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Abstract

The purpose of the paper is to examine the relationship between technological diversification and internationalisation of technology for large multinational firms, operating at the world technological frontier. More precisely we address the question as to whether internationalisation determines diversification. The analysis is based on a rich database of the European patenting activity of 345 large multinational firms with the highest levels of patenting over two periods of time (1988-1990 and 1994-1996). The relationship is tested using a variety of different regression models. The results show that for the sample as a whole there is no statistically significant relationship between technological diversification and internationalisation of technology. However when the sample is disaggregated according to the predominant internationalisation strategy adopted by a firm, we find a statistically significant relationship. Our results show that in a cross-section of firms adopting a home-base-augmenting strategy, internationalisation determines the level of diversification. Thus amongst such large firms a higher level of internationalisation of technology is associated with a greater level of diversification.

1. Introduction.

The aim of this paper is to investigate the relationship between two firm level processes: that of technology diversification and of internationalisation of technology. While there is a long history of research on product diversification (see, among others, Chandler (1977) and Markides (1996)) studies of technology diversification are of recent origin (see Cantwell et al. (2004) for a review). At the same time much has been written about internationalisation of technology at the firm level (see special issue of Research Policy edited by Niosi (1999)). However there are very few studies that have examined the relationship between these two phenomena. A notable exception is Cantwell and Piscitello (2000).

The recent literature on internationalisation of technology has shown that the world's largest firms are increasingly engaged in R&D and innovative activities outside the home country (Patel and Pavitt (2000)). At the same time their motives for conducting such activities in foreign locations have changed from simply adapting their products and processes to the local market to accessing world-class knowledge and skills available in fast moving areas of technology, wherever these may be located. One of the key results of the most recent analyses of technology diversification is that large firms need to master an increasing range of technical fields (Granstrand et al. (1997)). Thus firms from a number of different product groups, such as Automobiles and Machinery, are increasingly becoming involved in materials and 'high-tech' areas such as computing technology. This is partly because these products are becoming multi-technology. The measurable effects of such increasing spread of competencies over time (i.e. technology diversification) have been highlighted by Granstrand (1998): growth of R&D, growth of sales, growth of external technology sourcing and growing opportunities for business diversification.

Cantwell and Piscitello (2000) present a historical model of the links between technological diversification, the process of internationalisation and of growth. They distinguish between three different historical stages:

- The inter-war and early post-war period, when diversification and internationalisation were alternative strategies for corporate growth. Internationalisation strategy was mainly motivated by dissimilarities between home and foreign markets, and not by accumulation of technological competencies. The scale of technological diversification in most cases was small in this period.

- In a second stage (by the mid-1970s) technological diversification was now based on the inter-relatedness between separate technologies (and not related to an accumulation of competencies). At the same time lower transport and communication costs contributed to an expansion across large firms in internationalisation activity.
- In the most recent period of time they observe inter-relatedness between technological diversification, accumulation and creation of competencies and internationalisation.

This analysis shows that the only significant positive impact of technological diversification on internationalisation activity occurs in 1990. For Cantwell and Piscitello (2000) this proves that we have entered in a new (third) stage in which technological diversification, accumulation of competencies and internationalisation have become more closely interrelated. By contrast, the only significant effect of internationalisation on technological diversification occurs in an earlier period (around 1935).

Our reading of the literature is that theory does not provide a foundation for establishing a causal link between technological diversification and internationalisation of technology. In the light of this, in our analysis we consider the extent to which technological internationalisation explains technological diversification. The underlying rationale being that firms locate innovative activities in foreign countries in order to expand the range of technologies available to them. The plan of this paper is as follows: in Section 2 we outline the data set and in Section 3 we provide some descriptive results. Sections 4 and 5 contain the main empirical results, and Section 6 the conclusions.

