Technology and International Specialization *

In this paper we reconsider the cross-section analyses of international specialization. Starting from a criticism of the methodology currently adopted in these exercises, we analyse the relationship between supply characteristics and trade performance of different goods, using an analysis by sub-system, or vertically integrated sector, instead of the traditional analysis by industry. This procedure will allow us to take into consideration the interdependence between industries and final goods and to attribute correctly to each good the corresponding supply characteristics.

The adoption of the proposed methodology has several consequences. First it permits an appraisal of the rôle of the technological interdependencies within the system and allows the construction of indices of *total* technological intensity of each good, which seem more appropriate than traditional indices. Second, it leads to some major changes in the results of the cross-section econometric tests of the Italian patterns of trade.

In the light of these results a reappraisal of some characteristics of Italian specialization is possible.

1. The cross-section analyses of international specialization

In the empirical analyses of the determinants of international specialization, two different groups of exercises stand out: a group of

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aggregate tests, on the lines of the well known contributions by Leontief and a group of *disaggregate tests* based on cross-section regressions or correlations.[1] The latter tests attempt to explain the commodity composition of a country's trade by relating the trade performance of each good to corresponding supply characteristics, such as factor intensities, technological intensities, etc.

These disaggregate analyses were originally proposed as tests of the commodity version of the Heckscher-Ohlin theorem, but later have been extended to other theoretical approaches, falling mainly within neo-factor proportions and neo-technological theories of international trade.[2]

Several recent analyses of the Italian trade pattern are based on cross-section tests of this type and are mainly used to "discover" the supply characteristics regularly associated with the different trade performances of individual goods, both in a static and in a dynamic sense. In this article we concentrate on this type of tests and reconsider the rôle of technology and innovative activity in Italy's foreign trade. To do this, however, we deal first with a characteristic of the analyses under review. Our research, in fact, is prompted by a methodological dissatisfaction with certain general features of these exercises. The attempt to remove this source of dissatisfaction leads to a change in methodology, which in turn determines some major changes in the main results of the empirical analysis.

Consider the following model as a very general example of a cross-industry test of international specialization:

$$T_i = f(x_i, y_i, ... z_i),$$

where the dependent variable T_i is an index of the foreign trade performance of commodity i (i = 1,2...n) of a given country (e.g. an adjusted trade balance or an export market share) and x_i, y_i, and z_i are variables which characterise the supply of commodity i, (e.g. factor intensities, technology intensity or comparative cost indicators derived from a Ricardian framework).

[1] Complete surveys of this literature can be found in STERN (1975), HARTIGAN (1981) and ONIDA (1984) which also considers the Italian literature on the topic.

[2] It may be interesting to note that in the evolution of the empirical literature, the various tests inspired by different theoretical approaches became very similar to each other and seem to be characterised by serious theoretical ambiguities, so that none of them corresponds any longer to a specific theoretical view. On this point see, among the others, LEAMER and BOWEN (1981), STERN and MASKUS (1981) and SOETE (1981).

If we examine the actual variables generally used to estimate the model, one particular feature stands out. The various performance indices T_i always necessarily refer to goods (or groups of goods), because they are calculated on the trade of commodities, which are the object of exchange.[3] Variables x_i, y_i and z_i, which refer to the supply of each individual commodity i, are generally calculated using data referring to each industry i, and are in fact often defined as "industry attributes". This implies that the trade performance T_i of good i is described or explained by means of the characteristics of the corresponding industry i.

This procedure, which is intuitively obvious, and is generally followed in the literature, seems however to be incorrect and may lead to incomplete analyses and misleading results.[4]

In fact, in a system with interdependent industries, the supply counterpart of commodity i is not industry i alone, but is the set of activities which are used in the whole system to produce commodity i, given the backward links of industry i. This set of activities, which belong to many different industries, can be defined and isolated by disaggregating the system into *sub-systems* or *vertically integrated sectors*, following the analysis proposed by Sraffa (1960) and Pasinetti (1973) for theoretical purposes.

For this reason the relationship between the trade performance of commodity i and the corresponding supply characteristics requires an analysis by product and sub-system. The relationship between product i and industry i, in fact, is both logically and empirically incomplete. From the empirical point of view this lack of completeness is particularly serious in a historical phase of fast changing technologies and increasing division of labor between firms and branches.

[3] By their nature the performance indices can be calculated only on trade in products. Partly because sectors and branches are classified with reference to a commodity classification, the indices under review are often referred as "sectoral performances". This definition however may be misleading and is based on the product-industry nexus we criticise.

[4] The procedure of relating goods' performance T_i to *industry* attributes x_i, y_i and z_i is set out formally in HIRSCH (1974), STERN (1975), STERN and MASKUS (1981) and is used in the greatest majority of the disaggregated analyses of international specialization, such as BALDWIN (1971), BRANSON (1971), BRANSON and MONOYIOS (1977), WALKER (1979), SOETE (1980), MASKUS (1983). The only notable exception, to our knowledge, is represented by CARLSSON and OHLSSON (1976), who consider the backward links of the different branches in an analysis of Swedish trade.

2. Products, industries and sub-systems

As we have suggested in previous papers (Momigliano and Siniscalco 1982, Siniscalco 1982) it is empirically possible, starting from an input output table, to disaggregate a productive system into as many sub-systems as there are final commodities. In this disaggregation sub-system *i* is the unit of investigation identified by all the activities used directly and indirectly, in the whole system, to satisfy the final demand for commodity *i*.

The actual methodology used to disaggregate the system into industries and sub-systems is set forth in detail in Appendix A. The logical operation of this disaggregation consists of the subdivision of each branch into as many parts as there are final commodities, with shares of a size that allow us to reconstruct in a "vertical" way the complete productive processes of each final commodity *i* ($i = 1, 2 \dots n$). The result is a table which shows analytically, by row and column, all the relations between the branches and the sub-systems (i.e. final products). This table (which we call operator B) allows us to reclassify any variable linked to production from branches into sub-systems and to attribute the value of this variable to each final commodity, observing the industries of origin thereof.

