RESEARCH NOTES

Transnational corporations and international technological specialization

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This research note evaluates the relationship between patterns of international technological specialization and the competition provided by foreign direct investment. Using inferences drawn from models of international competition, correlation and regression analyses suggest that transnational corporations have a relatively weak overall impact on patterns of technological specialization within and between countries.

Introduction

> "In spite of the recognized importance of technology, both in theory and in practice, little attention has been paid by analysts to the nature and determinants of firm-specific or country-specific technological advantage . . ." (Pavitt, 1988, p.126)

The purpose of this article is to evaluate the role that transnational corporations (TNCs) play in international technology specialization. The linkages between TNC activities and technological change in host and home countries have long been a focus of research and policy debate.[1] The principal

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[1] For a comprehensive overview of the relevant literature, see the relevant chapters in John H. Dunning (1993). For more recent evidence, see Archibugi and Michie (1995), Patel (1995) and Cantwell (1995), as well as studies referenced in those articles.

focus of concern has been the overall rates of technological change (or productivity growth) in host and home countries as they are affected by the activities of foreign affiliates.[2] Related to this broad concern, there has been an interest in how the nature of technological activities in host and home countries are affected by TNC behaviour. The latter issue is the subject of primary focus here.

The discussion proceeds as follows. The next section considers various conceptual definitions of international technological specialization, as well as their potential relevance to public policy. The subsequent section discusses the potential relationships between patterns of international technological specialization and foreign direct investment (FDI). The section after that presents evidence regarding patterns of technological specialization and draws inferences about the influence of FDI on the observed patterns. The final section contains a summary and conclusions.

International technological specialization

As Cantwell (1989) and Archibugi and Pianta (1993), among others, have noted, proxy measures of different types of technological expertise are not distributed equally across countries at any given point in time. The total levels of patenting being held constant, countries are represented intensively in some activities and only weakly in others. Patent data have been used to construct indices of revealed technological advantage (RTA) comparable to indices of revealed comparative advantage familiar from empirical international trade studies (Cantwell, 1989 and 1991; Pavitt, 1988).

Indices of revealed technological advantage

Patents filed in the United States have been used in deriving most of the RTA indices that have appeared in the literature. United States patent data are relied upon for two primary reasons: they can be made available to researchers by the United States authorities in a convenient form and they are quite comprehensive. Since the United States has been the single largest

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[2] While technological change is ordinarily a large component of productivity growth, there are other contributing causes. Nevertheless, policy makers have been more concerned typically with the impacts of FDI on technological change than with other factors contributing to productivity growth, such as worker training or exploiting economies of scale and scope.

and wealthiest market for most of the post-war period, innovating companies have made it a point to protect their technologies by filing patents in that country.

In the literature, the RTA index constructed from patent data shows the share of patenting in the United States that firms headquartered in country *i* do in activity *j* compared with all other firms. Country *i*'s RTA index for activity *j* is calculated as in equation 1:

Equation 1
$$RTA_{ij} = P_{ij} / \sum_{i=1}^{m} P_{ij} / \sum_{j=1}^{n} P_{ij} / \sum_{i=1}^{m} \sum_{j=1}^{n} P_{ij}$$

The first quotient is total patenting in industry *j* by firms headquartered in country *i* divided by all patents filed by firms headquartered in country *i*. The second quotient is the ratio of all patents filed in industry *j* divided by all patents filed in all industries.

For *i* countries and *j* industries, the distribution of RTA values can be arranged in matrix form as in equation 2:

Equation 2
$$RTA = \begin{bmatrix} RTA_{1i} \ldots\ldots RTA_{1J} \\ \vdots \qquad\qquad \vdots \\ RTA_{i1} \ldots\ldots RTA_{ij} \end{bmatrix}$$

Weak correlation between the columns in the RTA matrix would suggest technological specialization on an inter-country basis. Large differences between elements in the columns of the RTA matrix would suggest technological specialization on an intra-country basis. Most studies tend to focus on inter-country specialization.[3]

Reliance on patent data to estimate RTAs can be criticized on familiar grounds. To the extent that propensities to patent, or the commercial significance of patenting, varies across activities, RTA indices based upon

