THE DETERMINANTS OF U.S. INTRA-INDUSTRY TRADE

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ABSTRACT

Responses from the Yale University survey of 650 research and development executives were linked to U.S. trade statistics at the four-digit SIC level for the years 1965-85 to test several hypotheses concerning intra-industry trade. A new index of intra-industry trade was developed to capture both the level and balance dimensions of import and export flows. Intra-industry trade is found to be more extensive, the higher industry R&D/sales ratios were, the more important economies of learning-by-doing were, and greater the relevance of academic engineering research was, and the more niche-filling strategies were emphasized in new product development. When firms oriented their R&D efforts toward meeting the specialized demands of individual customers, intra-industry trade was lower. The highest levels of intra-industry trade were found in loosely oligopolistic industries.

Keywords: Intra-Industry Trade, International Trade, Research & Development, Learning by Doing.

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I. INTRODUCTION

Since the appearance of pioneering works by Balassa (1966) and Grubel and Lloyd (1971), there have been many empirical studies of economic conditions giving rise to intra-industry trade, e.g., when a nation exports certain kinds of textiles or semiconductors and simultaneously imports other differentiated varieties produced within the same industry category. For a survey, see Greenaway and Milner (1986). This paper taps especially rich new data to provide cross-sectional insights into U.S. intra-industry trade patterns and their changes over time. It also proposes a new measure that captures more effectively than its precursors both the level and balance attributes one would expect when intra-industry trade is extensive.

II. THE DATA

The analysis was made possible by the linking of two major data bases, one estimating U.S. imports and exports as a percent of domestic output for 449 four-digit manufacturing industries over the years 1965-85, and another summarizing research and development executives' characterizations of the technological opportunity and appropriability conditions under which their industries operate.

The import and export to domestic output ratios are conventional, but were difficult to assemble at the four-digit SIC level of detail for a long, consistently defined industry time series. They were adapted from two compilations, one at the National Bureau of Economic Research (NBER) and another at the U.S. Department of Commerce Office of Trade Administration (OTA).[1] The NBER series was more complete and served as the basic building block for our data. Gaps in its coverage were plugged using OTA data, primary data reported by the Census Bureau, or, for nine four-digit industries whose coverage by extant trade statistics was particularly weak, by inserting mean ratios for all manufacturing industries.

More novel is our use of responses from a Yale University survey conducted during the early 1980s, asking 650 U.S. industrial research and development managers to characterize on a seven-point Likert scale numerous facets of the technological opportunity and appropriability environment within which their industries operated.[2] See Levin et al. (1987). Some of the questions elicited for the first time quantitative information on variables believed in principle to influence intra-industry trade. The main variables, a paraphrase of the questions asked managers (underlined), and their hypothesized relationship to intra-industry trade are as follows:

LEARNING. <u>How important is moving quickly down the learning curve as a means of capturing and protecting the advantages of new or improved products?</u> Trade theorists have long believed that the product-specific economies of scale inducing intra-industry trade are closely connected with learning by doing, but no satisfactory measure of the phenomenon was available prior to the Yale survey.

PROGRESS. <u>Since 1970, at what rate have new or improved products been introduced?</u> We expect intra-industry trade emphasizing physical differences in products to be greater, the more rapid progress in product technology has been.

SCIENCE. <u>How relevant were the basic sciences of biology, chemistry, and physics (average of three) to technological progress in the industry during the 1970s?</u> For reasons similar to those articulated in the previous paragraph, one might expect intra-industry trade emphasizing physical differences in products to be greater, the stronger an industry's links to the science base were.

ENGINEERING. <u>How relevant to technological progress was university-based research in chemical, electrical, and mechanical engineering (average of three) during the 1970s</u>? Since much product differentiation entails detailed engineering of product variants, links to the academic engineering research base are expected to influence intra-industry trade positively and more strongly than links to the pure science base.