Even if in our analysis we concentrate on technological variables, adopting a specific theoretical framework, we believe that the methodological point raised by us applies to all disaggregated exercises which explain specialization by means of supply characteristics. It applies to the disaggregated tests of the Heckscher-Ohlin theory, in which the methodology can be used to assign to each commodity the corresponding factor (or neo-factor) content. It applies to tests derived from technological or neo-technological theories, in which the methodology makes it possible to assess the total technological content of each good. It also applies to Ricardian tests, in which the efficiency indicators which refer to individual commodities in the different countries should be constructed by considering the whole set of activities that are used to produce each different good. Incidentally, it is interesting to note that this sort of disaggregate analysis is logically identical to the procedure which is used in the Leontief-type aggregate tests for calculating the factor intensities of a bundle of exports, imports or internal consumption.

In order to observe the empirical implications of the argument put forward above we constructed branch-subsystem tables for all the variables generally used in tests of international specialization.

Let us consider first some general characteristics of the actual sub-systems, as revealed by an analysis in terms of employment and value added.[5]

Table 1 shows the importance of sector *i* within sub-system *i* in terms of employment and value added for all sub-systems producing industrial goods. The values set out in the tables show how much each branch *i* counts in the production of final good *i*, in terms of the variable being examined. The complement to one of these values, on the contrary, shows the weight of the activities outside branch *i* in the production of final good *i*.

TABLE 1

EMPLOYMENT AND VALUE ADDED: WEIGHT OF BRANCH *i* WITHIN SUB-SYSTEM *i**
Italy, 1975

	Employment	Value added
Fuel and energy products	0.434	0.758
Ferrous and non ferrous ores and metals	0.514	0.531
Non metallic ores and mineral products	0.692	0.574
Chemical products including pharmaceuticals	0.461	0.482
Metal products except machinery and transport equipment	0.617	0.585
Agricultural and industrial machinery	0.492	0.301
Office and data processing machinery, precision and optical instruments	0.586	0.642
Electrical goods	0.614	0.654
Motor vehicles	0.489	0.369
Food drinks and tobacco products	0.196	0.485
Textiles and clothing, leather and skin goods, footwear	0.795	0.621
Paper and printing products	0.636	0.625
Rubber and plastic products	0.535	0.508
Timber and wooden products, furniture and other industrial products	0.752	0.633
Average value	0.558	0.554

* The values in column one and two indicate the weight of branch *i* within the corresponding sub-system *i* in terms of employment and value added. The complement to one of each coefficient represents the weight of external activities in sub-system *i*, i.e. the weight of external activities in the production of good *i*. For sources and methodology see Appendix A.

[5] Employment and value added are the variables used to normalise the different supply attributes calculated by branch and sub-system in the empirical exercises we shall present.

In summary, the empirical data in the table show that the weight of branch *i* within sub-system *i* in terms of employment and value added is on average 55%, with values of less than 50% for many major productions. This means that around 50% of the activities used in the production of industrial goods come from *outside* the respective branches.

The shortcomings of a branch-product analysis seem to be even more serious if we consider the specific variables commonly used in the disaggregated tests under review.

Let us consider first the technological variables, which play a central rôle in many explanations of the trade structure and are the focus of our analysis. The most common proxy for measuring the technological intensity of good *i* is the ratio of R&D expenditures to sales, or the ratio of R&D employment to total employment, in branch *i*.[6] In this respect the change of methodology we propose yields some fairly interesting findings. With the total R&D of each sub-system *i* (i.e. the total R&D embodied in each final good *i*) set at one hundred, we can see from table 2 that, on average, just under 50% of this R&D is carried out directly within branch *i*.

Even if we exclude the extreme case of textiles, for which only 1% of total R&D comes from the textile branch, we can see that for seven other important groups of industrial goods the external R&D embodied in commodities *via* intermediate inputs forms over 50% of the total R&D. This implies that a very considerable part of the total technology embodied in industrial goods comes from outside the respective branches and is therefore neglected in simple product-branch analyses of trade. In the input output tables we use, the flows of intermediate goods refer to circulating capital and uses of fixed capital (see Appendix A). As a consequence the total R&D is embodied in each goods *via* four channels: internal R&D, uses of fixed capital (domestically produced and imported), uses of circulating capital of domestic production, uses of imported circulating capital.

The same sort of calculations allow us to construct synthetic indices of *total technological intensity*, calculated as the ratio of employment in R&D to total employment of each sub-system. As far as

[6] On the different R&D indicators see OECD (1981). The use of data on R&D by "groups of products", published by the U.S. National Science Foundation (originally proposed by KELLY 1977), eliminates some distortions due to sectoral aggregation, but does not solve the methodological problem raised by us, since those data do not take into account the intersectoral flows of technology implicit in the intersectoral flows of intermediate goods.

TABLE 2

SOURCES OF TOTAL TECHNOLOGY EMBODIED IN FINAL PRODUCTS *
Italy, 1975

	Total R&D (domestic + imported) embodied in product *i*	Internal R&D	External domestic R&D	External imported R&D
Fuel and energy products	100	48.9	30.5	20.6
Ferrous and non ferrous ores and metals	100	34.2	44.7	21.1
Non metallic ores and mineral products	100	23.0	60.4	16.6
Chemical products including pharmaceuticals	100	83.1	7.2	9.7
Metal products except machinery and transport equipment	100	49.2	39.9	10.9
Agricultural and industrial machinery	100	33.2	53.6	13.2
Office and data processing machinery, precision and optical instruments	100	88.3	8.8	2.9
Electrical goods	100	80.2	8.3	11.5
Motor vehicles	100	75.3	15.1	9.6
Food, drinks and tobacco products	100	18.6	66.3	15.1
Textiles and clothing, leather and skin goods, footwear	100	1.1	76.4	22.5
Paper and printing products	100	18.9	63.6	17.5
Rubber and plastic products	100	67.1	20.0	12.9
Timber and wooden products furniture and other industrial products	100	74.4	19.0	5.7
Average value		49.67	36.76	13.55

* *Sources and Methodology*: see Appendices A and B.

these indices are concerned it is interesting to note how much they differ from the traditional indicators by branch.

In table 3, column one shows the traditional indices by branch; column two shows the indices of total domestic R&D calculated by sub-system, mainly for comparison with column one; column three shows the indices of total R&D, domestic plus imported, calculated again by sub-system.