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[3] Archibugi and Pianta (1993) measure the degree of similarity in technological specialization across countries using a "distance index". This is calculated by estimating first the percentage of total patents accounted for by each sample industry for each sample country. The differences between those percentages for any two countries compared is then squared, and the squared values for each industry are divided by the share of total world patents accounted for by that industry. The quotient values for all of the sample industries are then aggregated and the resulting summed value is then divided by the maximum possible value the distance index can take. In fact, observed patterns of technological specialization are broadly similar regardless of the precise measure of technological specialization employed.

patents may provide misleading information about the distribution of a country's technological efforts at any point in time. If the propensity to patent varies over time for specific activities, biases may be induced in temporal comparisons of technological specialization, although variations over time in patenting propensity are more likely to affect all industries rather than just certain industries. Also, there is a legitimate concern that evaluating patents based upon their classifications across activities may obscure more fundamental differences in technological expertise across countries. For example, a country might be represented by patenting efforts in a variety of activities in which the underlying technological expertise is common to a set of industrial applications, e.g., mechanical engineering. The potentially misleading nature of patent data becomes more pronounced when patents are attributed to individual industries. Classification by the type of technological activity is correlated with classification by the industry of the firms conducting research, but that correlation is imperfect.[4]

While these caveats are all potentially relevant, it is doubtful that biases render invalid broad conclusions drawn about patterns of technological specialization based on patent data. As discussed below, the empirical differences in patenting activities by industry are too large and too durable across countries to be the result of measurement error alone. Moreover, classifying patents at the industry level is appropriate from a policy perspective, as policy makers often target technology initiatives at specific industries or sectors.

The relevance of RTA indices

Policy interest in patterns of technological specialization is largely related to potential linkages between the technology areas in which a country concentrates, and the overall rates of productivity growth. For example, concerns are often expressed about countries with high levels of foreign ownership, such as Canada, concentrating on technological activities that are "mature" or "sunset", rather than "emergent".[5] The (usually)

[4] About 15-20 per cent of the total patenting of countries is attributable to individual inventors rather than firms. A focus on national patenting patterns may therefore be somewhat misleading as regards the patenting patterns of domestic companies, although individual inventors may ultimately assign their patents to domestic companies.

[5] Canadian researchers have been especially critical of the weak representation of Canadian firms in rapidly growing industries, such as software and biotechnology (McMillan, 1992). Similar concerns have been expressed about European companies too (Hughes, 1993).

implicit notion is that potential rates of productivity growth are higher in emergent or rapidly growing industrial activities. Hence, specializing in the "right" technological activities directly contributes to faster growth rates of real income. A related notion, also usually implicit, is that emerging or rapidly growing industrial activities are characterized by economic rents that can be extracted, in part, from foreign consumers. In the latter case, specializing in the "right" technological activities contributes to higher levels of national income by promoting more favourable international terms of trade.

Theoretical and empirical reservations can be expressed about the relevance of technological specialization to policy makers. In particular, countries differ in their capabilities and incentives to undertake specific technological activities. As a consequence, the productivity and growth performances of individual countries may be harmed rather than helped by an inappropriate focus on fast-growing areas of technological activities (Zander, 1992). Furthermore, the economic benefits of new technologies may be captured substantially by non-innovating countries through "spillovers" of various types.[6] Nevertheless, while countries are obviously well advised to specialize in technological activities in which they enjoy some type of comparative advantage, they need not necessarily accept the technological "hand of cards" they have been dealt with. Policies to increase the supply of specific types of technical expertise and to promote domestic demand for "high technology" products can alter national patterns of technological specialization, if such alterations are deserved (Eaton *et al.*, 1994).

The growing literature on endogenous economic growth underscores the potential relevance of technological specialization to policy makers. In particular, the premise that there are ordinarily agglomeration economies in specific technological activities suggests that firms (and countries) will do better to concentrate their research and development (R&D) and related investments in a narrow rather than broad range of activities. This imperative is particularly relevant for countries with small domestic markets. In principle, the productivity of all countries can improve as technologically sophisticated production agglomerates in each country at a faster rate and as spillovers, or, external economies of scale, contribute to a "virtuous cycle" of faster technological change and increased agglomeration in the speciality areas selected by the respective policy makers (Cantwell, 1992a; Archibugi

[6] In this regard, there is substantially greater variation in national patterns of technological specialization than in indicators of technological change such as R & D intensities and productivity growth. See Patel and Soete (1988).

and Pianta, 1992). Of course, specialization in technological areas that prove to be relatively stagnant, by the same process of path dependency, may result in domestic firms wandering in a proverbial technological desert for long periods of time.