STANDARD. <u>How important are technological activities aimed at moving toward a standardized or dominant product design?</u> The more standardized products are, the more significant traditional factor abundance rationales for trade are likely to be, and the more one nation with appropriate comparative advantage is likely to dominate trade flows. Thus, we predict a negative association with intra-industry trade.

NICHES. <u>To what extent have technological activities aimed at designing products for specific market segments?</u> Niche-filling and product proliferation strategies have occupied a prominent role in qualitative explanations of intra-industry trade, but measuring them has proved difficult. We hypothesize a positive association.

INDIVIDUAL. <u>To what extent have technological activities aimed at tailoring products to the needs of individual customers?</u> The more individualized product offerings are, the closer contacts must be between the manufacturer and its customers, and so, by analogy to gravitational models of trade, the less likely trade over long distances and national borders will be. Thus, we predict less trade generally, and hence less intra-industry trade, with higher values of this survey response. Several additional variables mentioned repeatedly in the intra-industry trade literature lay outside the bounds of the Yale survey responses, but could be quantified and used in our explanatory model. They include:

R&D/S: Company-financed research and development expenditures (R&D) as a percentage of sales (S) for 1977, as reported for 234 narrowly-defined manufacturing industry groups from the Federal Trade Commission's (FTC) Line of Business surveys (1985). When the survey coverage was for industry groups defined more broadly than at the four-digit level, ratios for the more broadly defined industry were repeated for each applicable four-digit industry. Prior studies using less disaggregated R&D data found intra-industry trade to be more extensive, the higher the R&D/sales ratio.

ADV/S: Media advertising outlays (ADV) as a percentage of sales for 1977, drawn also from the FTC Line of Business surveys. Intra-industry trade stems largely from product differentiation, and advertising intensity has been used as one surrogate for measuring the extent of differentiation.

CR4: The four-seller concentration ratio (in percent) for the applicable U.S. four-digit industry in 1977. Much of the intra-industry trade literature is rooted in the theory of monopolistic competition, but there is no reason to believe that markets must conform to the Chamberlinian large-numbers assumption to sustain high levels of trade. Indeed, product proliferation is more likely in differentiated oligopolies. See Scherer (1979). Since no four-digit manufacturing industries in the United States approached purely monopolistic structure, we hypothesize that intra-industry trade will be greater, the higher CR4. However, we also use a quadratic form to test the hypothesis that intra-industry trade peaks at middling levels of oligopoly.

BARS: The 1971-85 average of the sum of two dummy variables, one with unit value if an industry had trade barriers in place in any given year as a result of "escape clause" actions under the applicable U.S. Trade Act, and the other with unit value in the first three years following imposition of trade restraints under other sections of the Trade Act. The received literature predicts less trade, and hence lower intra-industry trade, when tariff barriers are high, but is ambivalent about the effects of special trade restraint actions like those taken with increasing frequency by the United States during the 1970s and 1980s. Forty-one of our 449 sample industries had such restraints in place during 1980, and 40 had them in 1985.

The Yale survey variables were developed for only 130 industry categories sharing two characteristics: (1) they tracked the definitions used in the Federal Trade Commission's Line of Business program; and (2) they emphasize industries in which technological innovation played a significant role in firms' business strategies. When Yale (or FTC) data were unavailable for specific four-digit industries, the variables for the most nearly corresponding industry group were utilized. To reduce the errors-in-variables problem caused by mismatching, the sample of four-digit industries was truncated for most analyses from 449 to 272, excluding all industries in low-technology Standard Industrial Classification groups 20-25, 27, and 31. Industry group 29 (petroleum refining) was also excluded because its import patterns were distorted by OPEC shocks and comprehensive governmental controls between 1973 and 1981. Of the 130 industry categories covered by the Yale survey, 105 pertain to the 272 industries retained in our smaller sample. The average number of R&D executive responses elicited per industry category in the Yale survey was five, but in 30 cases, there was only one response per industry. The paucity of responses in some cases and the pervasive problem of perceptual error in complex survey responses imply significant errors-in-variables for many of our explanatory variables, imparting a bias toward zero in estimated regression coefficients.