Three main findings can be observed in the table. First, in the switch from the branch to the sub-system indices the actual values of the coefficients of technological intensity change considerably for the main industrial goods. Second, even if the rank of the products ordered by technological intensity does not change very much, the variance of the technology indicators decreases substantially, meaning that the actual technological intensity of goods is much more evenly distributed than what it appears by merely observing the internal R&D. Third, the average value of the indicators is also reduced, because, in general, the industrial branches "give" technology to non-industrial productions (agriculture, building and constructions, trade, market and non market services) without receiving an equal amount of technology from them.[7]

If we now consider the other variables usually examined in the exercises under review, such as fixed capital, circulating capital or skilled labor, we note that the reclassification from branches to sub-systems gives rise to considerable changes in the absolute value of the variables (see table 6). In these cases, however, the change in the indices of intensity of these means of production (which represent the actual variables used in the regressions) vary much less radically than in the case of technology. In fact, in the reclassification from branches to sub-systems, the variables which are used to normalize fixed capital, circulating capital and skilled labor also tend to move proportionately in the same direction, thus leading to minor changes in the coefficients being considered.

Hence the change in the value of the indices of inputs intensity seems to be a particular characteristic of the technological variables which, unlike capital and labour, are not directly linked to production *per se*, do not have the nature of means or factors of production and are highly idiosyncratic to each particular branch.

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[7] The "technological matrices" presented in Appendix B allow us to observe analytically the origin and the final destination of the technology (R&D) embodied in each product, and to reconstruct sort of technological *filières* consistent with the national accounts.

TABLE 3

TECHNOLOGICAL INTENSITY (T.I.) OF INDUSTRIAL PRODUCTS *

Italy, 1975. Percentage values

	T.I. measured by branch	T.I. measured by sub-system (only domestic R&D)	T.I. measured by sub-system (domestic plus imported R&D)
Fuel and energy products	0.72 (6)	0.51 (7)	0.64 (6)
Ferrous and non ferrous ores and metals	0.23 (10)	0.27 (10)	0.35 (9)
Non metallic ores and metals	0.07 (12)	0.18 (11)	0.21 (11)
Chemical products including pharmaceuticals	3.38 (1)	1.69 (2)	1.88 (2)
Metal products except machinery and transport equipment	0.25 (9)	0.28 (9)	0.31 (10)
Agricultural and industrial machinery	0.25 (8)	0.32 (8)	0.37 (8)
Office and data processing machinery, precision and optical instruments	3.36 (2)	2.17 (1)	2.24 (1)
Electrical goods	2.27 (4)	1.54 (4)	1.74 (3)
Motor vehicles	2.67 (3)	1.57 (3)	1.73 (4)
Food, drinks and tobacco products	0.11 (11)	0.10 (14)	0.12 (14)
Textiles and clothing, leather and skin goods, footwear	0.002 (14)	0.11 (13)	0.14 (13)
Paper and printing products	0.06 (13)	0.17 (12)	0.20 (12)
Rubber and plastic products	1.77 (5)	1.33 (5)	1.52 (5)
Timber and wooden products, furniture and other industrial products	0.55 (7)	0.52 (6)	0.55 (7)
Average value	1.12	0.77	0.85
Standard deviation	1.24	0.69	0.74

* The indices are constructed by relating R&D employees to total employment for branches and sub-systems and multiplying the resulting coefficient by 100. The values shown in columns 1 and 2 are strictly comparable, since they are the result of a re-attribution of the same amount of domestic R&D. The figures in brackets show the rank of each product ordered by its technological intensity. The rank correlation coefficient is 0,965 for columns 1 and 2 and is 0,964 for columns 1 and 3.

3. An econometric exercise on Italian specialization

In this section we carry out some econometric exercises to assess the empirical importance of using an analysis by products and sub-systems instead of the traditional analysis by products and branches. To this end, we analyse the relationship between commodity specialization and supply characteristics measured separately by branch and by sub-system, using for this purpose a single consistent data set. We carry out this analysis by replicating some standard exercises on the Italian pattern of trade; in particular we take as an example the most complete cross-section tests of Italian specialization, recently published in two papers by Onida (1983) and Helg and Onida (1984). These two contributions are cross-section regressions which relate, for Italy, the individual products' performances with capital, technology and skilled labor intensity. In general, they can be regarded as a good example of the disaggregated tests carried out in the international literature.

The results by Onida and Helg and Onida show a negative (significant) relationship between trade performance and capital intensity, a negative (highly significant) relationship between trade performance and research intensity and a positive (significant) relationship between trade performance and skilled labor intensity. The results, on the whole, confirm the findings obtained in all earlier studies on Italian specialization which regularly show negative coefficients for capital and research intensities.[8]

With reference to the most general regression by Helg and Onida (1984), we constructed a data base consistent with the input-output tables at our disposal, disaggregated in twentythree NACE branches. To this purpose, we started by reclassifying into branches Helg and Onida's data by sectors and transformed these series into sub-systems. As a result we obtained three sets of variables: a set of trade performance indices referred to products; a set of independent variables measured by branch (namely capital, R&D and skilled labor intensity); a set containing the same independent variables reclassified into sub-systems.

[8] A negative association between trade performance and technological intensity was found, among the others, by Boggio (1971), Conti (1973), Walker (1979), Soete (1980) Onida (1983) and Helg and Onida (1984). This result does not change if technological intensity is measured with Italian (country specific) data, or is measured applying to Italian goods U.S. data on technology and capital intensity as in the earlier studies.

Using this data base, we estimated some equations in order to bring out separately the relationships between trade performance and supply characteristics measured by branch and by sub-system. All the equations were estimated OLS, by pooling the cross-sections and time series observations (i = 14, t = 2) due to the level of aggregation.