As performers of the bulk of world R&D activities and as powerful vehicles for transferring technology across borders, TNCs can be considered to be potentially strong agents for shaping technology specialization patterns. However, opinions expressed in the literature suggest that TNCs have played a very minor role in influencing international patterns of technological specialization. The next section presents a review and an assessment of the relevant literature.

Arguments about TNCs and technological specialization

While TNCs account for over half of global R&D expenditures (Dunning, 1993), most researchers conclude that the nature of the innovation process militates against TNCs playing a significant role in altering patterns of technological specialization within, or between, countries. There are two critical components of the argument:

- Technological innovation is a highly idiosyncratic process dependent upon resources that are location-specific. This specificity relates to the institutional nature of the innovation process that draws upon the expertise resident in networks of firms, universities and governments (Pavitt, 1988).
- Much technological knowledge is uncodifiable. As a result, it is difficult to transfer such knowledge across organizations, even within a TNC network (Zander and Solvell, 1992). On the other hand, codifiable knowledge can be transferred through a variety of channels, and there is nothing especially robust about TNCs as channels for transferring codifiable technology (Hutchinson and Nicholas, 1992).

The empirical evidence offered to support the argument that TNCs play no significant role in influencing patterns of technological specialization is both limited and indirect. Perhaps the most prominently cited evidence in this regard is the propensity of TNCs to centralize R & D and innovation in their parent firm. [7] Furthermore, the R & D that is carried out

[7] See Globerman (1995) for a summary of the studies and evidence documenting this assertion.

in foreign affiliates tends to concentrate on adapting to local conditions processes and product innovations developed by the parent company. This pattern is seen as evidence of the geographical specificity of innovation activities and, particularly, of the determining influence of home country attributes on the allocation of technological resources.[8] Since these attributes are immobile, TNCs are unlikely to alter the international endowment of technological attributes directly, although the extent and nature of their innovation activities can presumably alter technological endowments within the home country.[9]

Even if one accepts as persuasive the evidence that innovation is largely a home-country phenomenon, an indirect role for TNC influence must be acknowledged. Specifically, the actual and potential competition provided by TNCs to domestically owned firms could conceivably affect the allocation of technological (and other) resources in host countries. At the same time, the existence of scale economies could provide a linkage between outward FDI and patterns of technological specialization in home countries. Specifically, successful overseas sales by foreign affiliates allows home-country affiliates to capture more fully economies of scale in R & D and related activities, thereby stimulating increased technological activity at home. The significance of FDI as an indirect determinant of international patterns of technological specialization might be questioned on the grounds that TNCs account for a relatively small share of international production (Lipsey *et al.*, 1995). However, the influence of the competition of TNCs, as important potential indirect (through exporting) competitors, can be quite significant at the margin.

The relevant indirect effects of FDI can be illustrated by considering two alternative models. In the first model, assume that there are two countries and two industrial activities. Country one enjoys some technological advantage in activity one, and country two enjoys a technological advantage in activity two. The most efficient way to exploit a technological advantage is through FDI. Furthermore, all R & D is done in the home country. There are economies of scale in financing and performing R & D that can be asso-

[8] To be sure, TNCs from small home countries carry out relatively large shares of R&D in their foreign affiliates. For example, during the period 1969-1990, over 50 per cent of the shares of United States patenting of the largest Belgium- and Netherlands-based industrial firms resulted from R & D located abroad (Cantwell, 1995). However, United States and Japanese companies accounted for almost 80 per cent of world patenting activity in 1987; TNCs from those two countries do the bulk of their R & D at home (Globerman, 1995).

[9] John Cantwell (1992b) further identifies the locational specificity of technological attributes by showing that the largest TNCs are frequently drawn to the main geographical centres of innovation for their industries.

ciated with economies of agglomeration more generally. If bilateral FDI is possible, one would expect to see TNCs from country one investing in activity one in country two. Likewise, TNCs from country two should invest in activity two in country one. As a result, TNCs from country one should displace country-two firms in activity one, and TNCs from country two should displace country-one firms in activity two. Scientific and technological resources in country one should flow from activity two to activity one, as country-one firms expand in activity one. Conversely, scientific and technological resources in country two should flow from activity one to activity two as country- two firms expand in activity two.