III. MEASURING INTRA-INDUSTRY TRADE

Of the several indices proposed to measure intra-industry trade (see Greenaway and Milner, pp. 60-71), perhaps the most widely adopted has been some variant of the Grubel-Lloyd Index:

$$(1) \quad IIT_{GL} = \{(X_j + M_j) - *X_j - Mj*\} / (X_j - M_j) ,$$

where X_j is exports as a percentage of output or consumption in the j^{th} industry and M_j denotes similarly defined imports. One significant disadvantage is that it characterizes the balance between imports and exports more successfully than it measures the levels achieved by both. Thus, if imports are 2 percent of output and exports are also 2 percent, the Grubel-Lloyd index attains its maximum value of 1.0, even though one can hardly say that trade is very active in either direction.

An ideal index of intra-industry trade should increase with both the level of imports and exports experienced by an industry and also with the degree to which imports and exports are similar in magnitude. To satisfy these properties, we have devised a new index:

$$(2) \quad IIT = \frac{\frac{X + M}{2}}{F},$$

where F is the standard deviation of the import and export ratios (with one degree of freedom subtracted). The numerator rises monotonically with the average of imports and exports as a percentage of industry output, as desired. The denominator rises with the difference between the import and export ratios, causing the index to fall with increased disparity, all else equal. One disadvantage is that as the import and export ratios approach equality, the denominator approaches zero, causing the index to explode. To avoid this problem, F was replaced by a fixed cutoff value (set at 3.5) whenever it fell below that value. The choice of the cutoff value is essentially a choice as to how small a difference in the import and export percentages can be before it is no longer meaningful. The chosen value of 3.5 implies that differences smaller than five percentage points are too small to be meaningful.[3] Cutoff value substitutions were made on 171 of the 272 reduced-sample industries for 1965, on 136 for 1975

and on 125 for 1985. Sensitivity tests revealed the results of regressions presented subsequently to be affected inappreciably by cutoff values over the range of 2.0 to 8.0.[4]

Table 1. Average Values of the Intra-Industry Trade Indices at Five-Year Intervals, 1965-1985.

Year	All 449 Industries		272 Industry Sample	
	Mean	Median	Mean	Median
1965	0.763	0.720	0.890	0.793
1970	0.919	0.796	1.106	0.950
1975	1.137	0.901	1.370	1.112
1980	1.342	1.014	1.583	1.278
1985	2.334	1.643	2.321	1.830

Table 1 presents average values of our intra-industry trade indices for all four-digit manufacturing industries and the 272 industry higher-technology sample over five-year intervals from 1965 through 1985. The 272 industry sample is found to have slightly higher average intra-industry trade than the entire manufacturing industry population. More importantly, a strong upward trend over time is observed for both groups.

Grubel-Lloyd indices (equation (1)) were also calculated for the same years and industry cohorts. They correlate only weakly with our new index; e.g., for 449 industries, the zero-order correlation is 0.349 for 1965, 0.496 for 1975, and -0.045 for 1985. They also exhibit a much weaker upward trend over time, with mean values for 449 industries of 0.428 in 1965, 0.474 in 1975, and 0.480 in 1985. That our new index captures more effectively what is meant by intra-industry trade is suggested by Table 2. It tallies 1975 exports and imports as a percentage of domestic output value, our index, and the Grubel-Lloyd index for three groups of industries -- those ranked 1-7 within the higher technology sample, according to our index; seven industries clustered about the median value of our index; and the seven ranked 256-262 by our index. (The very lowest-ranked industries are uninteresting because of a preponderance of zero values.)

