-96. (The working paper version of this paper, issued as Federal Reserve Bank of New York Staff Reports #72, March 1999, has more detailed results.)

3. Hummels, David, Dana Rapoport, and Kei-Mu Yi. "Vertical Specialization and the Changing Nature of World Trade", Federal Reserve Bank of New York *Economic Policy Review*, June 1998, 79-99. Examples of international fragmentation

4. Partial list of other authors of studies measuring fragmentation include:
   - Jose Campa and Linda Goldberg (FRB, New York);
   - Robert Feenstra (U.C., Davis) and Gordon Hanson (U.C., San Diego);
   - Matthew Slaughter (Dartmouth);
   - Vanessa Strauss-Kahn (INSEAD);
   - Holger Gorg (Nottingham);
   - Peter Egger (Munich);
   - Salvatore Baldone, Fabio Sdogati, and Lucia Tajoli (Politecnico di Milano)

Example of International Fragmentation: Semiconductor Industry

Phases of the Semiconductor Production Process

Stage 1 - Design Process

Design the layout of the circuits on semiconductor. Mainly carried out by vendors, but there are companies that specialize in design.

Mainly dominated by US (48.8%), Japan (28.3%) and Korea (7.7%)

Source: John Schindler, An Overview of the Global Semiconductor Industry, 9/19/2001

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Stage 2 - Wafer Manufacturing Phase

Take raw material (sand), make ingots of silicon, and then cut up into circular wafers. Companies specialize in making wafers.

Japan has most of the market share (63.1%), followed by Germany (16.1%), US (11.7%), South Korea (5.3%) and Taiwan (2.7%).

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Stage 3 - Fabrication Step

Take wafer and place the electronic circuits onto it. (most sophisticated part of production process). Handled by vendor or foundry (specialized company in this stage)

Japan has 36.3% of total capacity, the US has 25%, followed by Taiwan and Korea at 8% and Germany at 3.4%.

There is revenue data on foundries, which are companies that just do fabrication.

Taiwan produces the majority of foundry-made chips with 63.5% of revenue, followed by Singapore (10.6%), US (9.4%), Japan (7.3%), and Korea (5.8%)

Source: John Schindler, An Overview of the Global Semiconductor Industry, 9/19/2001

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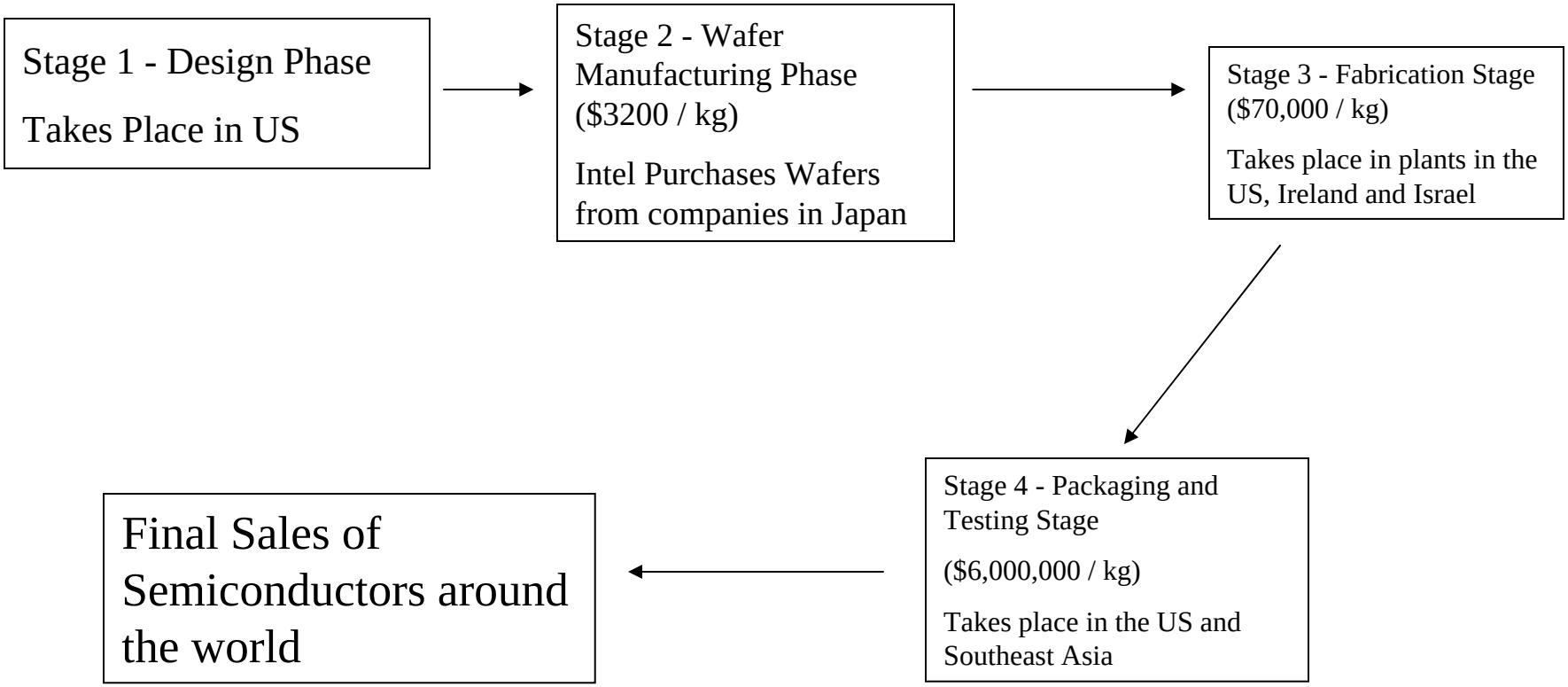
Stage 4 - Packaging and Testing (Back-end process)

Cut the wafers apart into the individual semiconductors that have been created. Takes place at a foundry or a separate packaging plant. Testing is either done at a foundry, packaging plant, or a testing company.

About 90% of the packaging and testing is done by emerging East Asian countries, led by Malaysia, Philippines, and Taiwan, with 28%, 20%, and 17%, respectively, of East Asian packaging and testing employment.

Source: John Schindler, An Overview of the Global Semiconductor Industry, 9/19/2001

Stages in the Intel Semiconductor Production Process (Example of Integrated Device Manufacturer)



Source: John Schindler, An Overview of the Global Semiconductor Industry, 9/19/2001

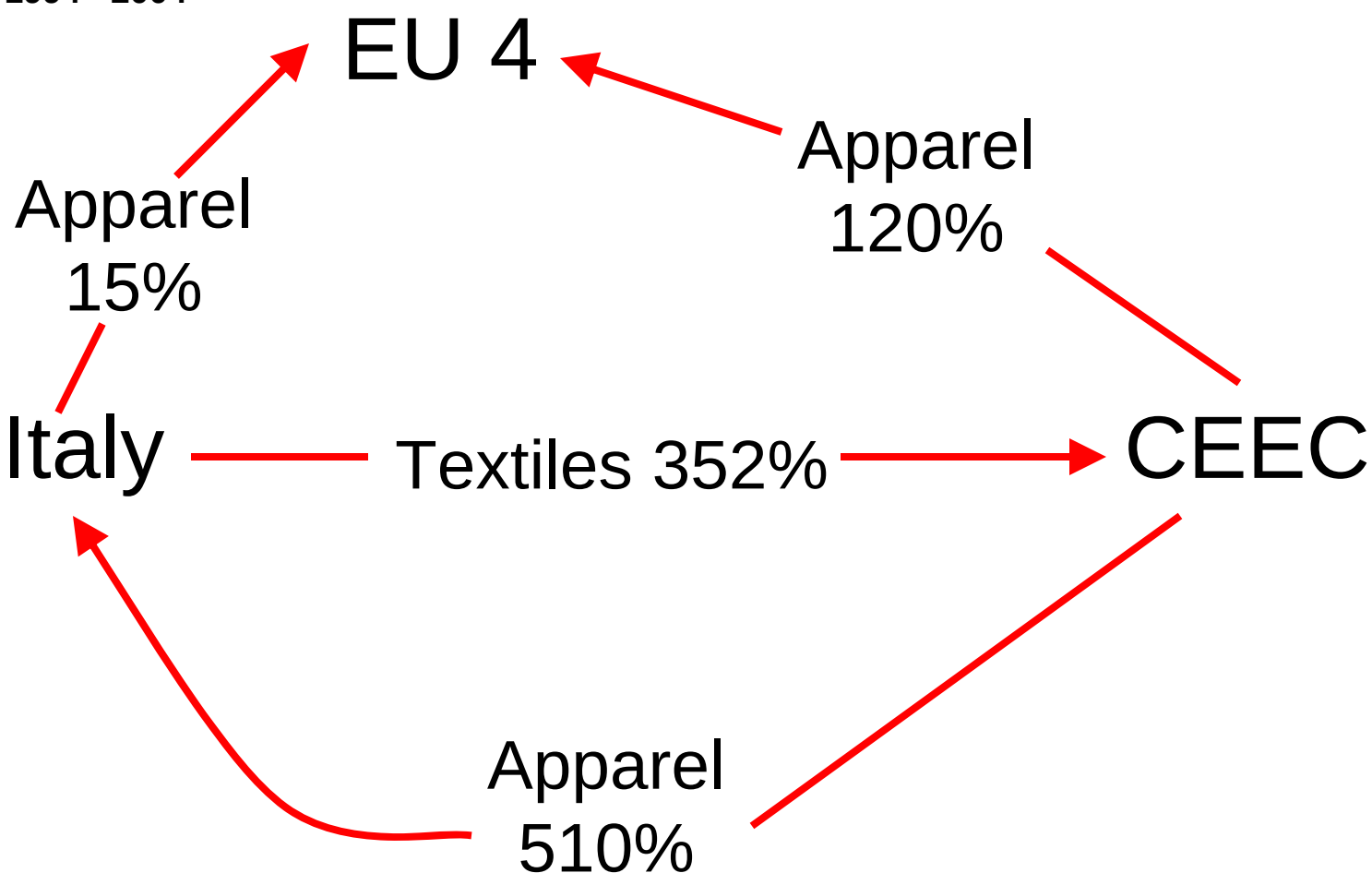
Four Examples of International Trading "Networks" involving Fragmentation

1. Italy and Central Europe: Textiles and apparel
2. Advanced East Asia and China: Everything
3. U.S. Multinationals
4. United States/UK and India: IT software and services