2. The Data set and Variables.

In common with many studies we analyse internationalisation of technology and technological diversification on the basis of patent statistics.[2] In contrast to Cantwell and Piscitello (2000), our analysis is based on information on patent applications at the European Patent Office. It utilises the so-called 'EPAT+' database developed in France by the OST. From this we have selected 345 firms with the highest level of patenting over two time periods: 1988-1990 and 1994-1996. These firms account for slightly over half of all EPO patents applied for by institutions.[3]

The main difficulty with the primary data is that many patents are granted under the names of subsidiaries and divisions that are different from those of the parent companies, and are therefore listed separately. In addition the names of companies are not unified, in the sense that the same company may appear several times in the data, with a slightly different name in each case. For the current dataset companies have been consolidated for the period 1994-96. This means that the structure of the firm over the two time periods of our analysis remains constant. Table 1 shows the distribution of multinational firms according to their nationality and main area of technological activity.[4]

Table 1. Distribution of the 345 firms in the sample by nationality and main area of technological activity (1994-1996).

Main area of technological activity	**USA**	**Japan**	**Europe**	**Other**	**Total**
Electrical - Electronics	25	23	22	4	74
Instrumentation	17	7	10	—	34
Chemicals - pharmaceuticals	41	26	40	1	108
Industrial processes	19	8	21	1	49
Machinery & engineering	20	13	35	1	69
Consumer goods, Building and public works	4	2	5	—	11
Total	126	79	133	7	345

[2] For the use of patent data in analysing internationalisation of technology see Patel and Pavitt (1991) and for their use in analysing technological diversification see Granstrand et al. (1997).
[3] i.e. excluding those attributable to individuals. In the period 1994-1996, there were a total of 235,150 patent applications made at the EPO. Of these 25,924 (i.e.11%) are by individual independent inventors, and 209,226 are by institutions, and our sample of 345 firms accounts for around a half of the institutional total.
[4] This is the technology class in which the firm has the highest number of patents.

We construct the following variables on the basis of the patent data:

DIV (i,t): the level of the technological diversification of firm i at time period t, defined as follows:

DIV (i,t) = 1 - Her (i,t).

where Her (i,t) is the Herfindahl index calculated for firm i at time period t, and is simply the sum of the squares of the shares of the firm's patenting in 30 technological fields. This measures the concentration/dispersion of patents across technological fields for the time period t. The value of the index is between zero and one. The lower the value of Herfindahl, the more technologically diversified the firm, i.e., the patents of the firm are dispersed amongst a large number of technological classes. Cantwell and Piscitello (2000) use an alternative indicator for measuring technological diversification, namely the inverse of the coefficient of variation of the index of the revealed technological advantage of each firm (1/CVi). The two measures are highly correlated, with a coefficient of correlation (Pearson) of 0.9[5]. This means that although we use a different measure for technological diversification we are able to compare our results with those of Cantwell and Piscitello.

INT(i,t): level of technological internationalisation for firm i at time period t. This is measured by the share of total patents applied for by the firm with an inventor address outside the home country. It is a proxy measure for technological activities undertaken in foreign locations, and has been used in studies of internationalisation of corporate R&D (in particular Patel and Vega 1999, and Le Bas and Sierra 2002).

Tecsize (i,t): number of patents owned by firm i at time period t. This is a proxy measure for the size (scale) of the technological activity of firm. The level of R&D expenditures would be a better measure, but this information is not available for many of the firms in our sample. We expect a positive correlation between Tecsize (i,t) and DIV (i,t).

KGROW (i,t) is the variable which takes into account a firm's knowledge accumulation, i.e. the growth of a firm's technological knowledge base. This is measured by the rate of variation of firm i patenting between two dates (t-j, t), and is used in the regressions below.

3. Overview of the Data.

A preliminary overview of the data reveals several patterns. Table 2 presents the distribution of firms by size of technological activity (i.e. number of patents). Nearly 75 % of the firms have less than 200 patent applications in the period 1994-96, and one-third less than 100 patents. The mean is 214 patents. In other words a large number of firms apply for a small number of patents and vice versa. Table 3 gives information about the distribution of firms according to proportion of their patenting outside the home country. According to this measure 50 % of firms are very weakly internationalised as far as technological activity is concerned with less than 5 % of their inventions coming from outside the home country, and 23 % are highly internationalised. For this indicator the average is 15.8 %.