Table 2. Intra-Industry Trade Statistics for Top-Ranked, Median-Ranked, and Low-Ranked Industries, 1975

SIC Code	1975 Exports as % of Output	1975 Imports as % of Output	Our IIT Index*	Grubel-Lloyd Index**
Top-Ranked Industries:				
2611	39.7	43.6	11.90	0.95
3552	35.3	35.3	10.08	1.00
3693	26.4	23.4	7.11	0.94
3699	26.4	21.6	6.86	0.90
3629	19.8	21.6	5.91	0.96
3832	14.4	16.6	4.44	0.93
3541	17.4	12.7	4.29	0.84
Median Industries:				
3497	2.4	5.8	1.17	0.59
3567	28.9	7.0	1.16	0.39
3651	11.0	50.0	1.11	0.36
3952	4.6	3.2	1.10	0.82
3873	8.2	38.6	1.09	0.35
3951	18.7	3.9	1.08	0.35
2899	22.9	4.8	1.08	0.35
Low-Ranked Industries:				
2647	0.7	0.6	0.19	0.94
2648	0.6	0.6	0.17	0.99
2655	0.5	0.6	0.16	0.94
3761	1.0	0.0	0.15	0.00
2652	0.9	0.1	0.14	0.16
3411	0.4	0.3	0.11	0.84
2651	0.6	0.1	0.09	0.25

* Equation (2) above.

** Equation (1) above.

For the top-ranked industries, both our index and the Grubel-Lloyd index have high values. From the import and export ratios, it is clear that industries satisfying both criteria -- a considerable volume of trade in absolute terms, and relative equality of export and import shares -- have indeed been selected. For the lowest-ranked industries, a quite different story emerges. Four of the seven Grubel-Lloyd indices have above-average values due to the close similarity of export and import ratios, despite the absolutely small volumes of trade. The median-ranked industries received middling values on our index because they had either large volumes of trade with considerable inequality or intermediate but well-balanced trade volumes. The Grubel-Lloyd technique assigns relatively high index values to the latter but not the former.

IV. RESULTS OF THE REGRESSION ANALYSIS

To explore why indices of intra-industry trade differ so widely from one industry to another, we perform ordinary least squares regressions using our IIT indices as dependent variable, with the Yale survey and other explanatory variables on the right-hand side. Theory provides little guidance as to model structure, so, with the exception of the market concentration variables, all are introduced in linear form. For a broad overview, we begin with a composite index averaging intra-industry trade indices (equation (2)) over the five years 1965, 1970, 1975, 1980, and 1985, first for the 449 four-digit industry observations and then for the higher-technology 272 industry subset. For the 272 industry group, the mean value of this five-year-average index was 1.45; the median value 1.27; and the maximum value 9.34. Regressions for individual years and a test for homogeneity of the estimated regression coefficients follow.

Table 3 summarizes the regression analysis results, with t-ratios given in parentheses. The differences between regression (3.1) for 449 industries, many with poorly measured explanatory variables, and regression (3.2) for the higher-technology subset, are mostly negligible, so we focus on the better-measured subset. Several of the standard hypotheses are strongly supported. Intra-industry trade was greater, the more important learning by doing is, the more R&D-intensive the industry was, the more relevant academic engineering research (but not basic scientific research) was, and the less individualized products were to specific customers' needs. Intra-industry trade appears to have been most extensive in middling oligopolies, with maximum dependent variable values occurring at four-firm concentration ratios of 40 percent in regression (3.1) and 51 percent in regression (3.2). A rapid rate of new product introduction during the 1970s (PROGRESS) and intensive advertising do not appear to have affected intra-industry trade significantly. The results for the niche-filling variable are contrary to hypothesis for the full 449-industry universe, as is the sign of the product standardization variable for both the full and partial samples.

Higher levels of intra-industry trade are found to occur in

Table 3. Regressions Explaining Cross-Sectional Differences in Inter-Industry Trade