Central Europe Integrating Into Italian Textiles and Apparel Market

Geography of European TA Trade

% change, 1994 - 2004

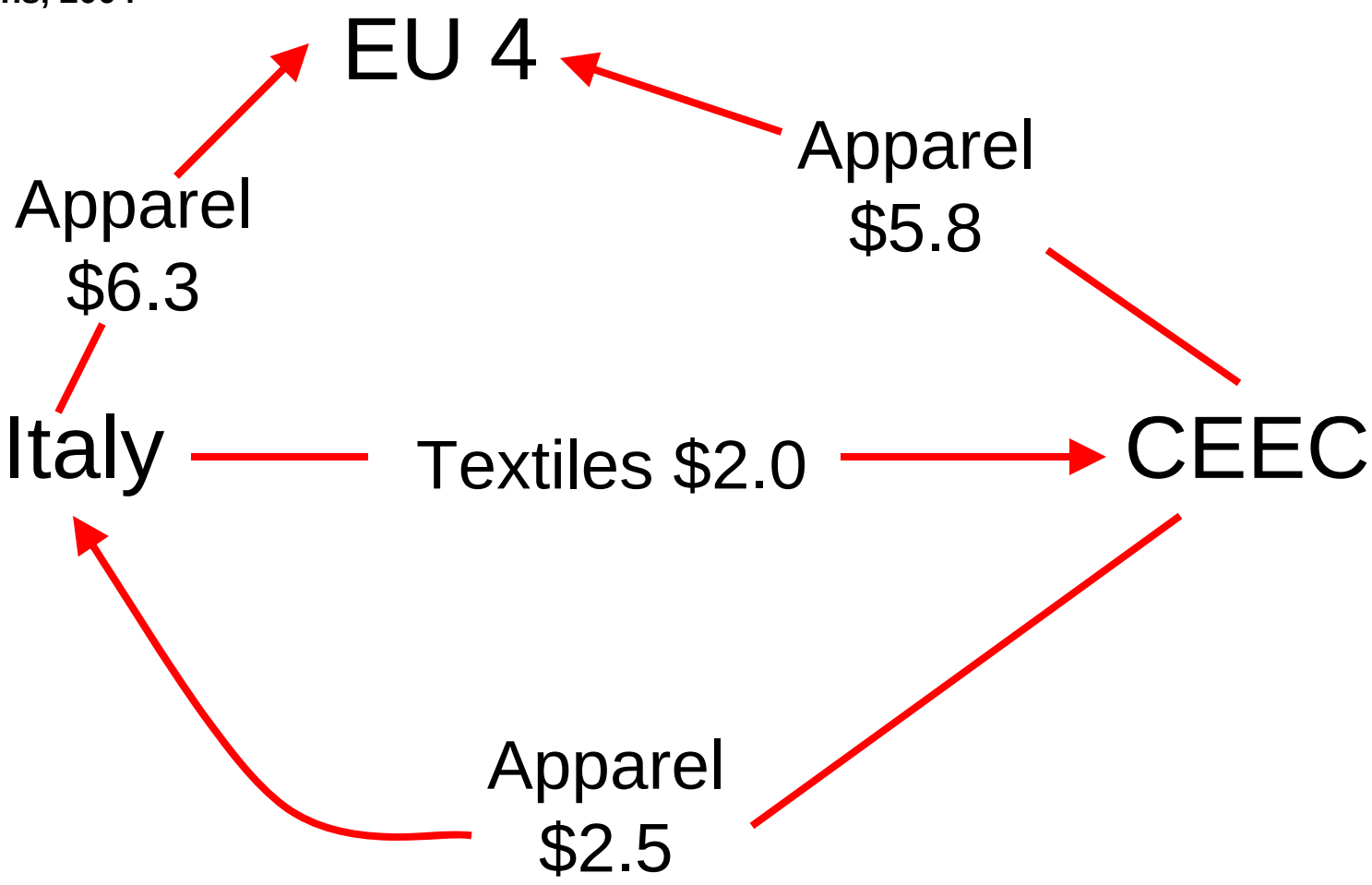


Note: EU 4 = England, France, Germany and Spain;
CEEC = Bulgaria (1996 onwards), Czech Republic, Hungary, Poland, Romania, Slovak Republic

Central Europe Integrating Into Italian Textiles and Apparel Market

Geography of European TA Trade

$U.S. billions, 2004



Note: EU 4 = England, France, Germany and Spain;
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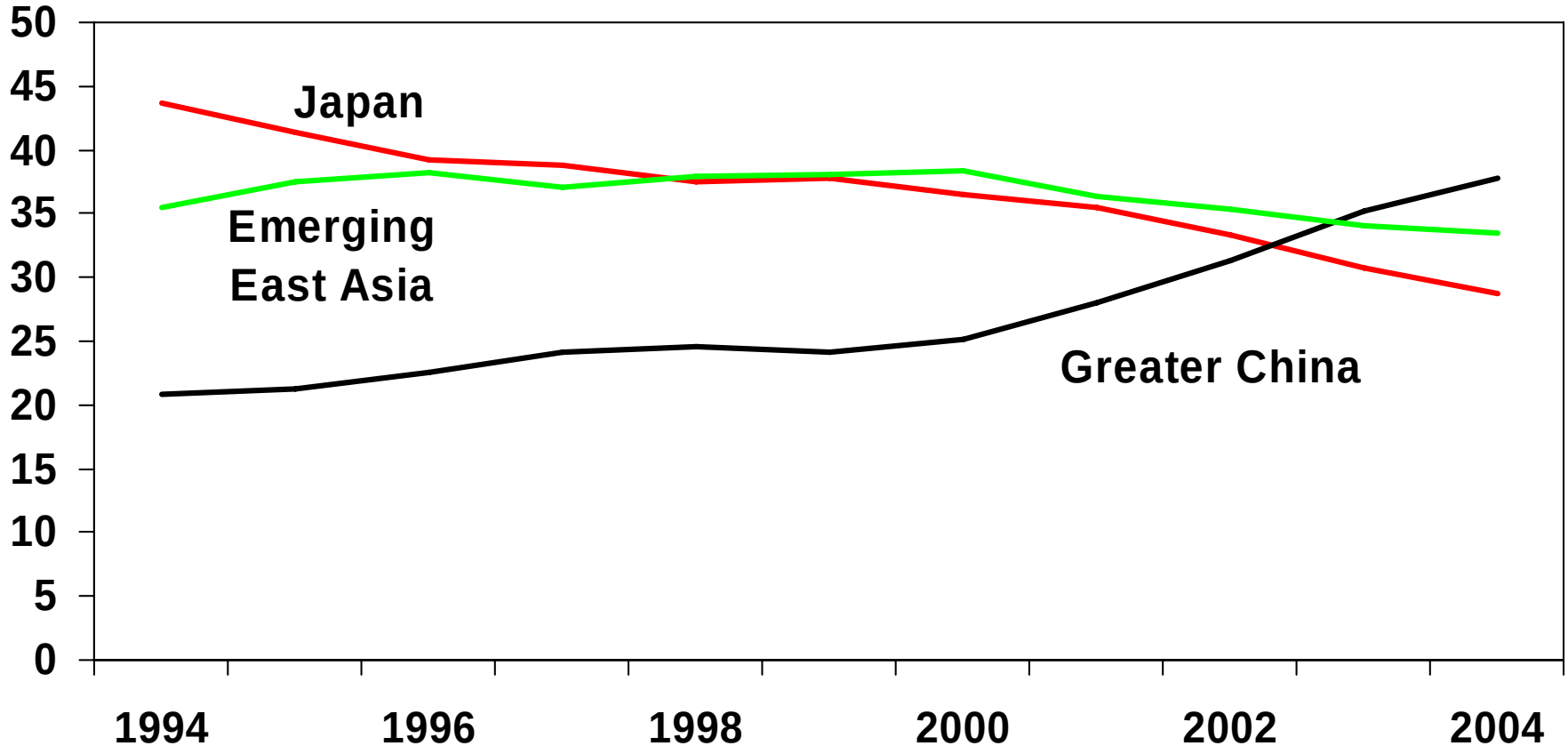
China Exports to U.S. Gaining, Japan and Emerging East Asia Exports Falling

Asia's Market Share in U.S.
Percent of total Pacific Rim Exports to U.S.



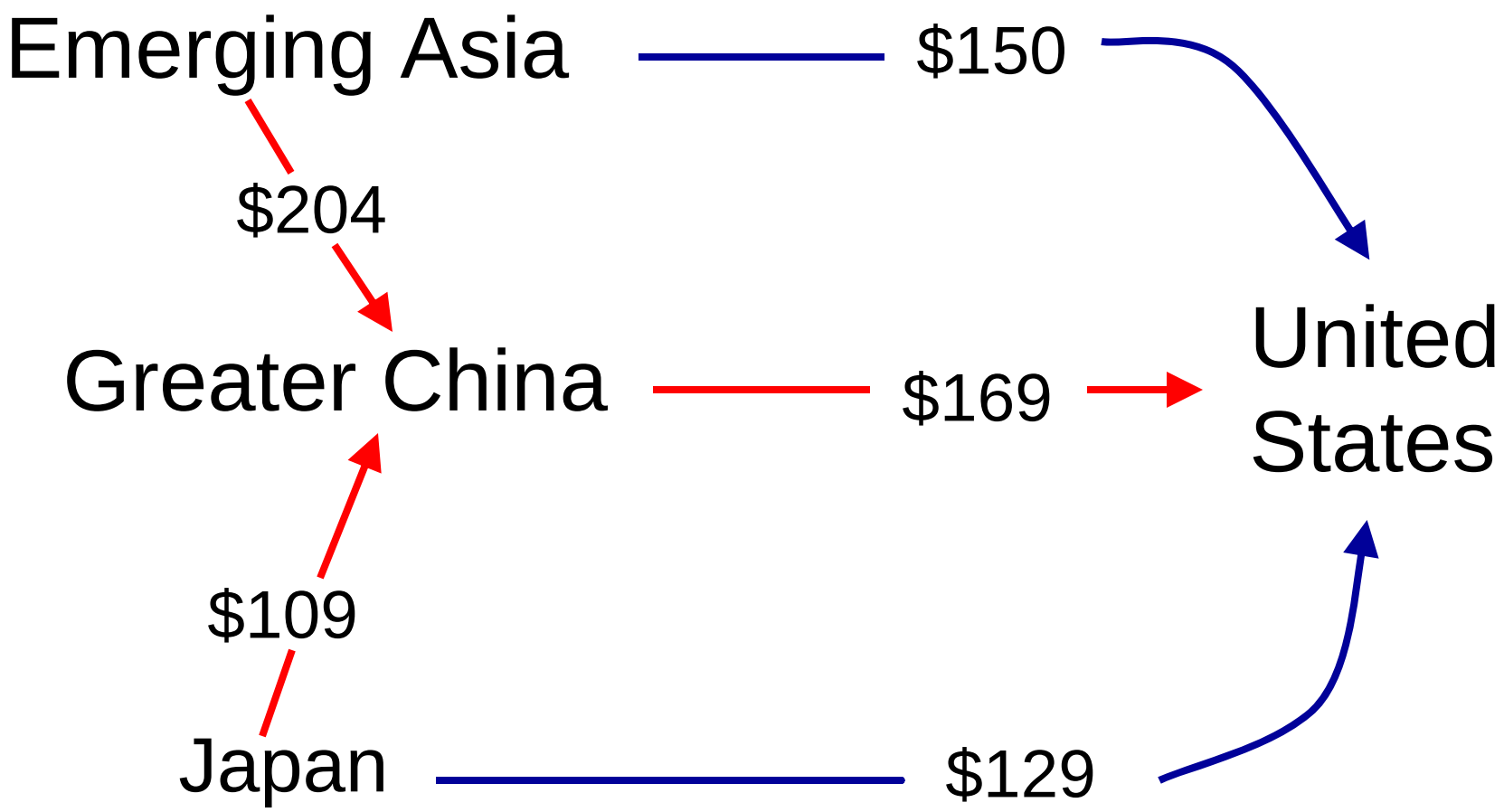
Note: Emerging East Asia = Korea, Indonesia, Malaysia, Philippines, Singapore, Taiwan and Thailand; Greater China=Mainland China + Hong Kong