The above model is a description of technological competition between two-countries. It suggests that, over time, countries with different technological endowments should become increasingly dissimilar in their patterns of technological specialization. In terms of equation 2 above, countries with negative correlations between the column values of RTAs in any base period should exhibit even larger negative correlations in future periods. Moreover, the concentration of scientific and technical resources should become more concentrated in each country. Also, in terms of equation 2, the standard deviation of the individual country columns should become larger over time.

In the second model, it is assumed that both country one and country two enjoy technological advantages in activity one relative to the rest of the world. However, scientific and technical resources are more effectively utilized in country one, perhaps because of greater competitive pressure, or larger endowments of complementary assets. Hence, there are underutilized scientific and technical resources in activity one in country two from the standpoint of country-one firms. Given barriers to direct labour mobility, country-one firms can acquire access to scientific and technical resources in country two by acquiring country-two firms in activity one. Presumably, country-one firms find it economical to bid above the reservation prices of country-two firms, since the latter can utilize the relevant resources more intensively than the former. As a consequence, one would expect activity one in country two to expand relative to activity two. All other things being the same, scientific and technical resources in country two should flow from activity two to activity one. At the same time, the larger overall international sales enjoyed by country-one firms in activity one should encourage increased innovation expenditures in country one.[10]

[10] Mansfield *et al.* (1982) identify a positive impact of foreign affiliates sales on home-country affiliate R & D expenditures.

The expectation from a model in which two countries have similar patterns of technological advantages in a base period, but different abilities to exploit these advantages, is that positive RTA correlations in the base period should become more positive in future periods. At the same time, the countries should become more specialized in the technological activities they undertake. Hence, the competition provided by foreign-based TNCs, either actual or potential, should encourage a convergence of technological specialization among countries with similar scientific and technological endowments in the base period, and a divergence among countries with different endowments, *ceteris paribus*. At the same time, it should encourage increased specialization across technological activities in host and home countries.[11]

Obviously, correlations among RTA distributions of different countries, as well as technological specialization within countries, can be affected by factors other than the potential or actual competition provided by FDI. In particular, exogenous innovation associated with basic research or research undertaken for non-commercial purposes can create new technological endowments that, in turn, can promote new technological activities. An example is the military R & D funded by the Government of the United States that spawned new electronics and computer communications-related activities, among other things. The proliferation of new technological opportunities may tend to obscure the impacts of competition by TNCs on patterns of technological specialization. It is also likely to encourage less, rather than more, technological specialization within those countries enjoying new commercial outlets for R & D activities.

Not all countries are likely to be centres for technological breakthroughs which spawn fundamentally new technological activities. As noted above, the performance of basic research can generate new technological paradigms which, in turn, may be best exploited by commercial interests located in countries performing basic research. In addition, large absolute R & D expenditures will generate more serendipitous technological breakthroughs to the extent that the latter are relatively random events. Since such

[11] The same story could be told using international trade as the competitive instrument. Likewise, technological collaboration between TNCs might encourage the same types of changes in RTA patterns. A focus on FDI is more appropriate to the extent that it is a more robust channel for exploiting firm-level advantages based upon intangible assets, such as technology. In fact, this is the conventional wisdom in models of international production. Dunning (1993) and Archibugi and Michie (1995) conclude that while technological cooperation between companies experienced a major boost during the 1980s, the area of cooperation was confined to very few, albeit fast-growing, fields.

breakthroughs may have the nature of quasi-public goods, i.e., all domestic firms performing R & D can exploit them in their applied R & D, the relevant size measure may be the overall volume of research carried out at "the national level.[12] Since the United States and Japan account for the bulk of R & D expenditures and patents (table 1), they are likely to experience the greatest changes over time in national technological endowments, and therefore the weakest tendencies towards specialization. To a much lesser extent, Germany, France and the United Kingdom will also experience changing national endowments. It might be expected, therefore, that RTA correlations between the United States and Japan with other countries are likely to be relatively weak, and that the United States and Japan are likely to be characterized by relatively weak patterns of technological specialization over time.