The main equations are as follows:[9]

$$[1]\quad ATB_{i,t} = \alpha_0 + \alpha_1\, ln\ K/L\ B_{i,t} + \alpha_2\, ln\ RD/L\ B_{i,t} + \alpha_3\, ln\ SK/L\ B_{i,t} + u_{i,t}$$

$$[2]\quad ATB_{i,t} = \alpha_0 + \alpha_1\, ln\ K/L\ S_{i,t} + \alpha_2\, ln\ RD/L\ S_{i,t} + \alpha_3\, ln\ SK/L\ S_{i,t} + u_{i,t}$$

$$[3]\quad ln\ RMS_{i,t} = \alpha_0 + \alpha_1\, ln\ K/L\ B_{i,t} + \alpha_2\, ln\ RD/L\ B_{i,t} + \alpha_3\, ln\ SK/L\ B_{i,t} + u_{i,t}$$

$$[4]\quad ln\ RMS_{i,t} = \alpha_0 + \alpha_1\, ln\ K/L\ S_{i,t} + \alpha_2\, ln\ RD/L\ S_{i,t} + \alpha_3\, ln\ SK/L\ S_{i,t} + u_{i,t}$$

where:[10]

$ATB_{i,t}$ is the adjusted trade balance of product *i* referred to years 1970 and 1975 (where i = 1,2...n are all the industrial products);

$RMS_{i,t}$ is the relative market share of product *i* in the same years;

$K/L\ B_{i,t}$ is the fixed capital intensity of branch *i* in 1970 and 1975 (data in constant lire);

$K/L\ S_{i,t}$ is the fixed capital intensity of sub-system *i* in 1970 and 1975;

$RD/L\ B_{i,t}$ is the technological intensity of branch *i*, proxied by the ratio of R&D employees to total employees of branch *i*, in 1970 and 1975;

$RD/L\ S_{i,t}$ is the technological intensity of sub-system *i* in 1970 and 1975;

$SK/L\ B_{i,t}$ is an indicator of skilled labor intensity in branch *i* in 1970 and 1975;

$SK/L\ S_{i,t}$ is an index of skilled labor intensity in sub-system *i* in 1970 and 1975. All the data are country specific, i.e. taken from Italian statistics.

[9] Equations (1) and (3) are substantially identical to the main equations estimated by Helg and Onida (1984). A detailed analysis of Helg and Onida results, which are very similar to ours, is contained in the Italian version of this article.

[10] The individual variables are described in greater detail in Appendix C.

The aim of the exercise, as we have noted, is mainly to assess the effects on the results of the change in methodology. Bearing in mind some well known *caveats* concerning this sort of exercise, the regression coefficients, in each case, should not be interpreted as elasticities or causal relations, but simply as associations between variables, and they are bound to give empirical insights about the supply characteristics of Italian trade specialization.

The main results of the exercise are summarized in table 4. The traditional regressions by product and branch (eq. 1 and 3) confirm the findings already obtained in other studies on Italy, with minor changes in the significance of some coefficients, and are very similar to the results obtained by Helg and Onida.[11]

The regressions by product and sub-system (eq. 2 and 4), on the contrary, show a considerable change. While the coefficients of variables K/L *S* and SK/L *S* retain the sign and the significance shown in the equations by branch, the coefficients of technological intensity change their sign and significance. When the dependent variable is ATB, the coefficient of technological intensity from non-significant by branch becomes positive and significant by sub-system. When the dependent variable is RMS, the coefficient of technological intensity from negative ignificant by branch becomes positive and non-significant by sub-system.

The statistics are generally satisfactory and the fit of the estimates, though acceptable in equations 1, 2 and 3, is considerably reduced in equation 4 which refers to RMS and is estimated on data by sub-system. In accordance with the recent literature, this finding seems to confirm that the performance indices based on *net* trade (such as the ATB) have greater economic meaning in the one-country exercises.

The decision to carry out the pooling proved legitimate. The Chow tests on the homogeneity through time of constant terms and coefficients are satisfactory, both when they are carried out at the overall level and separately on the constant term and the parameters. The existence of heteroschedasticity, moreover, appears to be excluded since all variables are appropriately normalized by the dimension of the respective markets, branches or sub-systems.[12] Finally, in the data set by

[11] In eq. (1), (2) and (3) the constant term is not significant. If we re-estimate these equations by constraining the constant to zero the results remain substantially unchanged. In particular, in eq. (3) the negative coefficient of RD/L *B* increases substantially its significance (t = 2,38).

[12] The Glejser test does not show any relation between the absolute value of the residuals and the dimension of the corresponding sub-systems. This result, however, is not robust, due to the limited number of sectional observations.

TABLE 4

ITALY'S INTERNATIONAL SPECIALIZATION AND SUPPLY CHARACTERISTICS REGRESSIONS BY BRANCH AND SUB-SYSTEM *

Eq.		Const.	*ln* K/L *B*	*ln* K/L *S*	*ln* RD/L *B*	*ln* RD/L *S*	*ln* SK/L *B*	*ln* SK/L *S*	R^2	adj R^2	F.	ChT(a) G	ChT(b) Cost	ChT(c) Coeff.
[1]	ATB	0.17 (0.80)	−0.48 (5.57)		0.028 (0.99)		1.11 (2.54)		0.59	0.56	12.0	0.23	0.11	0.12
[2]	ATB	0.81 (2.24)		−0.59 (4.97)		0.11 (2.064)		1.78 (2.73)	0.52	0.48	8.9	0.11	0.25	0.09
[3]	*ln* RMS	0.05 (0.02)	−0.36 (2.85)		−0.06 (1.83)		1.86 (2.98)		0.43	0.38	6.3	0.09	0.06	0.08
[4]	*ln* RMS	0.72 (1.35)		−0.47 (2.66)		0.025 (0.32)		2.64 (2.75)	0.29	0.20	3.5	0.17	0.05	0.10

* The estimated equations are described in the text. All the regressions are estimated OLS on 28 observations obtained by pooling cross-section and time series observations (i = 14, t = 2). The variables by branch are indicated by suffix *B* and those by sub-system by suffix *S*. In brackets *t* statistics of the estimated coefficients.
(a) Global Chow test on the homogeneity in time of constant term and coefficients.
(b) Chow test on the homogeneity in time of constant term.
(c) Chow test on the homogeneity in time of the coefficients.

sub-system the simple correlation between the independent variables falls sharply, therefore reducing the risk of multicollinearity.

In addition to eq. (1) - (4) we found it interesting to estimate some additional equations by sub-system, shown in table 5. Equations (2) and (4), for purposes of comparison with (1) and (3), and with the Helg and Onida exercises, use an indicator of total technological intensity (RD/L *S*) constructed on the basis of domestic research alone. Equation (5) replaces this variable by an indicator of total research intensity (TRD/L *S*) embodied in the products *via* inputs of domestic production and imported intermediate products; the results remain substantially unchanged, as regards both the value of the coefficients and their significance. This implies that the consideration of imported technology, at least at the quantitative level, is not such to alter the result of the analysis.[13]

Equation (6) replaces the domestic research indicator expressed in terms of employment with a different indicator ($ RD/V), calculated as the ratio of R&D expenditures to the value added of each sub-system; the result, once again, does not change.