Source: IMF Direction of Trade Statistics

China Integrating Into Asian Trading Network

Geography of Asian Trade

$U.S. billions, 2004



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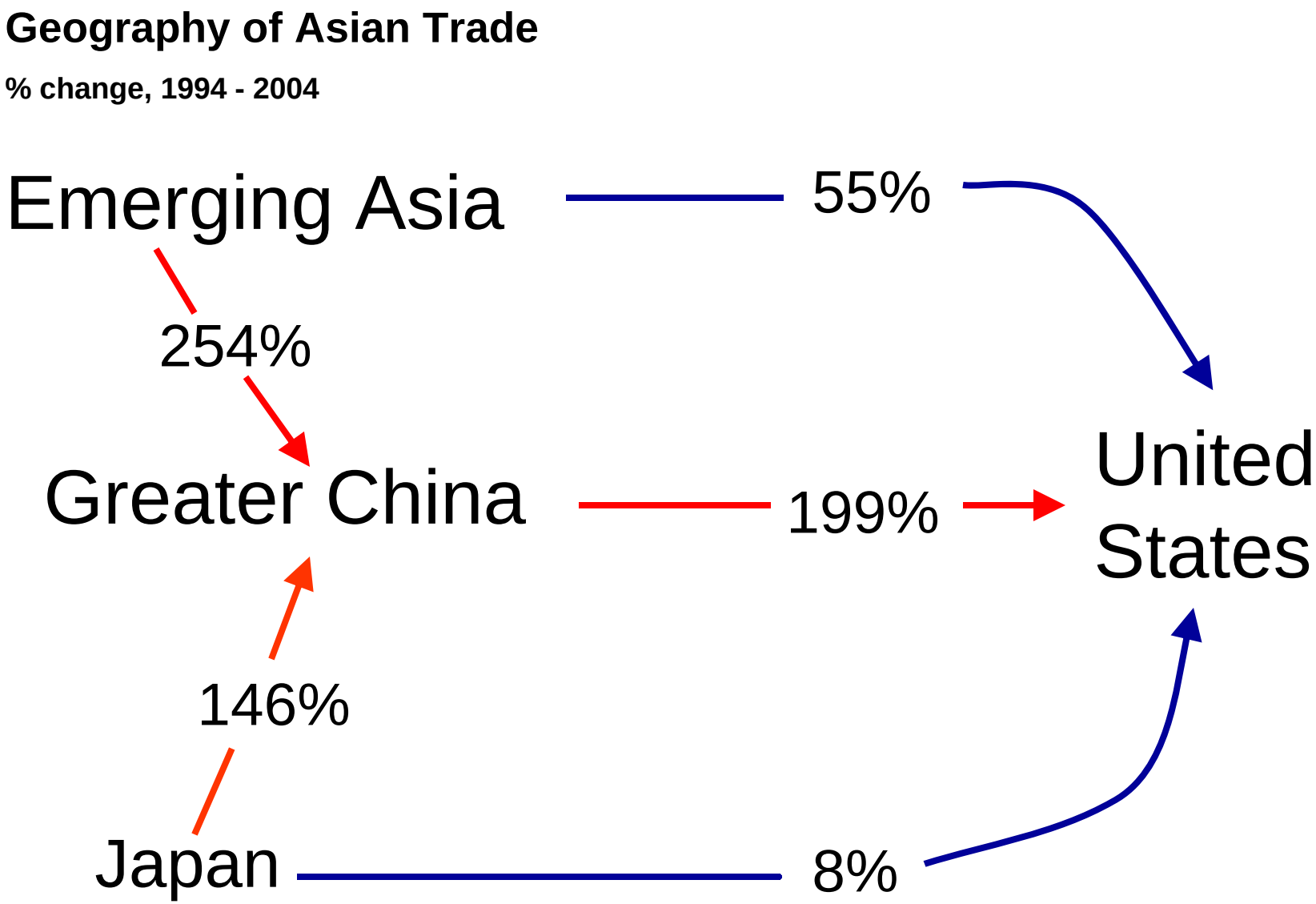
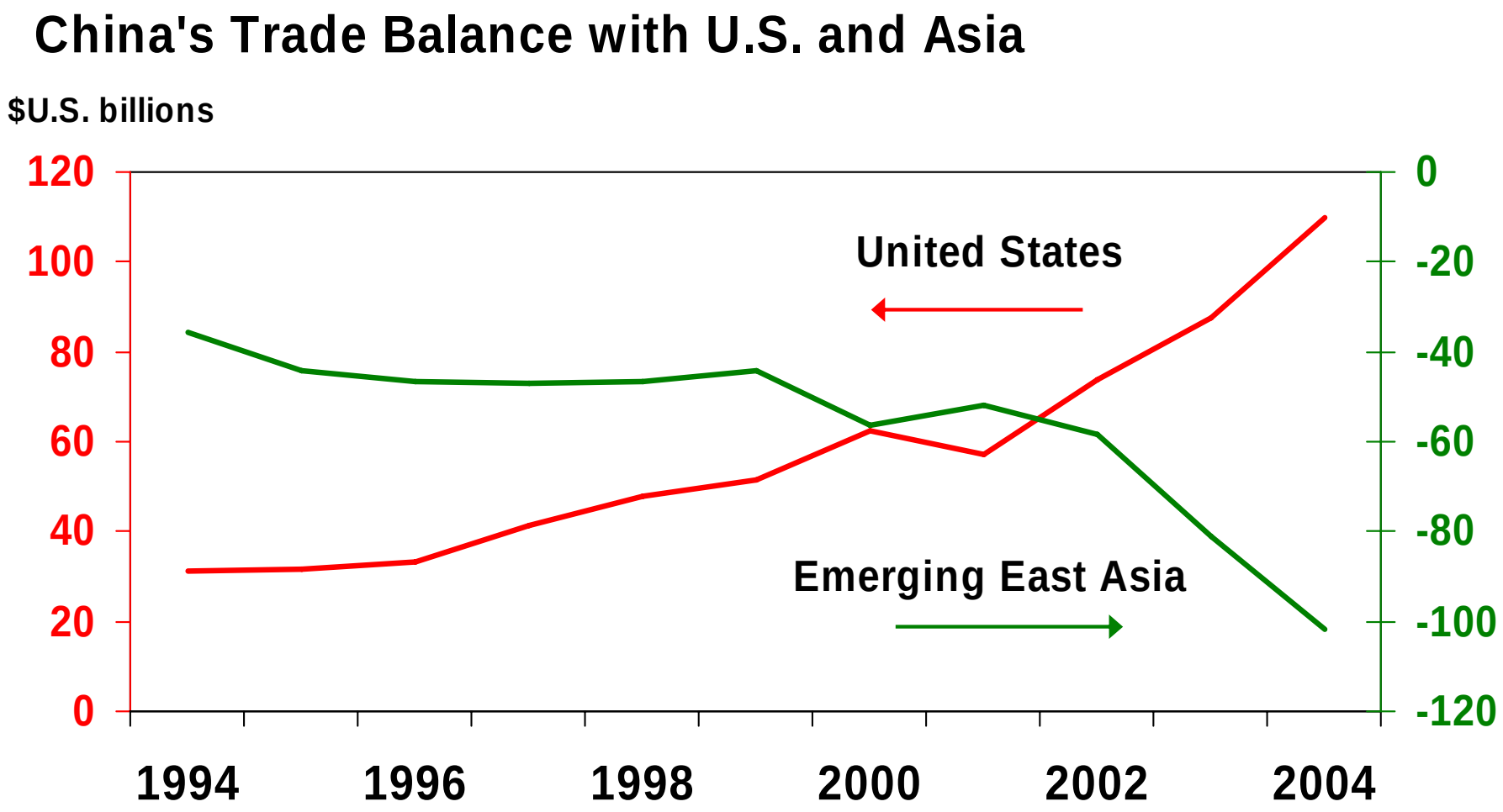
Source: IMF Direction of Trade Statistics

China Integrating Into Asian Trading Network



Source: IMF Direction of Trade Statistics

China runs increasing surplus with U.S. and increasing deficit with Asia



Note: Emerging East Asia = Korea, Indonesia, Malaysia, Philippines, Singapore, Taiwan, Thailand
Source: IMF Direction of Trade Statistics

U.S. Multinational Manufacturing Exports to Foreign Affiliates for Further Manufacture and Foreign Affiliate Exports are Increasing

U.S. Exports for further manufacture to Foreign Affiliates

Manufacturing	billions of dollars	Fraction of Total Exports (percent)	Fraction of Total Affiliate Sales (percent)	Fraction of Affiliate Sales that are Exports (percent)
1977	12.4	15.6	5.3	31.1
1982	26.6	18.8	9.8	33.9
1989	53.9	21.5	10.6	37.8
1994	84.9	21.3	12.2	40.7
1999	126.0	21.9	11.5	41.1

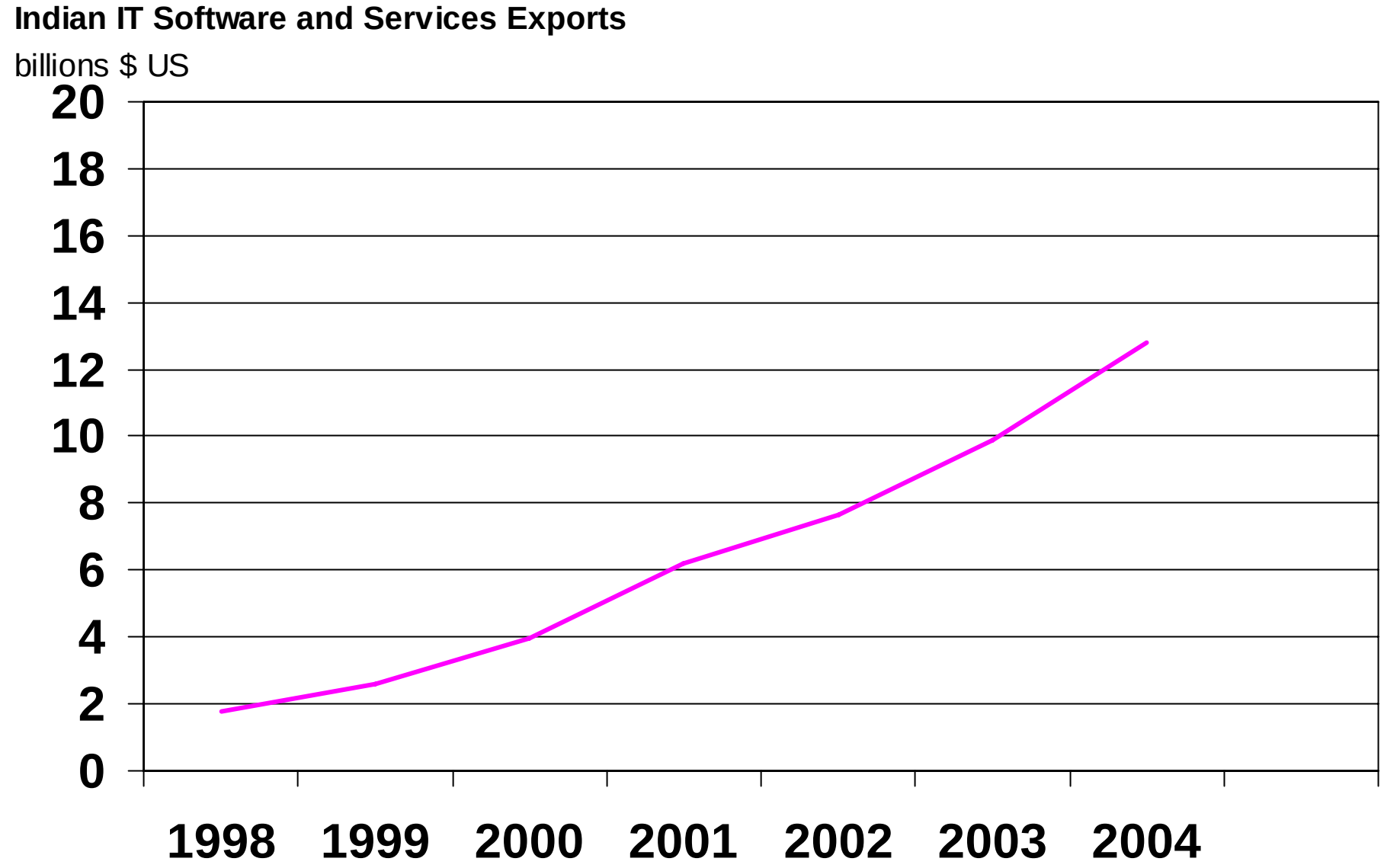
Source: BEA, U.S. Department of Commerce

Fragmentation is also occurring in Services

- India is leading the way among emerging markets in exploiting the fragment-ability of services, especially IT-related services and business processing offshore (BPO) services.
- From 2000 to 2004, India's IT and BPO exports grew from US $4 billion to $12.8 billion
- As of 2005, India has 65% of global offshore IT industry and 46% of global BPO industry
- By 2010, McKinsey projects US $110 billion IT and BPO industries off-shored with $60 billion going to India
- Total potential global off-shoring of IT and BPO industries to low-cost countries estimated to be US $300 billion