Empirical evidence

Several broad patterns have been noted by other researchers with respect to technological specialization, and these are summarized by Zander (1992). In general, it has been found that patterns of technological specialization within and among countries are generally stable, with gradual changes and shifts in relative positions taking place over several years. This basic finding is reinforced by a recent study by Archibugi and Pianta (1993). They measured the degree of similarity in technological specialization for 13 developed countries for two periods, 1975-1981 and 1982-1988, using 41 Standard Industrial Classification categories. As explained earlier, a specific measure of the degree of similarity can be calculated by estimating the percentage of total patents accounted for by each industry for each sample country, squaring the difference, dividing the squared value by the share that the industry has in the world total of patents, summing the 41 quotient values and standardizing the sum by dividing by the maximum possible value that the indicator can attain.

Archibugi and Pianta identified the (then) European Economic Community (EEC) and the United States as having the greatest similarity in terms of industrial distribution of patenting activities, with that distribution becoming more similar between the two periods. On the other hand, Japan was found to be much more different from the United States and the EEC.

[12] Other studies have established that large countries are more diversified technologically than small countries.

Table 1. Distribution of indicators of innovating capability among five leading innovating countries, 1970-1987

(Percentage)

Country	Constant R & D expenditure (Measured in terms of 1982 billions of dollars)		Patent	
	1970	1987	1970	1987
United States	61.7	54.0	80.0	58.5
Japan	12.3	20.9	4.5	23.3
Germany	9.8	10.4	7.5	10.6
France	7.0	7.3	2.9	3.8
United Kingdom	9.3	7.4	5.0	3.7
Total	100.0	100.0	100.0	100.0

Source: Dunning, 1992, p. 22.

Furthermore, the differences in the characteristics of Japan were found to be greater in the second period than in the first period. The pattern observed for the 13 countries in their sample is fairly complex. In general, differences between countries tend to shrink between the two periods. However, Archibugi and Pianta made no attempt to determine whether the observed convergence or divergence among pairs of countries was related to technological "distances" between those countries in the initial period.

As noted in the previous section, one implication of the competition provided by TNCs is that countries should specialize more intensively along the lines of comparative technological advantage. If the initial (base) period distribution of RTA is taken as an (imperfect) measure of comparative technological advantage, firms with similar RTAs in the base period should become more similar over time. Conversely, firms with dissimilar RTAs should become more dissimilar over time.

This pattern was tested here using the data described in the article by Pavitt (1988). Pavitt calculated RTA indices for 27 industries and 10 developed countries for two periods, 1963-1968 and 1976-1981. For each sample country, a correlation coefficient between the RTA distribution for that country and the other nine countries for each period was calculated. Table 2 reports the correlation patterns for each country in each period.

The results reported in table 2 are generally inconsistent with the implications of assuming strong competitive effects from TNCs on patterns

Table 2. RTA correlations between pairs of countries, 1963-1968 and 1976-1981

(*Correlation coefficients*)

Country	Canada		France		Germany		Italy		Japan		Netherlands		Sweden		Switzerland		United Kingdom		United States	
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
Canada			-.44	.01	-.20	-0.7	.06	-.14	-.21	-.66	.09	.29	.12	.56	.24	.26	-.41	.24	.46	.80
France	-.44	.01			-.43	.39	-.19	-.31	.05	-.47	-.41	-.14	.08	-.12	-.23	-.15	.52	.50	-.69	-.05
Germany	-.20	-.07	-.43	.39			.06	-.19	-.11	-.51	-.07	-.58	-.14	.16	-.01	-.33	-.39	.19	.40	-.37
Italy	.06	-.14	-.19	-.31	.06	-.19			.19	.11	-.09	-.01	-.30	-.01	.35	.23	-.40	-.30	-.18	-.04
Japan	-.21	-.66	.05	-.47	-.11	-.51	.19	.11			.14	-.03	-.17	-.57	.01	-.29	-.33	-.40	-.34	-.37
Netherlands	.09	.29	-.41	-.14	-.07	-.58	-.09	-.01	.14	-.03			-.03	-.04	.10	.72	-.39	-.26	.35	.30
Sweden	.12	.56	.08	-.12	-.14	.16	-.30	-.01	-.17	-.57	-.03	-.04			-.39	.21	.11	-.06	.01	.47
Switzerland	.24	.26	-.23	-.15	-.01	-.33	.35	.23	.01	-.29	.10	.72	-.39	.21			-.41	-.23	-.06	.12
United Kingdom	-.41	.24	.52	.50	-.39	.19	-.40	-.30	-.33	-.40	-.39	-.26	.11	.06	-.41	-.23			-.36	29
United States	.46	.80	-.69	-.05	.40	-.37	-.18	-.04	-.34	-.37	.35	.30	.01	.47	-.06	.12	-.36	.29		