Explanatory Variables	Regression Number and Dependent Variable				
	3.1	3.2	3.3	3.4	3.5
	Average IIT	Average IIT	Average IIT (Log)	1965 IIT	1970 IIT
LEARNING	.324	.292	.118	.142	.222
	(4.13)	(3.37)	(3.74)	(2.15)	(2.93)
PROGRESS	.045	-.067	.001	-.047	-.147
	(0.71)	(0.93)	(0.02)	(0.87)	(2.38)
SCIENCE	-.024	.003	-.008		
	(0.27)	(0.03)	(0.21)		
ENGINEERING	.129	.259	.081	.185	.315
	(2.14)	(2.83)	(2.44)	(2.82)	(4.18)
STANDARD	.066	.065	.045	.051	.030
	(1.15)	(0.98)	(1.86)	(1.02)	(0.52)
NICHES	-.056	.126	.018	.004	.153
	(0.65)	(1.31)	(0.52)	(0.06)	(1.92)
INDIVIDUAL	-.147	-.239	-.079	-.158	-.189
	(2.75)	(3.41)	(3.10)	(3.22)	(3.35)
RD/S	.150	.110	.044	.168	.067
	(3.85)	(2.50)	(2.77)	(5.20)	(1.81)
ADV/S	-.021	-.027	-.002		
	(0.85)	(0.81)	(0.20)		
CR4	.0102	.0151	.0113	-.0008	.0103
	(1.10)	(1.36)	(2.82)	(0.09)	(1.06)
CR4SQ	-.00013	-.00015	-.00009	.00001	-.00008
	(1.30)	(1.31)	(2.20)	(0.16)	(0.81)
BARS	.482	.713			

	(2.10)	(2.16)			
Intercept	-.521 (0.87)	-.927 (1.36)	-1.06 (4.30)	-.030 (0.06)	-.827 (1.57)
N	449	272	272	272	272
R^2	.128	.177	.228	.175	.142

Table 3 (continued)

	Regression Number and Dependent Variable			
	3.6	3.7	3.8	3.9
	1975 IIT	1980 IIT	1985 IIT	IIT (all years)
LEARNING	.303	.311	.495	.301
	(2.82)	(2.93)	(3.02)	(6.19)
PROGRESS	-.092	-.064	-.096	-.077
	(1.05)	(0.74)	(0.72)	(1.95)
SCIENCE				
ENGINEERING	.343	.329	.248	.293
	(3.22)	(3.12)	(1.52)	(6.08)
STANDARD	.033	.140	.090	
	(0.40)	(1.72)	(0.72)	
NICHES	.168	.095	.353	.146
	(1.49)	(0.85)	(2.05)	(2.87)
INDIVIDUAL	-.227	-.192	-.409	-.235
	(2.84)	(2.43)	(3.36)	(6.47)
RD/S	.106	.117	.061	.100
	(2.02)	(2.25)	(0.75)	(4.20)
ADV/S				
CR4	.0110	.0221	.0258	.0138
	(0.80)	(1.63)	(1.23)	(2.21)
CR4SQ	-.00014	-.00022	-.00024	-.00013
	(0.99)	(1.57)	(1.10)	(2.05)
BARS				
Intercept	-1.19	-1.63	-1.50	[5 values]*
	(1.61)	(2.21)	(1.31)	
N	272	272	272	1360

R^2	.120	.145	.105	.213

*See Footnote 6.

industries with high average levels of specially-imposed trade barriers over the 1971-85 period. However, this result may be spurious, since the BAR coefficients were statistically insignificant for the years 1975 and 1980 -- two of the three quinquennial years over which the 15-year average is applicable. Additional regressions relating individual year IIT indices to dummy variables measuring whether special trade barriers were in force during the specific year in question yielded t-ratios of 0.40 for 1975, 0.38 for 1980, and 2.21 for 1985. Thus, whatever relationship there was between trade barriers and intra-industry trade, it seems to have been confined to the particularly turbulent mid-1980s. We therefore omit the average barriers variable from further regressions.

Because the distribution of IIT index values is skewed to the right, it is important to determine whether the results might be sensitive to outlying values. Regression 3.3 takes logarithms of the dependent variable to make its distribution more closely approximate normality. Five zero or near-zero observations were plugged at the value of the sixth-smallest IIT industry index. No important changes in coefficient signs and t-ratios materialize, except that the standardization coefficient approaches statistical significance -- again, with a sign contrary to expectations. Maximum intra-industry trade levels are now found when the four leading U.S. sellers had a combined 62.5 percent share of domestic shipments.