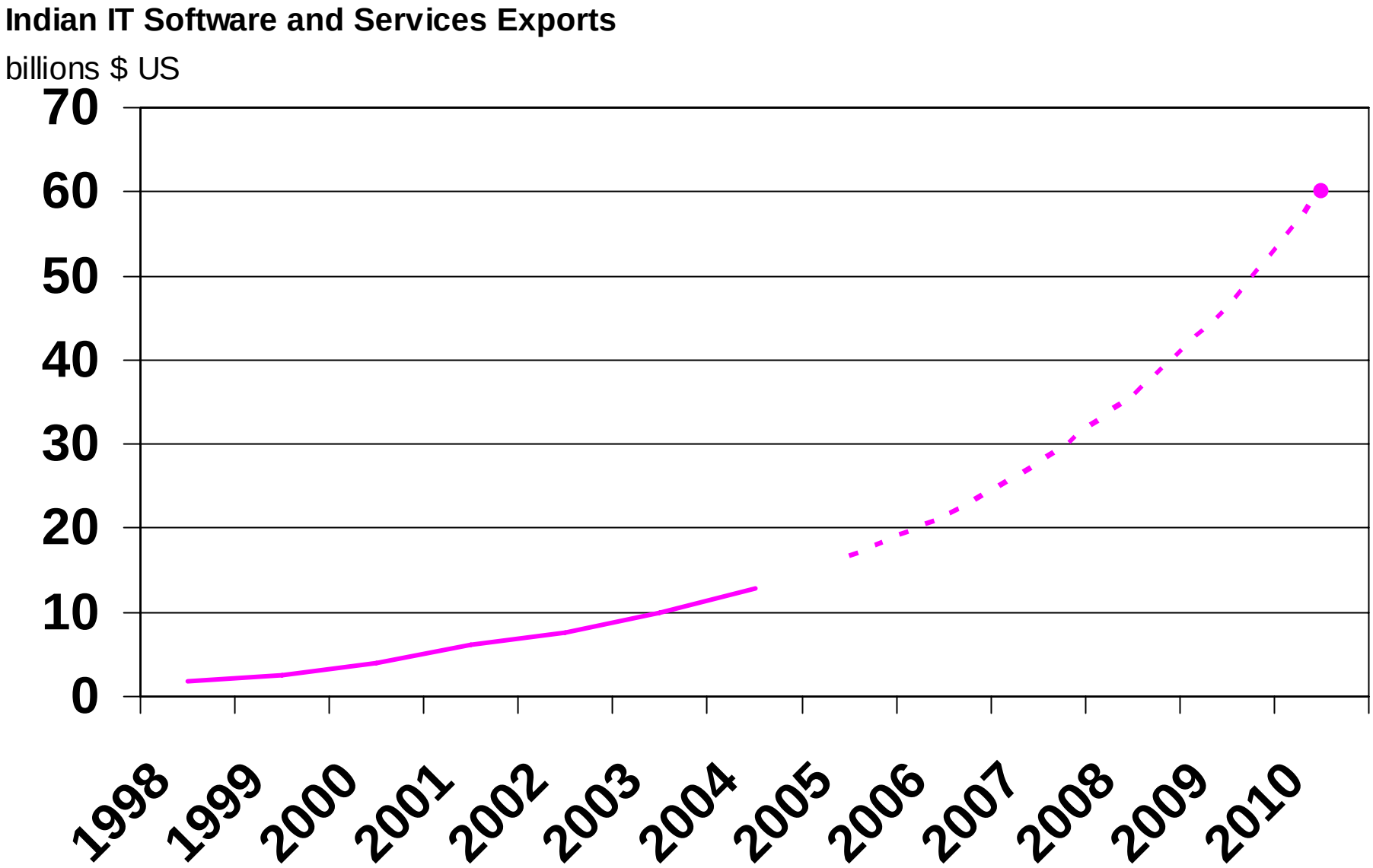
Source: McKinsey and NASSCOM

Off-shoring of IT and other Services to India Increasing Rapidly



Source: NASSCOM, McKinsey Strategic Review 2003 and 2005

Off-shoring of IT and other Services to India Projected to Continue Rapid Expansion



Source: NASSCOM, McKinsey Strategic Review 2003 and 2005

Measuring International Fragmentation

1. Vertical specialization: Definition
2. Measures of vertical specialization: VS and VS1
3. Another measure of fragmentation

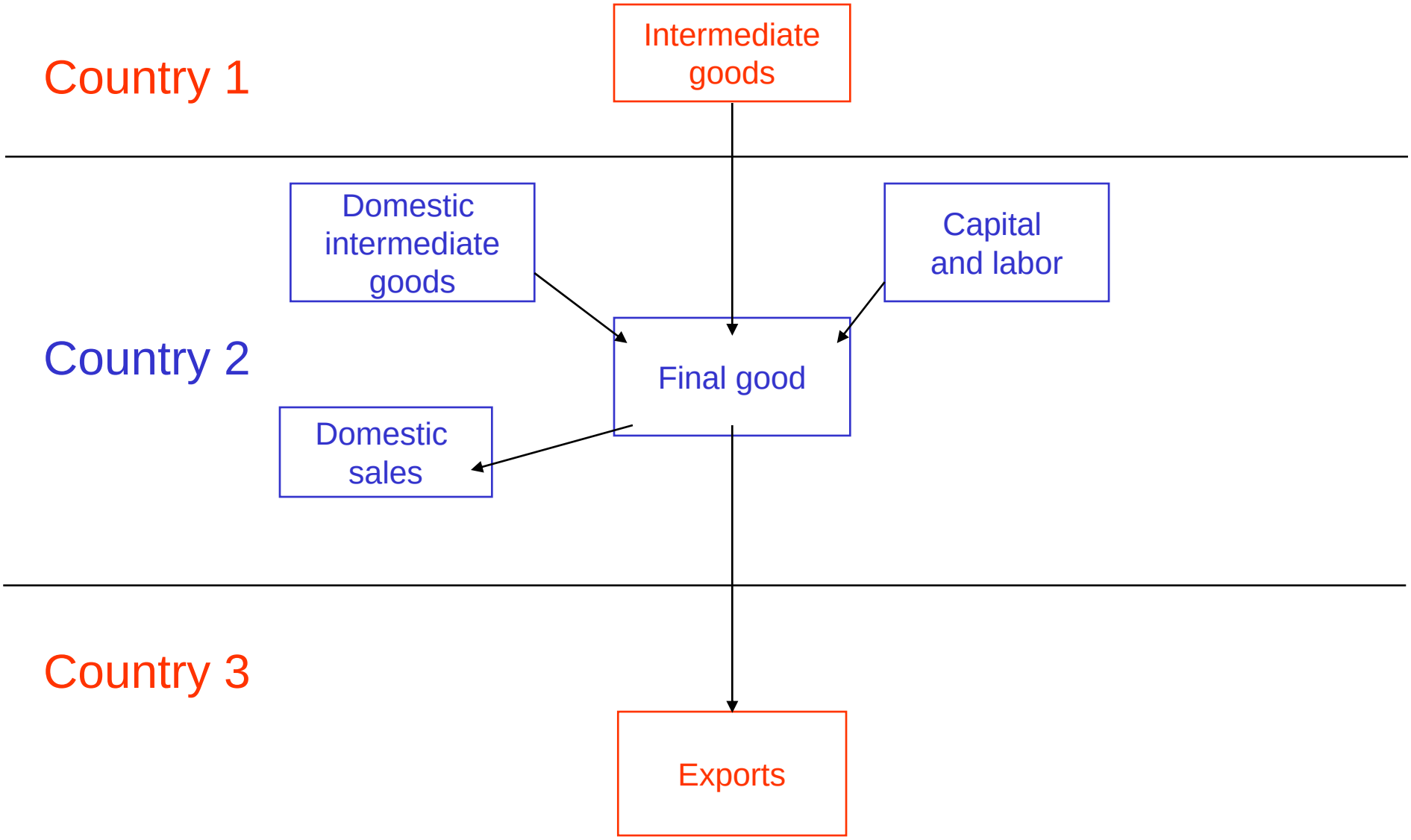
Vertical Specialization: Concepts

- **VERTICAL SPECIALIZATION**:
  - Goods are produced in multiple sequential stages
  - Two or more countries provide value-added in the good's production process
  - *At least one country 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 country 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 country k's exports of good i.

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

Extension of Basic VS Measure

• 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 and 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 n x n imported coefficient matrix, **X** is an n x 1 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 n x n domestic coefficient matrix.

- This is our primary measure of vertical specialization exports (VS)

Second Extension of Basic VS Measure

VS1: Those exports of a country that are used as intermediate inputs to produce another country's goods that are then exported

- Example: U.S. engine part exports to Mexico's *maquiladoras* that are later exported back to the U.S.
- For country *k* and good *i:*

$$VS1_{ki} = \sum_{j=1}^{n} XI_{kji}\left(\frac{X_{ji}}{GO_{ji}}\right)$$

- Much more difficult to calculate than VS
  - Need bilateral input-output tables

Other Measures of International Fragmentation

- Most common measure is: imported inputs / gross output
  - cf. Feenstra and Hanson, Campa and Goldberg, and many others

- VS share of exports is related to this other measure
  - At the most disaggregated level of detail of the data used, VS share of exports and II/GO are the same
  - However, when data are aggregated up to yield a country-level share, the VS share is equivalent to an *export*-weighted average of the detailed VS export shares, while II/GO is equivalent to an *output*-weighted average of the detailed II/GO shares.
  - If high VS share sectors also tend to be industries that export a large fraction of output, than II/GO will underestimate the vertical specialization share

Vertical Specialization Measures from Three Case Studies

1. Mexico's maquiladoras
2. Japan and emerging East Asia electronics trade
3. China

Mexico's *maquiladoras*

- *Maquiladoras:* Production plants in Mexico that complete processing or secondary assembly of imported components for export
- Almost all maquiladora trade is not subject to tariffs
  - Imports of components are not subject to Mexican tariffs
  - U.S. imports of maquiladora-made goods are subject to tariff only on Mexican value-added
  - Typical maquiladora good: 80% U.S. content, 20% Mexico content
  - E.g. in 2000, imported raw materials = $53.5 billion, value-added = $17.8 billion of value-added, and exports = $79.4 billion

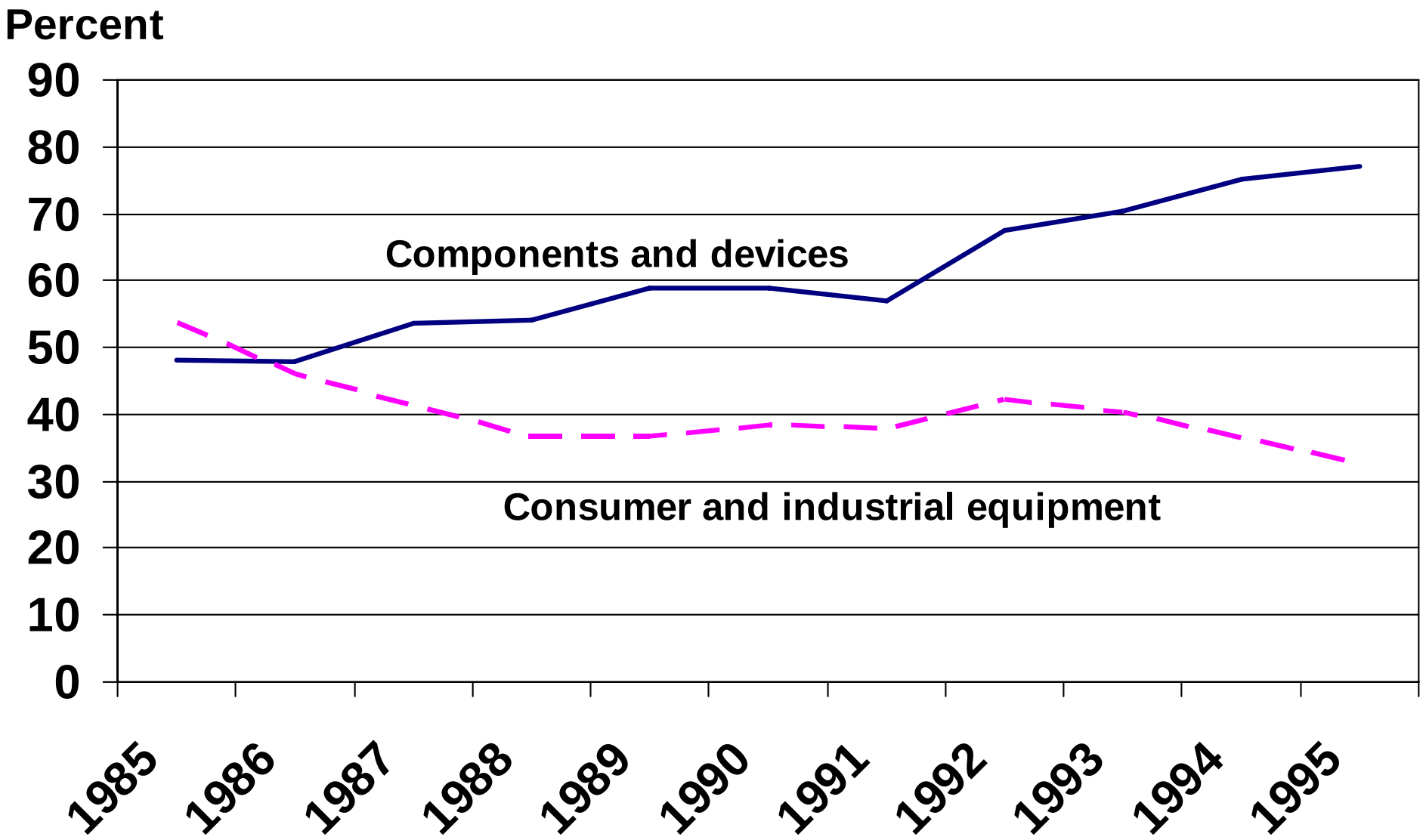
Mexico's *maquiladoras (con't)*

- Program existed since mid-1960s, but rapid growth only since early 1980s; now large
  - As of 2000, employed over 1.3 million workers; now about 1.2 million
  - Maquiladora exports account for 45% of Mexico's total exports in 2005
  - Because of maquiladoras, about 90% of Mexico's exports go to U.S.
  - Principle maquiladora industries in terms of employment as of 2006 are: electronics (32%), transportation equipment (23%), and textiles/apparel (14%)