Finally, in addition to fixed capital intensity, we inserted in equation (7) an indicator of the intensity of intermediate inputs (CIRC/L *S*), constructed as the ratio of circulating capital to total employment of each sub-system. The coefficient of this variable is not significantly different from zero, while the values of the other coefficients and their significance remain unchanged. This allows us to eliminate the doubt that the positive coefficients of RD/L *S* and SK/L *S* account for the variance of ABT actually explained by the use of intermediate input *per se*. In fact it is well known that a large number of Italian products with a good trade performance are end-products of the last stages of the productive processes, using many intermediate inputs from branches upstream.

[13] This result, due to the fact that the correlation between RD/L *S* and TRD/L *S* is very high (r = 0,983), does not mean, of course, that imported technology is unimportant for many Italian products analysed at a more disaggregate level.

TABLE 5

ITALY'S INTERNATIONAL SPECIALIZATION AND SUPPLY CHARACTERISTICS FURTHER REGRESSIONS BY SUB-SYSTEM *

Eq.		Const.	*ln* K/L *S*	*ln* CIRC/L *S*	*ln* RD/L *S*	*ln* TRD/L *S*	*ln* $ RD/V *S*	*ln* SK/L *S*	R^2	adj R^2	F.
[5]	ATB	0.79 (2.18)	−0.60 (4.96)			0.111 (1.98)		1.78 (2.71)	0.51	0.47	8.7
[6]	ATB	0.82 (2.24)	−0.57 (4.86)				0.109 (2.062)	1.95 (2.94)	0.52	0.48	8.9
[7]	ATB	0.75 (1.21)	−0.60 (3.84)	0.29 (0.11)	0.108 (1.99)			1.76 (2.62)	0.52	0.46	6.4

* All the regressions are estimated on 28 observations (i = 14, t = 2). The dependent variable is the adjusted trade balance. The independent variables, always calculated by sub-systems, are: K/L *S* fixed capital intensity; CIRC/L *S* circulating capital intensity; RD/L *S* domestic R&D intensity, in terms of employees; TRD/L *S* total R&D intensity, domestic plus imported, in terms of employees; $ RD/V *S*, domestic R&D intensity, in terms of R&D expenditures; SK/L *S* skilled labor intensity. All the variables in money terms (i.e. fixed capital K, circulating capital CIRC, R&D expenditures $ RD, and value added V) referred to years 1970 and 1975, are in constant lire.

4. Italy's pattern of trade and the characteristic of supply: a re-appraisal

The empirical results of the exercises presented so far have two main implications.

First, they show that the adoption of a more appropriate methodology to attribute supply characteristics to products is empirically as well as conceptually important. The decision to ignore the backward links of production (intermediate inputs), introduced by some authors in the form of an assumption,[14] is therefore empirically as well as theoretically unsound and can even reverse the sign of some crucial relationships in the standard econometric tests on the determinants of trade.

The second implication, that we discuss in this section, specifically concerns Italy's pattern of trade and specialization. Despite the great number of theoretical and empirical *caveats* which have to be considered in interpreting an exercise like ours, we believe that the change in the empirical results illustrated in sections 2 and 3 is such as to prompt a re-appraisal of the interpretation of Italian trade specialization.

As we recalled, the results obtained so far in all the disaggregated analyses of Italy's pattern of trade always brought out, with different degrees of significance, a negative association between goods' performance and technological intensity as well as capital intensity.

The interpretation of these results was generally non-causal. For a number of reasons, also related to their specific characteristics, the results were generally interpreted as mere insights into the structural regularities of products with a given performance, "within a scheme in which the specific determinants of competitiveness are unknown to the researcher. [...]. Otherwise — as it has been observed — one would arrive at the paradox of affirming that a greater amount of R&D expenditure, or a greater volume of patents, would affect negatively the average performance of Italy's manufacturing industries" (Onida 1983, section 3).

Even if the interpretation was purely descriptive, the results obtained, together with more detailed analyses by commodities only[15] (which brought out a persistent and increasing inferiority of Italian exports of products with a high technological content), have nevertheless led to the familiar and widespread concern of a country specialized in "mature" and "traditional" products, with a low technological content and a non-dynamic demand, subject to increasing competition from newly industrialized and from developing countries.

[14] See, for example, STERN and MASKUS (1981) sect. 4.

[15] Recent analyses of Italian trade by commodities can be found in CREDITO ITALIANO (1983) OECD (1983) PIERELLI (1983) FERRAGUTO (1984).

On the basis of these considerations, policies of abandoning traditional products and of "re-converting" the system towards high technology productions have been often recommended, just tempered by the observation that the good and improving performance of traditional products was the major factor contributing to the adjustment of the Italian trade balance after the two oil crises.[16]

These sorts of diagnoses and preoccupations are certainly not unjustified. The adoption of a more correct methodology, however, allows us to qualify these views and to propose a more accurate interpretation. This interpretation, based on the concepts of "technological interdependencies" and "system", makes use of some concepts and ideas taken from the modern theories of technological innovation, in the belief that certain aspects of international trade, and in particular the sources of competitiveness of a large number of goods, can be usefully studied using these tools.

The econometric exercises carried out with data by sub-systems show:

i) a significant negative relationship between product performance and fixed capital intensity, as in the traditional analyses by branch;[17]

ii) a significant positive relationship between product performance and skilled labor, confirming once more the results of the analyses by branch;

iii) a significant positive relationship between net exports (ATB) and technological intensity, and a non-significant positive relationship

[16] It may be worthwhile to recall that the Italian trade balance is characterised by a structural deficit in energy products (31,866 billion lire in 1983), in agriculture and food products (8,712 billion lire), in chemicals (3,900 billion lire) and in industrial raw materials (about 5,000 billion lire), matched by a structural surplus in manufacturing products (34,500 billion lire in 1983). A structural surplus in "traditional" products such as textiles, clothing, leather goods, footwear and furniture, together with a surplus in mechanical goods and machinery other than motor vehicles, accounts for about 90% of the manufacturing surplus, and has been rising substantially over the last few years.