Source: Author's estimates.
Note: The first coefficient refers to the period 1963-1968 and the second coefficient refers to the period 1976-1981.

of technological specialization. Of the 45 pair-wise comparisons possible between RTA distributions for the sample countries between the two periods, only one-third exhibited the predicted pattern. Specifically, in six cases, countries with positive RTA correlations in the first period exhibited higher positive RTA correlations in the second period. In nine cases, countries with negative RTA correlations in the first period exhibited larger negative RTA correlations in the second period. Furthermore, in a number of cases, correlations that were statistically significant in the first period became statistically insignificant in the second period.

Another implication of TNC-induced competition is that countries should become more specialized in their technological activities. There are several possible approaches to investigating this hypothesis. One is to estimate standard deviations of RTA distributions over time. Increased specialization would be exhibited by increases in the estimated standard deviations. Using the previously cited data set (found by Pavitt, 1988), the standard deviation of the RTA distribution for each country in both sample periods was estimated (results are reported in table 3). In 2 of the 10 sample countries (Japan and the United Kingdom), the standard deviation coefficient actually decreased between the two periods, suggesting that these countries became less, rather than more, technologically specialized. The decreasing technological specialization for Japan is not unexpected given that it is a large absolute and relative performer of research. It should be noted, however, that the difference in the standard deviation was statistically significant (at the 0.05 critical value for the F-statistic) only in the case of Japan. The other sample countries exhibited higher standard deviations in the second period compared with the first period, indicating greater technological specialization. The differences between the two periods were statistically significant for France, Italy, the Netherlands and Switzerland. Hence, the majority of the sample countries showed increased technological specialization.[13]

In another test, the RTA distribution for the period 1976-1981 was regressed against the RTA distribution for the period 1963-1968 for each of the 10 sample countries. In a linear regression, the slope coefficient indicates whether any significant change took place in the RTA value for the

[13] Using a different sample of industries and a larger sample of countries over roughly the same period covered by Pavitt's data, Cantwell (1989) found that technological specialization increased for the majority of countries. Differences in results for individual countries, using the two data sources, were perhaps the consequence of different industry definitions.

Table 3. Standard deviations of the RTA distributions

	Period	
Country	**1963-1968**	**1976-1981**
Canada	0.700	0.736
Japan	0.350	0.501
Germany	0.212	0.246
Italy	0.310	0.462
Japan	1.340	0.463
Netherlands	0.617	1.020
Sweden	0.391	0.482
Switzerland	0.429	0.729
United Kingdom	0.436	0.340
United States	0.115	0.141

Source: Author's estimates.

"average" industry.[14] Specifically, an estimated slope coefficient greater than unity suggests that the leading RTA industries in the earlier period became even more prominent in the later period. This, in turn, is consistent with increased specialization. A slope coefficient between zero and unity suggests that leading RTA industries become weaker—but still leading—in the later period. A negative slope coefficient suggests that the leading industries in the first period became lagging industries in the second period, and vice versa. These latter two results are consistent with decreased technological specialization. Finally, a slope coefficient not significantly different from unity suggests that no change has occurred in the RTA indices between the two periods.

There are several modifications that could be made to the ordinary least-squares regression of RTA indices when it is acknowledged that ordinary least-squares regression analysis is inappropriate for a dependent variable whose value is bounded between zero and unity. One modification suggested by Dalum and Villumsen (1995) is to define the dependent variable as (RTA - 1/ RTA + 1), which makes it continuous in the range of plus-to- minus unity. In fact, the results presented here do not change much when this modification is used, and so only the results of the ordinary least-squares regression using the unmodified estimate of the dependent variable are reported here. Another modification acknowledges that the entire RTA

[14] For an extensive discussion and application of this test, see Cantwell (1989).

distribution can become more or less stable over time. As a result, it might be desirable to standardize the estimated slope coefficients by the overall goodness of fit (R^2) of the estimated equation to assess whether technological specialization patterns became more densely or less densely distributed between the sample periods.[15]