Mexico's VS Exports

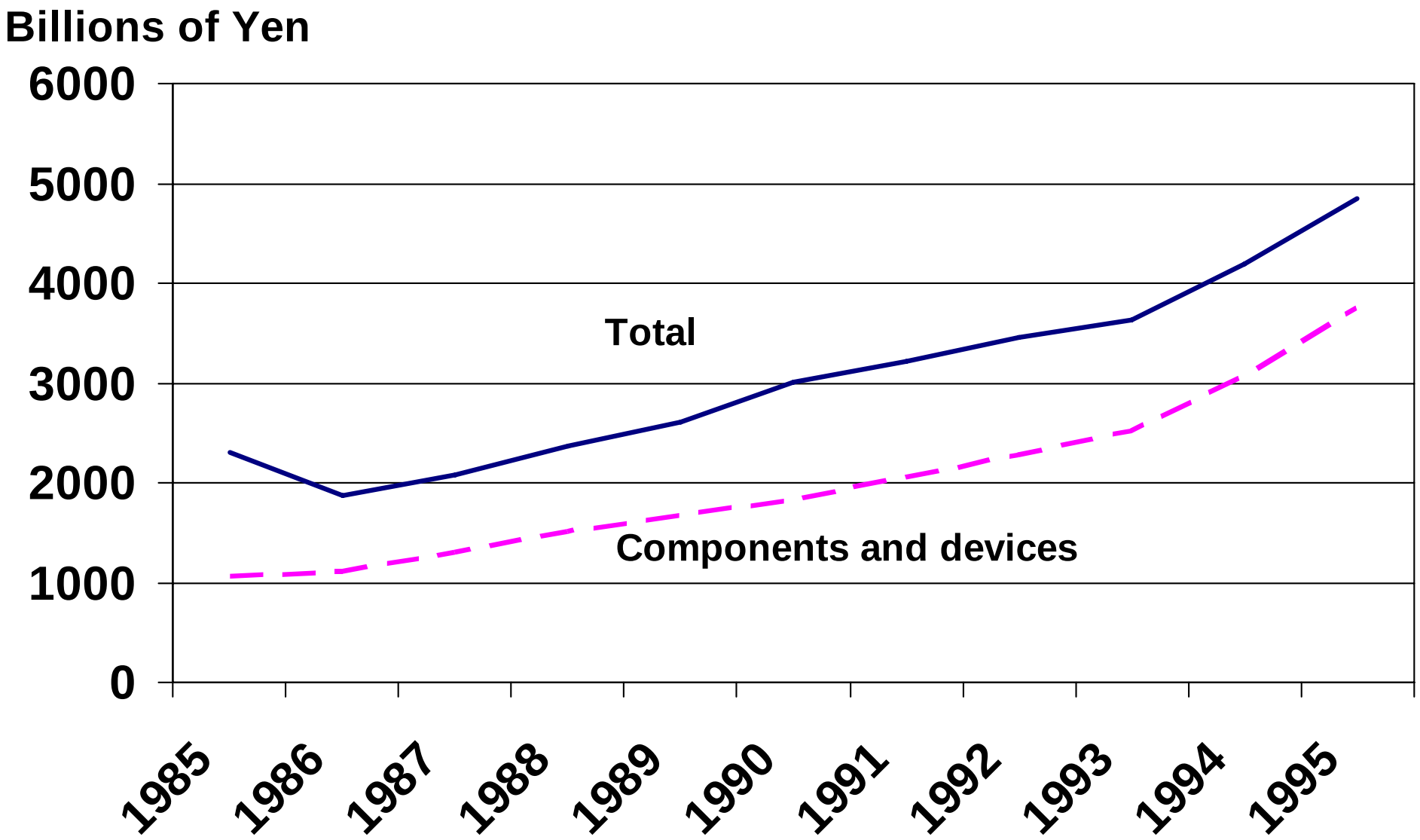
Source: Hummels, Ishii, Yi (2001)

Japan Electronics Industry: Export share of production



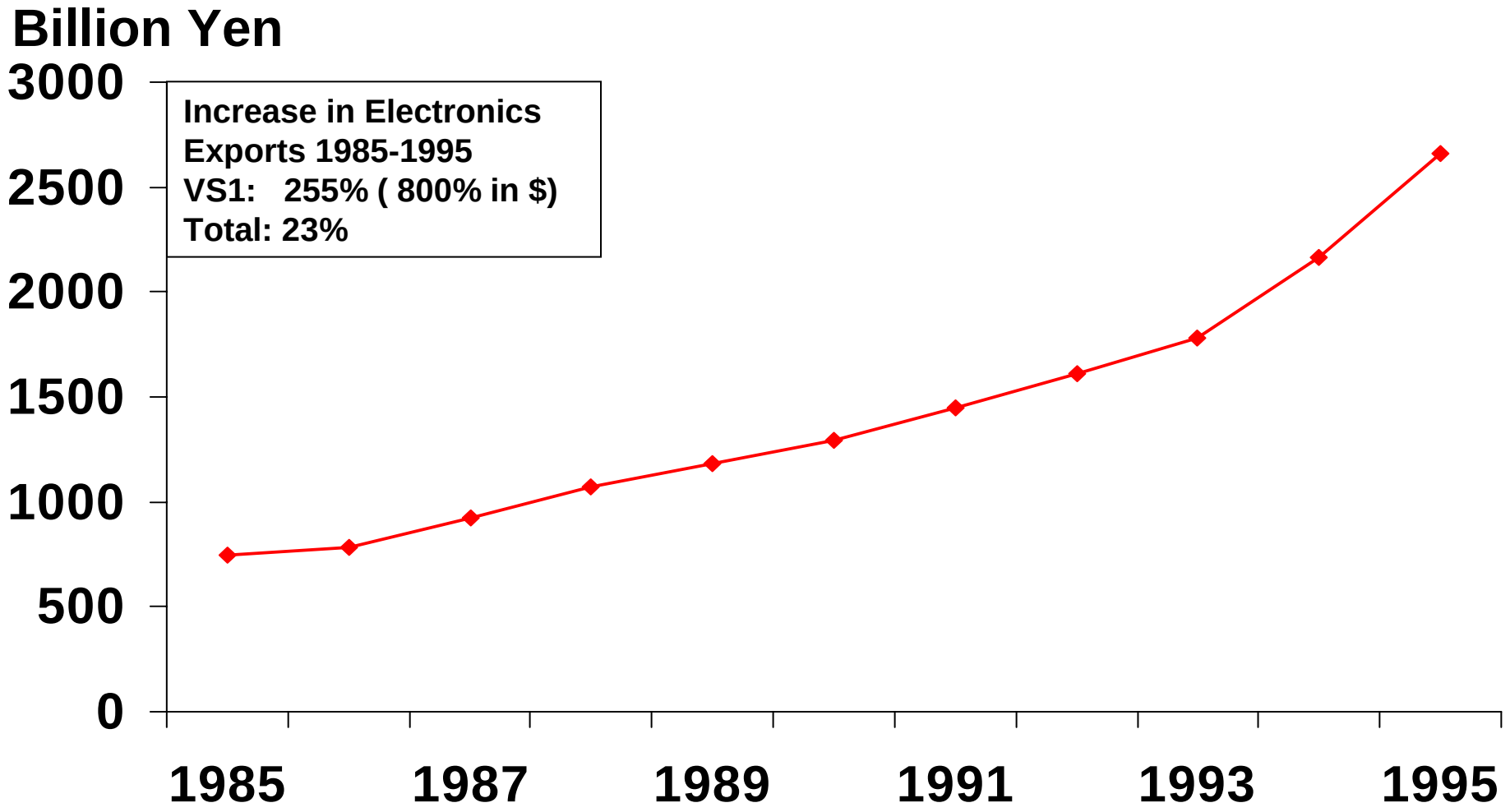
Sources: Electronic Industries Association of Japan; Japan Electronics Bureau; IMF International Financial Statistics

Japan Electronics Industry: Exports to Asia



Sources: Electronic Industries Association of Japan; Japan Electronics Bureau; IMF International Financial Statistics

Japan's VS1 in Electronic Components with Emerging East Asia



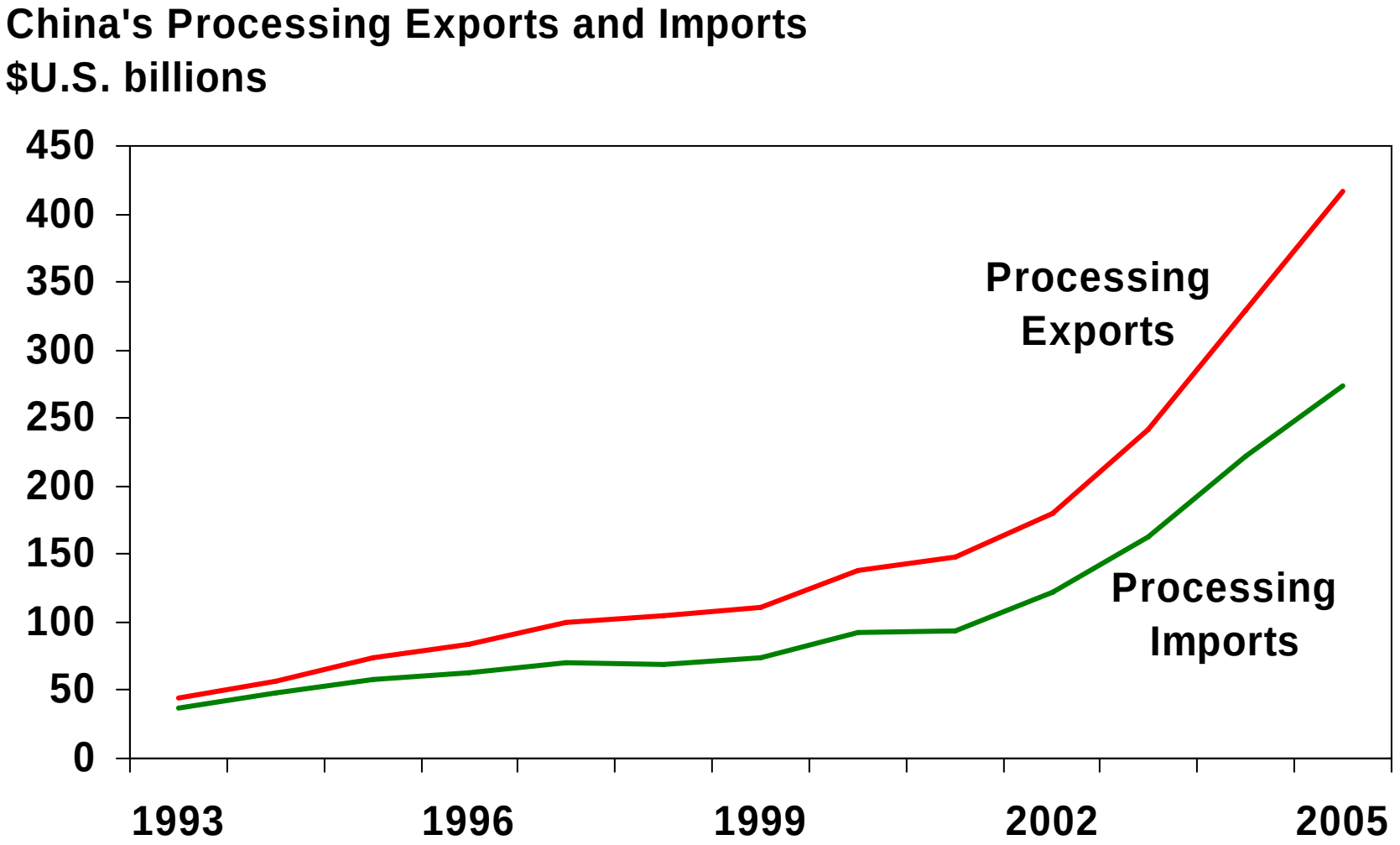
Source: Hummels, Rapoport, Yi (1998)