[17] A negative coefficient which relates trade performance and fixed capital intensity is a common finding in industrial countries not endowed with raw materials and natural resources, since resources and fixed capital seem to be complementary. For this reason this finding was expected for Italy and did not generate particular concerns.

between the relative export share of the different goods (RMS) and technological intensity.

As a result, a more appropriate attribution of supply characteristics to products allows us to correct one piece of conventional wisdom, by stating that, in Italy too, the trade performance of products seems to be positively related to technological intensity.

The comparison of the regressions by branch and sub-system, together with a detailed analysis of the matrix of technological interdependencies, allows us, moreover, to qualify the latter proposition in a rather important way. The technology embodied in the most successful products comes mainly from external R&D, while the technology of the products with a more disappointing performance comes mainly from internal R&D.

In the light of these considerations, we can re-examine the conventional interpretation of Italian specialization, as regards both products with a high technological content and traditional ones.

As regards products with a high technological content we can endorse the preoccupation generally expressed. In quite a few of them — especially in those on the most advanced technological frontiers, in which a dominating (and quantitatively important) rôle is played by internal R&D — Italy, in fact, is not being sufficiently innovative and competitive. On the other hand,for many products with a low technological content, in which the contribution of external R&D predominates, the reason for concern referred to above may be reduced.

Indeed, as we shall argue, it appears that technological interdependencies and the availability of a highly articulated system represent a factor of advantage for traditional products too.

The recent literature on the determinants and effects of innovation has begun to devote increasing attention to the system of sectoral and technological interdependencies, considered to be a "new external economy".[18]

A well known study by Hirsch (1967) had maintained, on a purely qualitative level, that a system of sectoral interdependencies may be an

[18] Cf. Rosenberg (1976, 1982). As far as technological interdependencies are concerned, recent investigations dealt with the direct and indirect effects of R&D on the total productivity of industry (Griliches 1978, 1980, Terleckyi 1980, Scherer 1982). Moreover, some other empirical analyses dealt with the intersectoral linkages of technologies in order to study the interindustrial diffusion of innovations. (Pavitt 1983, 1984). These new lines of research have been stimulated by the observation of the growing intersectoral pervasiveness of some modern technologies (e.g. microelectronics) and by the consequent need to study how a product innovation in a given industry leads to important process innovations in other industries downstream.

external economy and a factor of comparative advantage that favours the smaller developed countries in the production of goods in the "intermediate" phase of the product life cycle. It is possible to argue that such a system is an external economy because it allows firms to change easily the productive processes which are not yet (or cease to be) standardized and to select the most appropriate inputs, making possible the required process modifications.

At present many products which are usually regarded as "traditional" are being affected by profound innovations in their productive processes. As a result, the advantage stemming from a highly articulated system of sectoral and technological interdependencies extends to them too, to the extent that their production ceases to be standardized because of important process innovations, deriving from highly pervasive product innovations in other branches. Moreover, the availability of such a system of sectoral and technological interdependencies, together with the concept of "economic distance" seems to be a factor of advantage both *per se* and as a factor hampering, to some extent, the competitive imitation and appropriability of innovations by developing countries with respect to traditional goods as well.

Having said all this, we still have to understand how advanced products in Italy can contribute to the success of the traditional goods which embody them, but are not competitive *per se* on the international markets. In our opinion, the answer to this apparent contradiction should not be sought in the fact that the productive processes of Italian traditional goods as such require intermediate inputs with worse technological characteristics than those required by the international markets. The more plausible, though tentative, answer is that the Italian firms producing the most successful goods seem to reveal a marked entrepreneurial and organizational capacity to choose and modify the productive processes and to select and combine most appropriately internal production and intermediate inputs (domestic and imported) so as to achieve a high level of price and non-price competition.

Conclusions

In the previous paragraphs we have replicated some standard exercises on Italian specialization, making use of an analysis by sub-system. The proposed methodology provided some new insights into the relationship between patterns of trade and supply characteristics, in particular technology.

If we take a careful look at the logic of the exercises, however, we can see that their theoretical meaning is rather limited. On the one hand, as convincingly argued by Leamer and Bowen (1981), this kind of one-country cross-industry exercises cannot be tests of the Heckscher-Ohlin theorem nor can reveal the factors abundance of one country as implied in a Vanek-Bertrand model. On the other hand, the same exercises generate even greater dissatisfaction as tests of technological or neo-technological theories.

The theoretical hypothesis of technological gap explains the commodity specialization of countries on the basis of technological asymmetries between countries for each specific good. The tests under review, on the contrary, consider the asymmetries between goods in each individual country. In order to carry out an appropriate test of the technological theory and of similar hypotheses, we propose therefore to extend the analysis by sub-system to a cross-country analysis for each product, instead of a cross-product analysis for one country.

However, in order to have a sufficient number of observations, a cross-country product-specific analysis using data by sub-systems would require a hardly feasible mass of calculations (given also the non-comparability of input output tables and classifications). For this reason we propose a simplified test which nevertheless seems to suit our purposes. The test is a cross-section regression which relates the usual indices of trade performance of one country T_i to a set of independent variables by sub-system, constructed as *differentials* of technological intensity, factor intensities etc., between the country considered and a group of countries representative of the techniques of the competitors.

In this case the number of observations depends on the number of goods considered in the indices T_i, while the number of countries (and the number of input-output tables) to be considered in the construction of the differential can be extremely limited, making much simpler the required calculations.

The result of the regression analysis would allow us to test in a more appropriate way the technological gap theory for the different goods, as well as different Ricardian models of international specialization.

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APPENDIX A

VARIABLES BY BRANCH AND SUB-SYSTEM: METHODOLOGY AND STATISTICAL SOURCES

The methodology to disaggregate a productive system into branches and sub-systems is the same we presented in Momigliano and Siniscalco (1982) and in Siniscalco (1982). This methodology is based on the construction of a matrix, we call operator B, which brings out in one table all the nexuses between branches and sub-systems.