Table 4 presents the results of the ordinary least-squares regression of RTA indices for the period 1976-1981 against the RTA indices for the period 1963-1968. (The t-statistic is indicated in parentheses under each slope coefficient.) The overall goodness-of-fit (R^2) coefficient and the ratio of the slope coefficient to the simple correlation coefficient (b/R) are also reported. Not surprisingly, the findings in table 4 reinforce those in table 3. Specifically, the majority of the estimated slope coefficients cluster around unity, while the majority of the slope coefficients standardized by the overall goodness-of-fit (the b/R ratio) are greater than unity. The highest values for the latter are exhibited by France, Italy, the Netherlands and Switzerland, the four countries with statistically significant increases in the standard deviations of their RTA distributions. Canada exhibits a more modest increase in technological specialization by the b/R ratio, while the slope coefficients for Germany and the United States are statistically insignificant. The slope (and adjusted slope) coefficients for Japan suggest increased technological diversification, and the United Kingdom shows a weaker tendency in the same direction.

Taken as a whole, the evidence presented in table 4, while mixed, points to a modest pattern of increased technological specialization over the sample periods. The results are also consistent with findings reported by Cantwell (1989) and Archibugi and Michie (1995).

Summary and conclusions

The observation that TNCs tend to concentrate R&D in their home countries underpins the claim that international patterns of technological specialization have little to do with TNC activities. However, this argument ignores the potentially important influence competition by TNCs can have on the technological resource-allocation patterns of TNCs, as well as local companies, in the home countries.

[15] The rationale for using Gaussian regression estimates is discussed in Cantwell (1989) and Dalum and Villumsen (1995).

Table 4. Regression of RTA indices for 1976-1981 against RTA indices for 1963-1968

Country	Regression	R^2	b/R
Canada	RTA_2=.255+.794 RTA_1[a] (5.59)	0.566	1.05
France	RTA_2=.258+.806 RTA_1[a] (3.34)	0.317	1.44
Germany	RTA_2=.867+.093 RTA_1 (0.39)	0.006	1.21
Italy	RTA_2=.118+.863 RTA_1[a] (3.48)	0.335	1.49
Japan	RTA_2=.758+.161 RTA_1[a] (2.59)	0.218	0.35
Netherlands	RTA_2=.014+1.08 RTA_1[a] (4.25)	0.430	1.65
Sweden	RTA_2=.333+.753 RTA_1[a] (3.72)	0.372	1.23
Switzerland	RTA_2=.153+1.25 RTA_1[a] (5.40)	0.548	1.69
United Kingdom	RTA_2=.670+.354 RTA_1[b] (2.50)	0.206	0.78
United States	RTA_2=.997+.003 RTA_1 (.600)	0.015	0.03

Source: Author's estimates.
[a] Significant at the 0.1 level.
[b] Significant at the 0.5 level.

Available data do not permit direct statistical estimations of the relationship between changes in the industrial distribution of patents and changes in FDI for the same industries. Moreover, even if possible, such estimations might fail to capture the influence of potential foreign competition on the allocation of national technological resources. This research note attempts to evaluate the indirect influence of TNCs on international patterns of technological specialization by testing the implications of the assumption that TNCs do exert competitive pressures on home-country firms. Some modest statistical support is provided for the case that TNCs exert an indirect influence on international patterns of technological specialization.

Certainly, patterns of technological specialization at the national level change over time, and the failure to identify a stronger influence exerted by TNCs may reflect offsetting influences from other sources not being held constant in this analysis. Indeed, it may be the case that home- and host-country government policies bias international patterns of technological specialization away from patterns dictated strictly by distributions of national comparative advantages. For example, some countries used to restrict FDI in technology-intensive industries in the past. Countries have heavily subsidized "national champions" in industries in which the home country was arguably at a comparative technological disadvantage. Yet another possibility would be that firms in comparatively disadvantaged locations are able to cooperate with one another, thereby increasing their ability to withstand competition from TNCs headquartered in comparatively advantaged locations.[16]

It is therefore possible that regional economic agreements in Europe and North America, as well as multilateral investment agreements, will permit a fuller realization of the potential for TNC activities to influence international patterns of technological specialization by extending national treatment and non-discrimination provisions to a greater range of TNC activities. This may be particularly significant given that budget constraints in the public sector could lead to reductions in innovative activities undertaken in universities and government laboratories. In any event, commercially oriented laboratories are more likely to be influenced by competitive conditions than non-commercially oriented ones. ■

[16] In this regard, however, it should be noted that the major agglomeration of one form of cooperative arrangement—joint ventures—can be found in the United States (Archibugi and Michie, 1995).

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