China Becoming Major Processing Hub

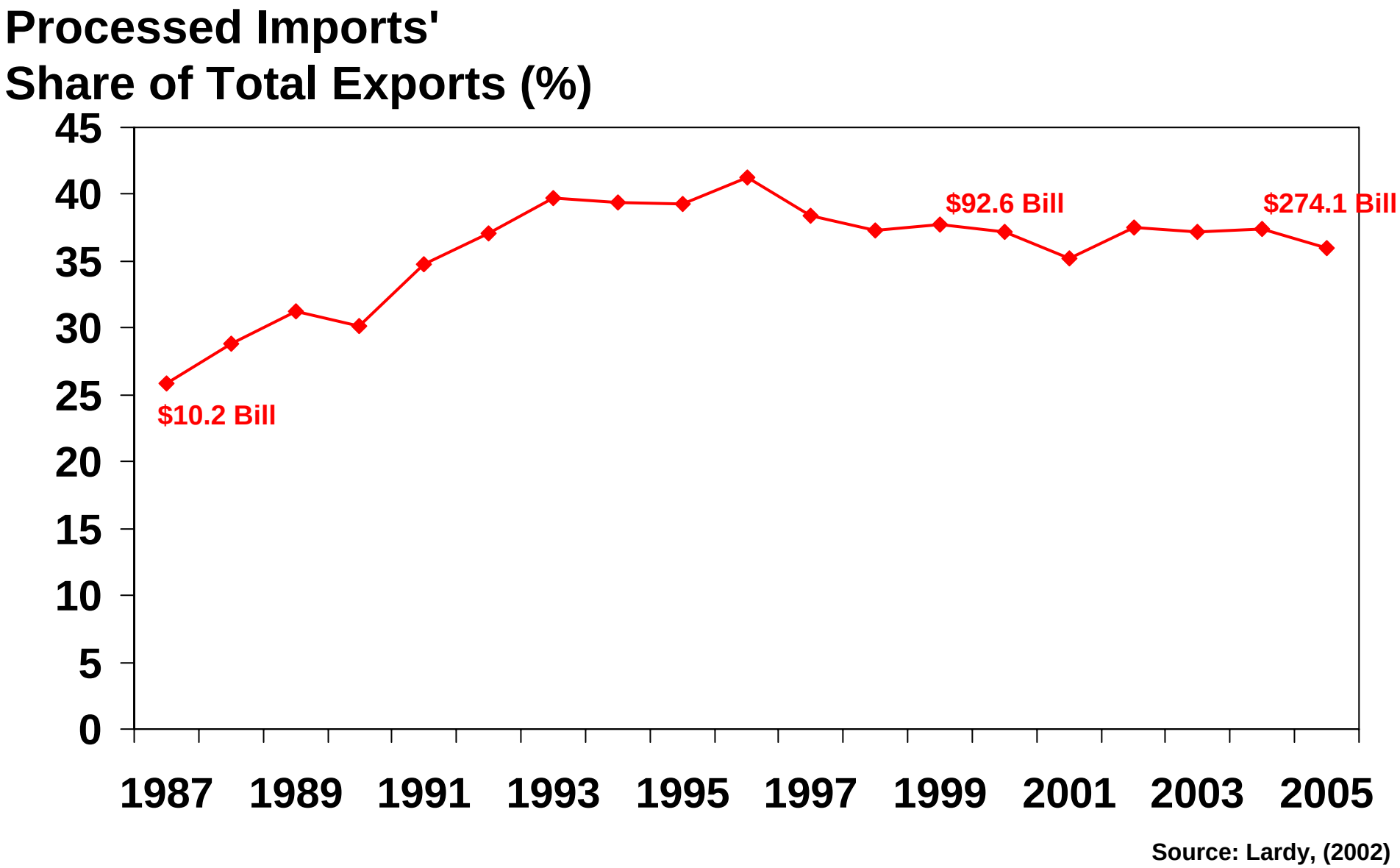
- Japan, Korea, Taiwan, etc. produce and export parts and components to China
- China does final assembly and then exports finished goods to the rest of the world — especially United States

- Processing trade accounts for about 50% of China’s total trade

Result of Integration: Surging Processing Trade



China's Vertical Specialization (VS)



Source: Lardy, (2002)

The “Made in China” Fallacy

- Up to $600 billion of U.S. goods purchased by U.S. consumers in 2005 were “Made in China”.
  - This is 37 percent of all U.S. consumption expenditure on goods other than food, fuel, and autos
  - However, most of this spending is “markup” to cover U.S. R&D, distribution, marketing, and other costs.
  - U.S. imports from China were only $244 billion in 2005.

The “Made in China” Fallacy

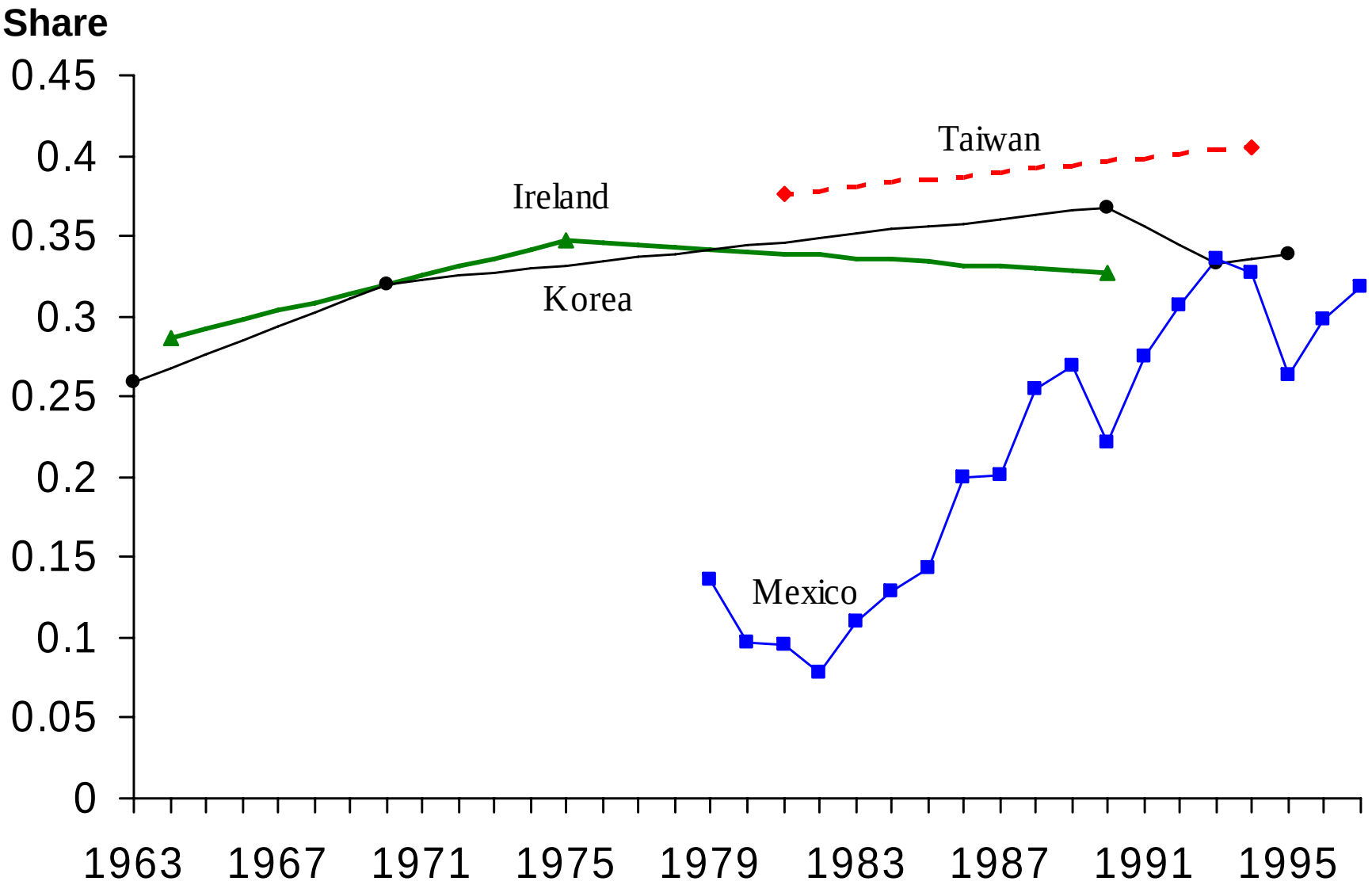
- Also China imports many of the inputs used in its production.
  - Imported inputs are about 50 percent of gross production
  - China’s value-added was about $120 billion.

- Only about 20 percent of value of “Made in China” goods is truly from China.

Vertical Specialization Measures from Input-Output Tables

1. Ireland, Taiwan, South Korea
2. OECD countries
3. United States

VS Exports As a Share of Merchandise Exports



Source: Hummels, Ishii, Yi (2001)

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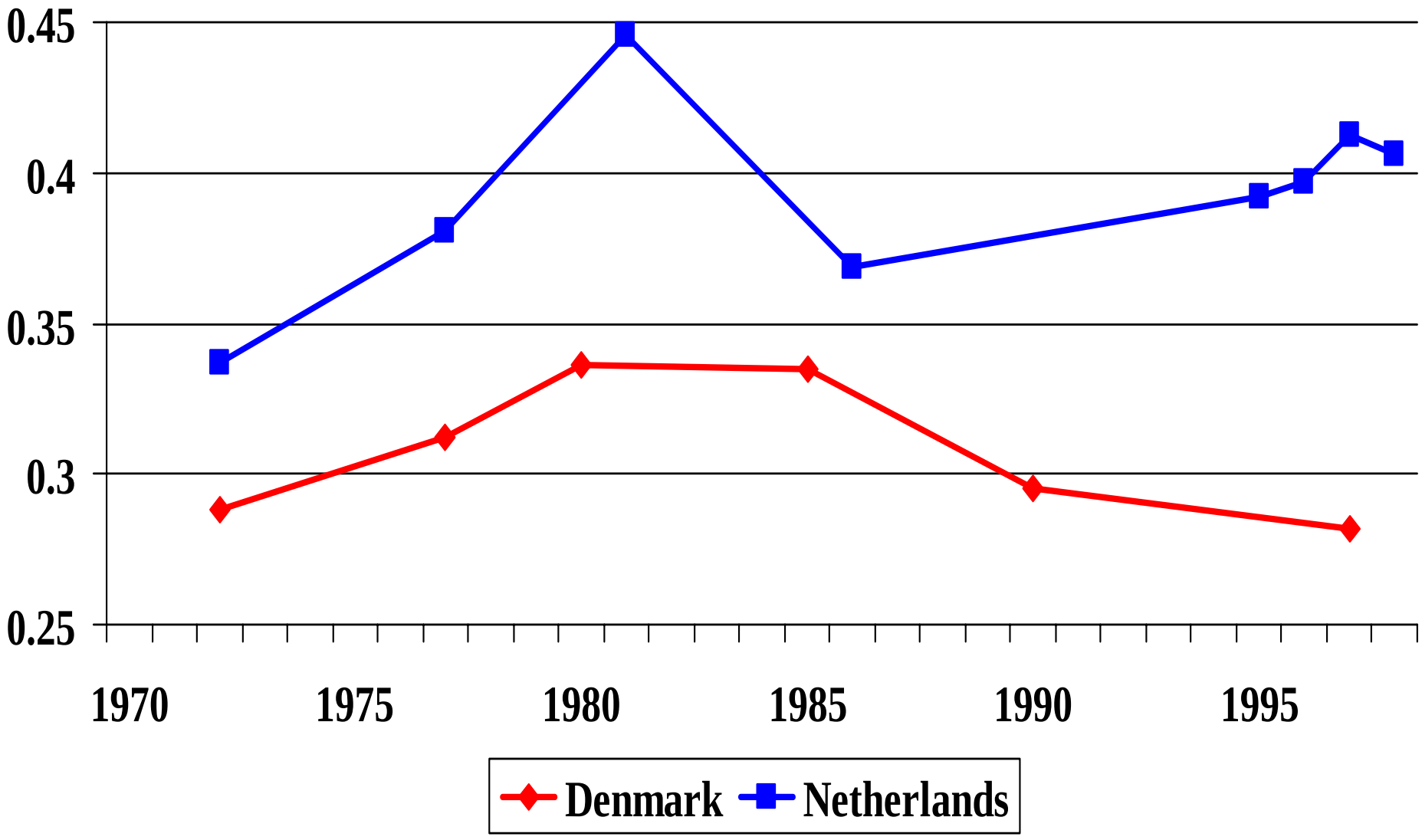