Starting from an input output table, operator B can be calculated as

$$\underset{nxn}{B} = \underset{nxn}{(\hat{x})^{-1}} \underset{nxn}{(I - A)^{-1}} \underset{nxn}{\hat{f}},$$

where x is the vector of total output, f is the vector of final demand, $(I-A)^{-1}$ is the Leontief inverse and the superscript ^ indicates that the vector underneath has been transformed into a diagonal matrix. In the matrix B so obtained the coefficients in each row i show the shares of output of branch i which contribute to the different sub-systems. The same coefficients, read by column, show the shares of output of the different branches which contribute to each sub-system j. Operator B, read by column, therefore, shows all the nexuses between branches and final products, *via* sub-systems.

By assuming that each branch i contains "homogeneous units of production" (or, better, by noting that each unit of product i is represented *as if* it were produced with the "average technology" of branch i) we can use operator B to reclassify from branches into sub-systems any variable linked to production and classified by branch (e.g. employment, value added, R&D, skilled labour, etc.).

This transformation is carried out by pre-multiplying operator B by a diagonal matrix $\hat{y}$, where y is a vector expressing a generic variable y classified by branch. The result is a matrix $Y = \hat{y}$ B which shows all the branches-sub-systems flows of y implicit in the flows of intermediate goods. The sums by column give rise to a vector y = Yu' which shows in each element the variable y reclassified into sub-systems, i.e. attributed to each final product.

A final word should be said about the data. In order to assess the *total* technology embodied in each product (see appendix B), in the actual calculations we made use of input-output tables containing flows of circulating capital and *uses* of fixed capital, following the methodology proposed by Pasinetti (1973). Matrix $(I - A)^{-1}$ is therefore calculated starting from an input output table $F \equiv F^c + F^k$, where F^c is the usual table of flows of circulating capital (intermediate inputs) and F^k is a table of *uses* of fixed capital.

Statistical sources

The input-output tables we use are published by ISTAT (Italian Central Statistical Office) and are referred to 1970 and 1975. The original tables are disaggregated in 44 NACE branches, which have been re-aggregated in 23 NACE branches in order to be compatible with the tables of uses of fixed capital. These latter tables have been produced by a CNR group working in the University of Pavia and are published in P. Mori, G. Rampa and L. Rampa, "Costruzione di tavole di consumo annuo di capitale fisso per gli anni 1965-1975", CNR group on *Analisi strutturale dell'economia italiana*, working paper no. 2, 1982.

The matrices of labor L and value added V, used to construct the coefficients in tables 1 and 3 and to normalise the various independent variables are obtained making use of vectors l and v, taken from ISTAT official publications.

APPENDIX B

MATRICES OF TECHNOLOGICAL INTERDEPENDENCIES IN THE ITALIAN ECONOMY

The methodology presented in Appendix A has been used to construct "matrices of technological interdependencies" for the Italian economy in 1970 and 1975.

These matrices are constructed as

$$R = \hat{r}B \qquad \text{and} \qquad R' = \hat{r}'B$$

where r and r' are respectively the vectors of employees and expenditures in R&D classified by branch, and B is the branch-sub-system matrix. In matrices R and R', the elements of row *i* allow us to attribute to each final product a share of the R&D carried out in branch *i*; the elements of column *j*, on the contrary, allow us to see the R&D carried out in the various branches and embodied in final product *j*. Lastly the sum of all the elements of column *j* shows the *total* R&D (employees or expenditures) vertically integrated in product *j*.

In the exercises we carried out we used R&D as a proxy of technology: the methodology, however, would allow us to use any other indicator of technology classified by branch (e.g. patents). The figures contained in matrices R and R' represent intersectoral flows of technology implicit in the flows of intermediate inputs. Since we do not consider R&D as a factor of production, these flows of technology represent a mere imputation of sectoral R&D to final products, and should not be considered, in any case, as the result of "R&D technical coefficients".

Besides the matrices described, we also constructed matrices of imported technology R_{IMP}, again measured in terms of R&D employees or expenditures. To construct these tables we first constructed matrices of direct and indirect uses of imports M = MB (where M is the matrix of flows of intermediate imports), and then premultiplied matrix M by a vector of imports' research intensity, based on country specific data or proxied by Italian data. The matrix R_{IMP} can be used *per se* or added to matrix R to obtain a matrix R_{TOT} of domestic and imported technology. Matrix R_{TOT} was used to construct table 2 and column 3 of table 3.

The whole set of technological matrices makes it possible to assess the technological intensity of products, to study the interindustrial diffusion of innovations and to construct a taxonomy somehow similar to the one proposed by Pavitt (1984). In our taxonomy we can distinguish *products* according to their high or low technological opportunity (as proxied by R&D intensity) and *branches* according to the absolute and relative amount of technology they give to other branches in the system. This taxonomy can be the basis of selective industrial policies which are discussed at length in the Italian version of this article.

Statistical sources

The R&D series by branch (employees and expenditures) are based on data contained in ISTAT, *Indagine statistica sulla ricerca scientifica*, for the years 1970 and 1975. The original data, by sector, have been transformed into branches.

APPENDIX C

THE DATA BASE

The econometric exercises presented in paragraph 3 are based on three sets of variables. A set of dependent variables referred to products; a set of independent variables (supply attributes) measured by branch; a set containing the same independent variables measured by sub-system.

1. Dependent variables

The dependent variables in equations 1 - 7 are an *adjusted trade balance* (ATB) and a *relative export market share* (RMS).

ATB is an index which takes into account *net exports* of industrial products and is defined as

$$ATB_i = \frac{X_i - M_i}{X_i + M_i}$$

where X are exports, M imports and i = 1, 2...n are all the industrial products, in NACE classification.

RMS is an index which considers *gross exports* only and is defined as

$$RMS_i = \frac{X_i^{ITA}}{X_i^{OECD}} \div \frac{X_{tot}^{ITA}}{X_{tot}^{OECD}}$$

where X_{tot}^{ITA} and X_{tot}^{OECD} are total exports of industrial goods from Italy and OECD countries to the World.

In the exercises presented ATB and RMS are put in relation to structural characteristics: in order to reduce the impact of cyclical phenomena and fortuitous events on the dependent variables, the indices referred to 1970 and 1975 have been constructed as three years' simple averages, in accordance with the practice of many authors and of Helg and Onida.