Table 2. Distribution of Firms by size of technological activity: 1994-96.

Number of patents	% of firms
0-99	46.7
100-199	27.0
200-499	16.5
500 and more	9.9
Total	100.0

Table 3. Distribution of Firms by internationalisation of technological activity:1994-96.

% Patents invented abroad	% of firms
0-5	50.1
5-10	12.8
10-20	8.1
15-20	6.4
20 and more	22.6
Total	100

[5] We have also calculated for each firm the relative entropy index which is a natural candidate for assessing dispersion. It varies between 0 and 1 like the Herfindahl index. The Pearson coefficient of correlation between the relative entropy index and the Herfindahl index is nearly 0.95.

Table 4 indicates the distribution of firms according to the level of their technological diversification (measured by the indicator DIV).

Table 4. Distribution of Firms by technological diversification: 1994-96.

DIV	% of firms
1- 0.9	5.8
0.9-0.8	33.9
0.8-0.6	44.1
Lower than 0.6	16.2
Total	100.0

It is well worth noting some trends over time. The overall level of technological internationalisation has increased from 1988-90 to 1994-96 (the same pattern was observed by Patel and Vega (1999), on the basis of US patent data): our sample of MNCs undertake 19.5% of their total patenting outside their home country in the period 1994-96, compared to 15.8% in the period 1988-90. On the other hand technological diversification (based on the DIV variable defined above) has decreased slightly over the same period. Also as discussed above the volume of patenting in our sample of firms has increased over time: in 1988-90 the average number of patent applications for the sample as a whole was 214 compared to 306 in the period 1994-96. A part of this growth might be due to the emergence and the development of the so-called " pro-patent era" (Grandstrand 1999). So the main observation from analysing the trends in our key variables is that while technological internationalisation and technological volume are increasing over time, technological diversification is decreasing slightly.

4. Empirical model and regression results.

As our basic aim is to explore the links between technological diversification and the process of technological internationalisation, we began by running simple regressions between the two variables (these regressions are not reported here). We estimated 4 models: simple linear regression, quadratic function, log-log regression, level-log regression.[6] These preliminary investigations showed that technological internationalisation explains a very small amount of the variance of technological diversification. However we would not expect a single variable to explain the entirety of a phenomenon as heterogeneous as technological diversification. A second finding of this preliminary analysis is that the sign of the coefficient related to internationalisation variable (INT) is always negative whatever the form of the relationship. This indicates that technological diversification and the process of technological internationalisation are inversely linked. The quadratic function gave us interesting information. It indicated a U-shaped (non-monotonic) relationship between technological diversification and technological internationalisation. What emerged from these first regressions is that the level-log model shows the better goodness to fit in terms of R^2 and Student-t. Another element is that the fit is better (in terms of R^2 and Student-t) for the first period under observation (1988-90) than the second (1994-96).

The next step in our analysis was to run multiple regressions which control for some of the factors affecting technological diversification. Based on the results of the simple regressions we chose the level-log specification of the variables. The models we estimated were:

Model 1

$Div(i,t) = a_0 + a_1 \log INT(i,t) + a_2 \log Tecsize(i,t)$ + Dummy (Technology Groups) + Dummy (Countries) + Dummy (period 1988-90) + $\varepsilon(i,t)$

The aim was to assess the determinants of firm technological diversification, using a cross-section model. All the variables are contemporaneous. In model 1, technological diversification is explained by two explanatory variables: the log of technological internationalisation of a firm (INT (i,t)) and the log of the size of technological activity of that firm (Tecsize (i,t)). We pooled the data of the two periods of time (1988-90, 1994-96) to build one unique sample, essentially exploiting inter-firm heterogeneity. We included dummy

[6] We ruled out log-level regression that gave the worst goodness of fit.

variables in order to control for specific factors related to technological classes and to the groups of countries. We were able to test the existence of a temporal effect by including a time dummy.