Source: Author's calculations from OECD Input-Output Tables

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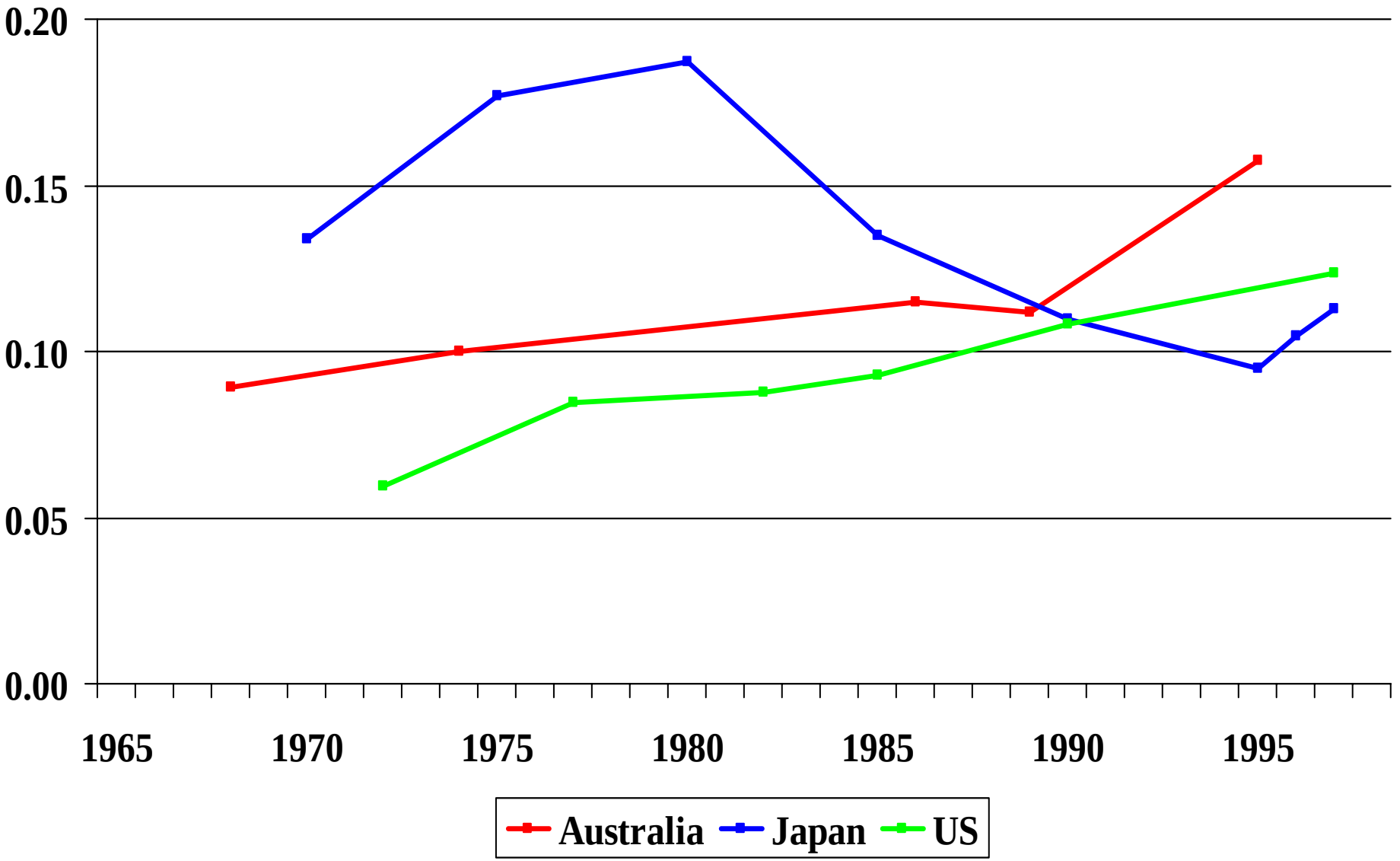

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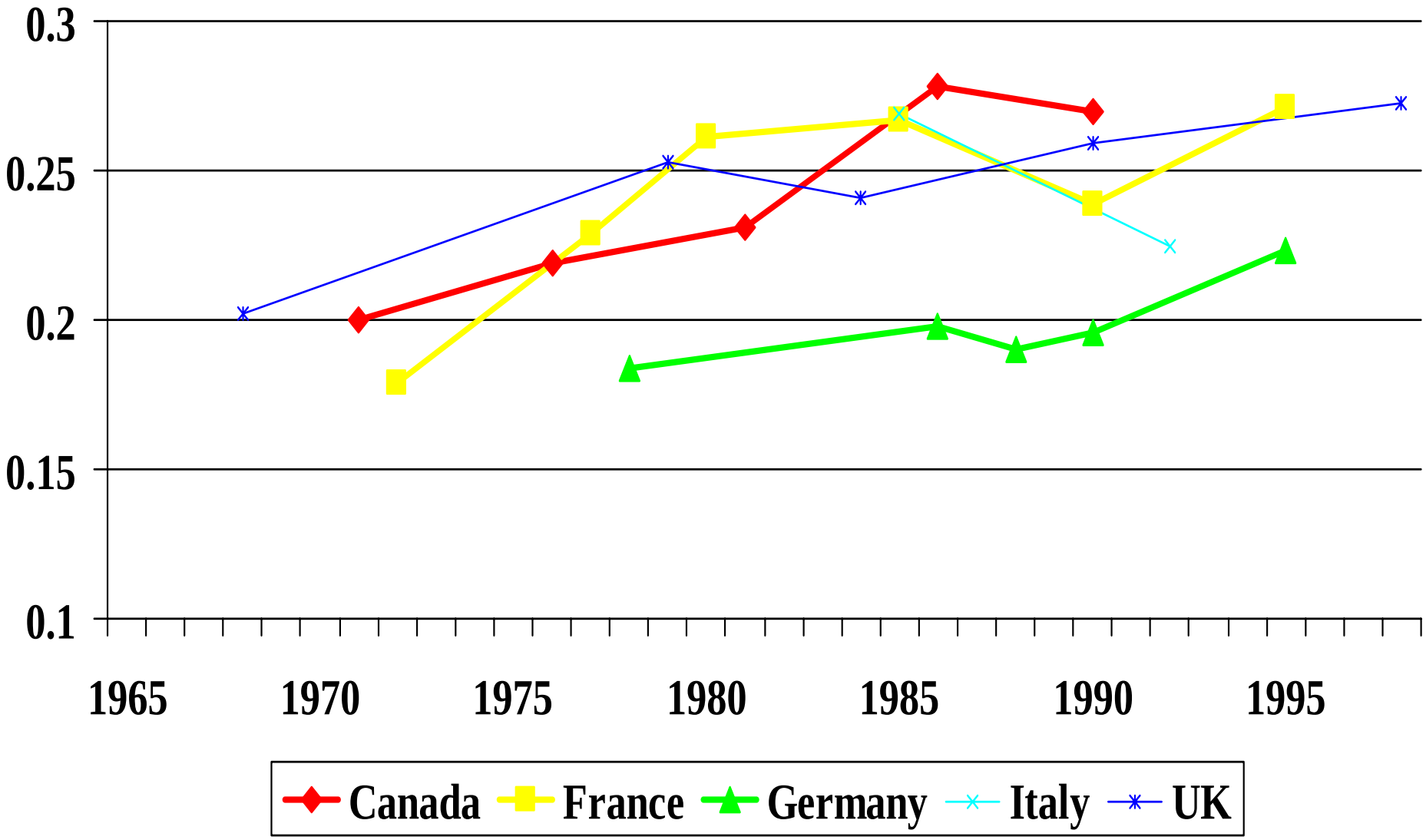


Source: Author's calculations from OECD Input-Output Tables

VS Exports as a Share of Merchandise Exports

Year	Australia	Canada	Denmark	France	Germany	Italy	Japan	Netherlands	UK	US
1968	8.9%								20.2%	
1969										
1970							13.4%			
1971		20.0%								
1972			28.8%	17.9%				33.7%		5.9%
1973										
1974	10.0%									
1975							17.7%			
1976		21.9%								
1977			31.2%	22.9%				38.1%		8.5%
1978					18.4%					
1979									25.3%	
1980			33.6%	26.1%			18.7%			
1981		23.1%						44.6%		
1982										8.8%
1983										
1984									24.1%	
1985			33.5%	26.7%		26.9%	13.5%			9.3%
1986	11.5%	27.8%			19.8%			36.9%		
1987										
1988					19.0%					
1989	11.2%									
1990		27.0%	29.5%	23.9%	19.6%		11.0%		25.9%	10.8%
1991										
1992						22.5%				
1993										
1994										
1995	15.7%			27.1%	22.4%		9.5%	39.2%		
1996							10.5%	39.7%		
1997			28.2%				11.3%	41.3%		12.3%
1998								40.7%	27.2%	

Source: Author's calculations from OECD Input-Output Tables

VS Exports as a Share of Merchandise Exports

TABLE 1

VS EXPORTS AS A PERCENTAGE OF MERCHANDISE EXPORTS: OECD DATABASE, SECTOR AND OVERALL RESULTS

	Australia		Canada		Denmark		France		Germany		Italy	Japan		Netherlands		United Kingdom		United States	
	1968	1989	1971	1990	1972	1990	1972	1990	1978	1990	1985	1970	1990	1972	1986	1968	1990	1972	1990
OVERALL	**9**	**11**	**20**	**27**	**29**	**29**	**18**	**24**	**18**	**20**	**27**	**13**	**11**	**34**	**37**	**20**	**26**	**6**	**11**
CHEMICALS	**17**	**21**	**17**	**21**	**35**	**33**	**21**	**27**	**24**	**24**	**33**	**12**	**18**	**30**	**42**	**23**	**26**	**5**	**9**
Industrial chemicals	18	22	17	21	39	39	21	28	24	24	34	13	19	30	42	24	28	5	10
Drugs & medicines	11	17	13	12	26	25	19	25	0	0	24	7	8	29	33	14	16	3	5
MACHINERY	**19**	**23**	**37**	**44**	**31**	**33**	**18**	**25**	**15**	**17**	**24**	**10**	**9**	**36**	**42**	**15**	**29**	**6**	**12**
Non-electrical machinery	12	20	20	25	28	31	19	22	14	14	23	10	9	32	34	14	24	5	9
Office & computing machinery	0	0	37	52	0	0	23	32	15	19	36	10	10	37	44	11	37	5	18
Electrical apparatus, n.e.c.	13	20	17	22	29	32	17	21	14	15	22	14	12	37	42	19	26	6	10
Radio, TV & Comm. Equip.	20	32	21	41	33	36	14	18	0	0	25	9	9	0	0	16	29	5	13
Shipbuilding & repairing	9	19	16	33	36	38	17	27	17	21	23	9	9	35	34	11	22	6	8
Other transport	10	12	24	29	51	39	9	11	0	0	16	9	9	32	47	13	28	8	12
Motor vehicles	27	27	44	51	0	0	18	25	16	20	25	9	9	43	51	16	32	8	17
Aircraft	26	16	23	25	0	0	22	35	18	22	27	25	31	48	59	13	32	5	9
Professional goods	22	21	16	26	25	28	14	15	12	14	21	9	8	28	30	13	23	5	8
OTHER	**8**	**10**	**11**	**15**	**27**	**27**	**17**	**22**	**22**	**22**	**28**	**18**	**16**	**33**	**34**	**25**	**22**	**6**	**10**
Agriculture, forestry & fishing	6	7	7	11	17	20	6	13	15	16	13	5	6	14	16	16	14	4	6
Mining & quarrying	6	9	6	7	21	7	21	23	10	14	4	7	7	3	6	7	13	2	5
Food, beverages & tobacco	8	8	10	13	22	24	11	16	22	21	22	15	12	28	32	28	19	6	7
Textiles, apparel & leather	21	23	23	26	42	39	20	26	24	25	25	15	15	45	53	24	32	7	12
Wood products & furniture	14	16	10	13	31	31	15	18	17	17	19	24	18	31	39	33	27	6	7
Paper, paper products & printing	18	18	9	12	24	28	13	20	19	24	22	9	9	23	28	21	23	6	8
Petroleum & coal products	57	22	38	37	77	53	34	37	47	44	58	42	51	64	63	52	16	10	27
Rubber & plastic products	19	20	19	23	36	38	23	33	19	21	33	11	11	37	41	20	29	5	9
Non-metallic mineral products	10	11	10	13	19	23	8	11	14	14	19	11	9	17	21	15	18	4	6
Iron & steel	9	15	17	22	26	31	24	25	25	20	36	22	17	34	29	21	25	10	9
Non-ferrous metals	6	10	16	24	44	44	43	45	40	39	49	38	43	0	0	44	33	18	15
Metal products	9	15	15	21	33	33	16	19	17	16	20	11	10	29	32	18	24	7	9
Other manufacturing	14	18	17	25	27	26	15	16	17	18	34	11	9	41	32	18	26	10	10

Source: Authors' calculations based on OECD Input-Output Database.