For the calculation of ATB and RMS we used data contained in OECD, *Trade by commodities, statistics of foreign trade, Series B*, selecting the series used by Helg and Onida (1984), together with the conversion criteria adopted by these authors.

The indices are published in table 6. The correlation between ATB and RMS is 0.68.

2. Independent variables: supply attributes measured by branch

The supply attributes measured by branch are:

Capital intensity, defined as K/L *B* where K is the use of fixed capital (in constant lire) and L is total employment by branch;

Technological intensity, defined as RD/L *B* where RD is total employment in R&D by branch;

Skilled labor intensity, defined as SK/L *B* where SK is a series of skilled employment (including senior management, staff, skilled clerks and skilled workers) substantially identical to the series used by Helg and Onida.

Vectors L, RD and SK by branch are all taken from official ISTAT publications. Vector K is taken from the tables of uses of fixed capital, cit. in Appendix A.

3. Independent variables: supply attributes measured by sub-system

Capital intensity (K/L *S*), *technological intensity* (RD/L *S*) and *skilled labor intensity* SK/L *S*) measured by sub-system have been constructed by transforming vectors L, K, RD, SK from branches to sub-systems and calculating the appropriate coefficients.

In addition to these variables, in eq. 5-7 we made use of three other additional variables measured by sub-system: two technological variables ($RD/V, TRD/L) and an index of circulating capital intensity (CIRC/L). The first technological variable, $RD/V *S*, proxies technological intensity by relating R&D expenditures ($RD) to value added (V) for each sub-system (data in constant lire). The second technological variable TRD/L *S* is constructed making use of vector TRD which considers domestic and imported R&D in terms of employment, as discussed in Appendix B. Lastly, the index circulating capital intensity (CIRC/L *S*) relates the use of circulating capital (in constant lire) to employment of each sub-system. The data on R&D expenditures are taken from ISTAT publications. The data on circulating capital are contained in the input-output tables.

Table 6 contains the data used to construct the main variables. Variable TRD can be obtained by adding vectors RD *S* and RDIMP *S*. Variables $ RD, V, and CIRC, which are not included in the table for reasons of space, can be obtained from the authors, together with the technological matrices for 1970 and 1975. A much more detailed description of the specific ISTAT publications used in the construction of the data base is contained in the Italian version of this article.

F.M. - D.S.

TABLE 6

DATA BASE *
(Italy, 1970 and 1975)

		Data calculated by:										
		Products		Branches				Sub-Systems				
		RMS	ATB	K B^1	L B^2	RD B^3	SK B^2	K S^1	L S^2	RD S^3	RDIMP S^3	SK S^2
1970	1	1.276	−0.559	478.2	175.4	1264	164.8	241.6	193.3	1002	196	140.5
	2	0.492	−0.479	196.8	241.1	602	166.3	41.2	63.0	191	56	42.0
	3	1.287	0.308	120.8	427.8	256	286.6	34.8	106.0	163	33	69.9
	4	0.802	−0.087	176.2	282.2	11206	223.4	135.2	264.4	5474	559	185.9
	5	1.114	0.390	86.9	415.5	1368	240.4	51.9	167.0	547	65	100.4
	6	1.155	0.282	105.9	358.4	1184	258.0	153.3	437.7	1633	221	295.0
	7	0.757	0.010	15.6	82.2	2330	56.0	26.7	104.1	1982	91	67.9
	8	1.003	0.194	96.7	332.0	6324	182.6	105.6	316.8	4329	629	184.8
	9	0.763	0.251	141.7	333.5	10176	206.8	195.0	479.1	8410	777	299.0
	10	0.527	−0.551	119.6	475.8	711	256.9	456.5	2124.7	2152	360	1204.1
	11	2.356	0.493	141.7	1539.3	44	1046.6	241.9	1737.4	1722	530	1165.8
	12	0.429	−0.213	73.1	241.2	168	161.7	52.1	158.4	335	74	103.3
	13	1.567	0.395	62.8	174.9	3900	124.2	42.2	113.9	1947	242	78.2
	14	1.495	0.486	59.4	583.1	3079	308.0	61.3	414.8	2113	96	226.5
1975	1	1.133	−0.669	565.1	186.5	1345	177.1	222.6	147.2	746	193	112.6
	2	0.590	−0.349	251.3	280.5	645	216.1	73.3	99.7	277	74	72.1
	3	1.285	0.305	169.9	414.1	290	318.8	49.8	108.9	192	38	80.8
	4	0.853	0.013	252.4	307.8	10415	237.0	227.4	341.4	5789	618	245.1
	5	1.385	0.557	126.8	437.4	1095	284.3	99.2	243.5	681	83	162.7
	6	1.111	0.332	159.6	390.9	978	300.9	219.0	485.7	1562	237	350.9
	7	0.722	−0.074	23.3	84.8	2855	53.4	34.9	102.2	2224	67	66.4
	8	0.981	0.181	133.7	397.9	9031	238.7	163.3	409.3	6295	820	260.2
	9	0.742	0.296	133.6	367.9	9826	242.8	208.6	500.8	7853	833	338.6
	10	0.590	−0.538	220.3	469.2	516	290.9	622.8	1988.7	1967	348	1179.8
	11	2.454	0.501	289.9	1430.4	26	1087.1	426.1	1681.9	1825	523	1245.0
	12	0.415	−0.184	129.1	260.4	155	1927.0	61.9	130.5	218	46	92.5
	13	1.283	0.379	105.5	214.7	3798	173.9	59.3	120.6	1604	237	91.5
	14	1.666	0.530	84.6	569.8	3135	490.1	110.5	492.2	2581	156	400.3

* The NACE classification 1-14 is the following: 1 Fuel and energy products; 2 Ferrous and non ferrous ores and metals; 3 Non metallic ores and mineral products; 4 Chemical products including pharmaceuticals; 5 Metal products except machinery and transport equipm.; 6 Agricultural and industrial machinery; 7 Office and data processing machinery; 8 Electrical goods; 9 Motor vehicles; 10 Food, drinks, tobacco; 11 Textiles, clothing, leather, footwear; 12 Paper and printing products; 13 Rubber and plastic products; 14 Timber, wooden products, furniture and other manufacturing products.
[1] Billions of 1970 lire.
[2] Employees: thousands.
[3] Employees: units.

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