In order to test whether technological internationalisation "causes" technological diversification, we needed to modify the model, as the notion of Granger causality cannot be applied in a pure cross-sectional framework. Only an autoregressive model can have an element of a causality test. In other words if past INT (i,t-j) helps to forecast current Div (i,t), after controlling for past Div (i,t-j), then we can state INT (i,t-j) can "cause" Div (i,t). We consequently estimated model 2 having the following form:

Model 2

ΔDiv (i,t) = b_0 + b_1 Div (i,t-1) + b_2 log INT(i,t-1) + b_3 log Tecsize (i,t-1) + b_4 KGROW (i,t) + Dummy (Technology Groups) + Dummy (Countries) + ε (i,t)

Model 2 is a dynamic cross-section model. The endogenous variable is the absolute difference of Div (i,t) between 1994-96 and 1988-90. The explanatory variables are now related to the first period of time (1988-90). We included in the regression KGROW (i,t) as a proxy for technological knowledge accumulation that we now can calculate. Generally we test the null hypothesis that INT (i,t-j) does not cause Div (i,t) when the coefficient estimated related to INT (i,t-j) is null.[7] If not there is a presumption in favour of the causal relationship.

We used OLS and estimated level-log models for all the relationships. The results have been checked for heteroskedasticity. The first column of Table 5 contains the estimates of model 1, and shows that model 1 explains 32% of the variance. The dummies for technology groups are significant but not the dummies for countries, showing that technological diversification strategy is strongly determined by the sector to which a firm belongs or to a group of technologies.[8] In contrast previous results show that technological internationalisation strategies of firms are more dependent on the characteristics of nations (USA, Europe, Japan).[9]

[7] On this aspect see Wooldridge (2003).
[8] Electronics and electricity and instrumentation are the most specialised technological groups.
[9] Guellec and van Pottelsberghe (2001) have shown that large cross-country differences exist in the extent of technological internationalisation, depending on the size of the country and its level of technological activities.

The size of technological activities (Tecsize) has strongly significant positive effects on Div(i,t), showing that as the volume of patenting increases a firm becomes technologically more diversified (or less specialised). This validates the general notion that larger firms are more diversified[10] and is consistent with the results of Cantwell and Piscitello (2000). This result is also well established by Granstrand and Sjölander (1990) who gave evidence of the existence of a relationship between firm size and technological diversification. Last but not least, the coefficient related to the main explanatory variable (INT) is not significantly different from zero.

The main result in the framework of a cross-sectional model is that technological diversification is not explained by technological internationalisation once we control for other factors.[11] Is this observation still true in the framework of the dynamic cross-sectional model? The regression results for model 2 are given in Table 5. We have run different variants of this model in order to test the robustness of the results. For the 3 estimations the coefficient estimate related to INT is not significantly different from zero. Thus the null hypothesis that INT does not cause Her is valid.[12] We now want to explore the consequences of a last source of heterogeneity: the type of internationalisation strategy followed by the firm.[13]

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[10] Santangelo (2002) points out that technological diversification cannot be explained only in terms of firm size, technological interrelatedness is also another explanatory variable.

[11] We ran regressions for each technology group. The results were inconclusive.

[12] This result is not in accordance with the recent Cantwell and Piscitello (2000) study. They found an impact of INT(i,t) on Δ DIV (i) occurs in only one period of time (1935) and it is positive**.**

[13] We wanted to explore variants of model 2 in order to assess differently the effects of firm growth on technological diversification. We have built three firm sub-samples: the first contains firms for which KGROW is negative (i.e. firms' overall patenting decreased from 1988-90 to 1994-96); in the second are firms characterised by the low growth of their knowledge base (KGROW (i) ‹ AVERAGEKGROW, their growth is lower than the average); in the third we have firms with stronger knowledge base growth (KGROW (i) › AVERAGEKGROW). We estimated the model for each of these sub-samples but the results were not convincing. The effects of technological internationalisation on technological diversification are not significant.