Geographic Distribution of VS

TABLE 5

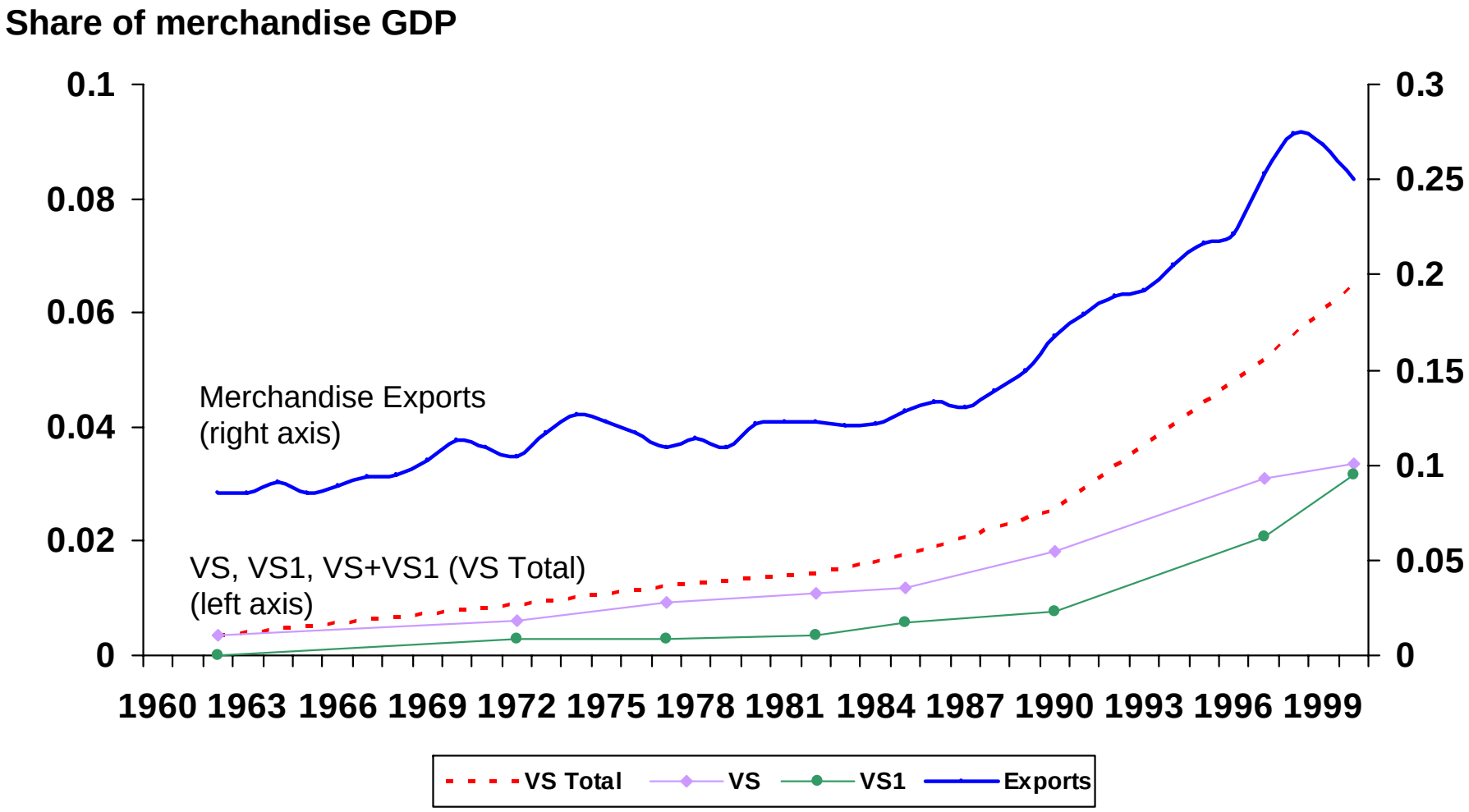
NORTH-SOUTH DISTRIBUTION OF VS

Initial year		**Partner VS as a % of total VS**		
		Origin - Destination		
Country	N-N	N-S	S-N	S-S
Australia	47.4	26.3	17.3	9.0
Canada	87.5	6.6	5.3	0.6
Denmark	64.6	15.3	17.3	2.8
France	50.5	21.6	20.0	7.9
Germany	59.1	18.2	17.2	5.5
Italy	50.1	19.0	22.8	8.1
Japan	29.2	28.5	20.9	21.3
Netherlands	67.0	14.3	15.6	3.1
United Kingdom	48.5	24.5	18.2	8.9
United States	48.8	25.1	17.2	8.8

Final Year		**Partner VS as a % of total VS**		
		Origin - Destination		
Country	N-N	N-S	S-N	S-S
Australia	43.1	27.5	17.0	12.4
Canada	86.0	5.5	7.9	0.6
Denmark	72.4	12.6	12.9	2.1
France	62.1	17.3	16.2	4.4
Germany	61.4	15.8	17.9	4.9
Italy	56.3	16.9	20.5	6.2
Japan	29.8	24.9	23.2	22.2
Netherlands	69.5	9.7	18.5	2.3
United Kingdom	66.1	17.2	13.3	3.4
United States	40.7	22.6	22.6	14.2

Source: Authors' calculations. See Appendix V.

U.S. VS and VS1



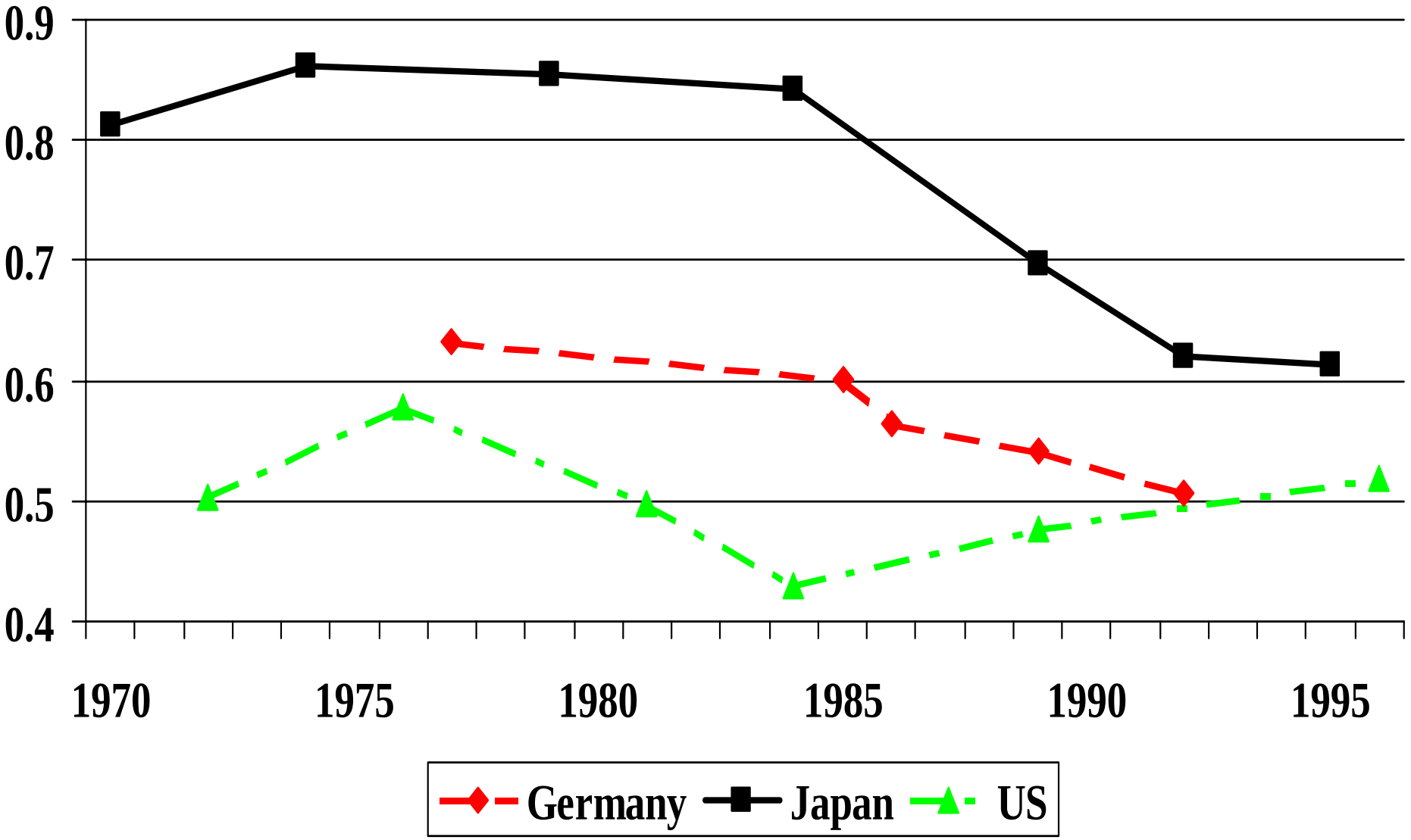
Source: Yi (2003)

Conclusion

- Great deal of anecdotal evidence that international fragmentation is increasing
- Systematic measurement is necessary
- Vertical specialization is one such measure
- VS and VS1 measures indicate that for most emerging market countries, it is large and/or increasing rapidly
- However, most VS still involves rich countries

- Estimate of VS share of exports for the world:
  - 1970: 16.5% (G-7, Ireland, Korea, Taiwan, Mexico, Australia, Denmark Netherlands) or 18% (larger sample)
  - 1990: 21.1% (same 14-country sample) or 23.6% (larger sample)
  - 2004: 26.5% (G-7, Emerging East Asia, Other Euro area, NAFTA)

Figure 3 - Share of Intermediate Goods in Imports, 1970-1996



Source: OECD Input-Output Tables

Table 1 - Share of Intermediate Goods in Imports

Year	Australia	Canada	Denmark	France	Germany	Italy	Japan	Netherlands	UK	US
1968	59.7%								65.0%	
1970							81.3%			
1971		59.1%								
1972			58.1%	66.8%				65.0%		50.4%
1974	57.9%									
1975							86.2%			
1976		58.1%								
1977			56.0%	69.5%				65.5%		57.8%
1978					63.2%					
1979									60.6%	
1980			59.5%	67.8%			85.5%			
1981		59.1%						71.8%		
1982										49.8%
1984									52.5%	
1985			56.7%	65.5%		75.8%	84.2%			43.0%
1986	56.1%	55.4%			60.0%			63.7%		
1988					56.5%					
1989	53.1%									
1990		54.0%	52.4%	56.9%	54.2%		69.8%		57.2%	47.8%
1992						67.6%				
1995				60.2%	50.7%		62.1%	50.4%		
1996							61.3%	50.1%		
1997			53.6%					48.6%		51.9%
1998								46.7%	55.7%	

Source: OECD Input-Output Tables

Table 3 - Adjusted Services as a Share of Total Exports (U.S.)

Year	Unadjusted Share	Adjusted 1*	Adjusted 2*	Adjusted 3*
1986	**24.9%**	**40.5%**	**44.0%**	**27.7%**
1987	24.5%	39.0%	42.4%	
1988	23.2%	37.1%	40.4%	
1989	23.7%	38.6%	42.0%	
1990	**25.2%**	**39.5%**	**42.7%**	**28.3%**
1991	25.9%	41.5%	45.0%	
1992	26.3%	41.5%	45.0%	
1993	26.7%	42.3%	45.8%	
1994	26.4%	42.9%	46.5%	
1995	25.4%	41.4%	44.9%	
1996	26.0%	42.9%	46.6%	
1997	**25.3%**	**43.1%**	**46.9%**	**30.1%**
1998	25.9%	44.3%	48.2%	
1999	26.4%	46.1%	50.0%	
2000	25.9%	45.4%	49.3%	

Adjusted 1 "Gross" services trade added to services trade. (Assumes 7 to 8 stages with equal value added in each stage.) A multiplier of 6 was used for vertically specialized services.

Adjusted 2 Similar to 1, but assumes 9 to 10 stages with equal value added in each stage. A multiplier of 7.5 was used for this stage as explained in the appendix.

Adjusted 3 Value-added merchandise trade only

Source: Bureau of Economic Analysis (SCB and NIPA) and author's calculations using OECD Input-Output Tables

Table 6 - U.S. Exports to Foreign Affiliates for Further Manufacture and Foreign Affiliate Exports

U.S. Exports for further manufacture to Foreign Affiliates				
Manufacturing	billions of dollars	Fraction of Total Exports (percent)	Fraction of Total Affiliate Sales (percent)	Fraction of Affiliate Sales that are Exports (percent)
1977	12.4	15.6	5.3	31.1
1982	26.6	18.8	9.8	33.9
1989	53.9	21.5	10.6	37.8
1994	84.9	21.3	12.2	40.7
1999	126.0	21.9	11.5	41.1

Source: BEA, U.S. Department of Commerce