Regressions (3.4) through (3.8) proceed year-by-year at five-year intervals with a slightly reduced set of variables. The learning-by-doing, academic engineering relevance, and product individualization variables perform robustly. Intensive company-financed research and development is also consistently associated with higher intra-industry trade, although the coefficient for turbulent 1985 fades to insignificance.[5] Except in 1965, the market structure relationship has an inverted U-shape, with peak intra-industry trade levels occurring at CR4 values in the range of 39 to 64. The niche-filling orientation variable has the sign predicted by theory in each of the five years and is statistically significant for 1970 and 1985.

Regression (3.9) pools the higher-technology industry group observations for all five years, letting each year have its own intercept value (which increases significantly over time).[6] Again, the results are consistent with patterns observed for the individual years, although t-ratios are generally higher because there are many more degrees of freedom. The NICHES variable performs particularly strongly, and the collinear CR4 and squared CR4 coefficients both attain statistical significance, indicating maximum intra-industry trade with seller concentration at 53 percent. A Chow test for heterogeneity of regression coefficients over time is strongly rejected, with $F(32,1315) = 0.87$. Thus, even though some individual coefficients vary erratically, there is significant consistency over the 1965-85 period in the pattern of intra-industry trade relationships.

V. CONCLUSION

Using a particularly rich set of explanatory variables, we have tested several of the received hypotheses concerning the determinants of intra-industry trade for the United States. Product-specific economies of scale associated with learning by doing, which have figured prominently in the theoretical literature but have previously proved resistant to measurement, live up to expectations. So does an industry orientation toward technologically new product development, manifested in high research and development intensities, high relevance of academic engineering research, and (less consistently) a strategic emphasis on filling niches in product characteristics space. Intra-industry trade is significantly lower when firms tailor their efforts toward meeting the specialized demands of individual customers. It tends to thrive most in industries whose domestic market structure is loosely oligopolistic.

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ENDNOTES

1. We are enormously indebted to John Abowd and Larry Katz of the NBER and Bill Sullivan of the OTA for making available their raw data in machine-readable form. After considerable revision, the NBER and OTA import/output data sets for the overlapping years 1972-86 were highly correlated, with a zero-order Pearsonian coefficient of +0.892. When each set was regressed on the other, the slope coefficients were both less than 1.0, confirming the hypothesis that there are measurement errors in both series.

Richard Caves, Jeff Frankel, and Robert Stern provided invaluable help in guiding us toward usable trade data sources.

2. We are indebted to Richard Levin for providing the data in machine-readable form.

3. With only two observations, F is a constant 0.7071 of the absolute difference between the import and export ratios.

4. With the 272 industry sample, the averaging approach of regression (3.2), and the variables used for regressions (3.4) - (3.8), no coefficient sign reversals or lapses from significance occurred. R^2 values were 0.160 for a cutoff of 3.5, .153 for 2.0, .190 for 5.0, and .201 for 8.0. With F $\geq$ 8.0, 209 of the 272 industry observations required cutoff value substitutions for 1975.

5. During the 1980s, there was evident deterioration not only of the relationship between R&D intensity and intra-industry trade, but also of U.S. comparative advantage in high-technology trade. For 1965, 1970, 1975, and 1980, the zero-order correlations between company-financed R&D/sales ratios and the ratio of net exports (exports less imports as a percentage of domestic output) across 272 industries were 0.188, 0.158, 0.160, and 0.123 respectively. All are statistically significant. In 1985, the correlation fell to 0.024. Similar patterns are evident for all 449 manufacturing industries. The transition to low correlations was gradual as high-technology imports flooded the U.S. market, encouraged by rising and high values of the dollar. The net export correlations were 0.123 in 1980, 0.122 in 1981, 0.087 in 1982, 0.074 in 1983, 0.043 in 1984, and 0.024 in 1985.

6. The intercept values are -1.41 for 1965, 0.22 for 1970, 0.48 for 1975, 0.69 for 1980, and 1.43 for 1985.