Table 5. Technology Diversification and Internationalisation: Regression results

Here the dependent variable is DIV and Δ DIV

	Model 1 DIV (i,t)	Model 2 ΔDIV (i,t)
Her(i,t)	Not included	15.86 *** (-5.87)
Log Int(i,t)	0.54 (-1.58)	- 0.18 (0.71)
Log Tecsize(i,t)	17.22*** (-12.74)	- 0.23 (1.21)
KGROW(i,t)	Not included	0.01*** (-3.31)
Tecgroup 1	9.78*** (-2.61)	3.74 (-1.05)
Tecgroup 2	6.73 * (-1.69)	2.82 (-0.75)
Tecgroup 3	18.04 *** (-4.99)	5.52 (-1.59)
Tecgroup 4	23.78 *** (-6.26)	4.36 (-1.18)
Tecgroup 5	16.39*** (-4.42)	5.71 (-1.61)
Europe	- 7.06 (1.57)	- 7.45* (1.78)
USA	- 7.46* (1.66)	- 6.95 * (1.66)
Japan	- 3.18 (0.68)	- 7.10 * (1.66)
Period effects	- 4.44*** (3.46)	Not included
Intercept	71.53 (12.40)	- 18.27 *** (2.66)
N	690	345
R squared	0.3228	0.2353
Adjusted R squared	0.3118	0.2077
F statistic	29.38 ***	8.51 ***

Method of estimation: OLS. t-statistics in parentheses.
*, **,*** indicate the parameter is significantly different from zero at the 10%, 5%, 1% probability thresholds.

5. Firm technological diversification and technological internationalisation strategy.

Recent studies which shed light on the determinants of the foreign location of technological activities of large firms raise the following question: do they locate their technological knowledge activities as a consequence of their home country technological advantages or according to host country technological strengths? Four types of strategy are defined according to revealed technological advantages (for a more detailed analysis see Le Bas and Sierra, 2002):

- Strategy 1: Technology-seeking foreign direct investment (FDI) in R&D. This type of strategy is directed towards offsetting home country weaknesses in a given technological field by selecting a host country with proven strength in the desired technology. Patel and Vega (1997, p. 111) suggested qualifying such a strategy as ‘host country-exploiting FDI’ in R&D, where a firm is simply exploiting host country technological advantages in areas of domestic weakness.

- Strategy 2: Home-base-exploiting FDI in R&D (Kuemmerle, 1999). This is the exact opposite of the first strategy. The rationale for the investment here is to exploit existing firm-specific capabilities in foreign environments.

- Strategy 3: Home-base-augmenting FDI in R&D. The third type of strategy consists of targeting technologies in which the investing firm has a relative advantage at home and the host country is also relatively strong. This kind of investment has accordingly been labelled as ‘home-base-augmenting’ FDI in R&D by Kuemmerle (1999), and as ‘strategic asset-seeking R&D’ by Dunning and Narula (1995).

- Strategy 4: Market-seeking FDI in R&D. The fourth type of strategy corresponds to situations where a firm invests abroad in technological activities in which it is relatively weak in its home country and the host country is also relatively weak. The motivation for this fourth type of strategy is thus apparently not technology-oriented.

Patel and Vega (1997), using US patents, and Le Bas and Sierra (2002), using European patents, find that in a great majority of cases (nearly 70%) multinational corporations (MNCs) locate their R&D activities abroad in technological areas where they are strong at home (strategy 2 and strategy 3). Moreover, strategy 3, which corresponds to 'dynamic learning', outclasses strategy 2, which corresponds to 'myopic learning', and becomes increasingly important over time. The strategy of Japanese firms is very different from European and US MNCs: in Europe, Japanese firms seek out locations that have complementary strengths to their own (strategy 2).

These previous studies employing this taxonomy (Patel and Vega, 1999; Le Bas and Sierra, 2002) consist of analysis at the level of the sector and country in order to account for the scale of activity related to each of these four strategies. Here we deliberately chose to study the question at the firm level. We defined sub-samples of ***firms according their dominant technological internationalisation strategy.***[14] Thus in the case of 134 firms in our sample the predominant strategy is strategy 2, and for 203 firms this is strategy 3 (the rest of the firms are divided between the other two strategies). As far as technological internationalisation strategy is concerned each sample is composed of homogeneous firms.

We ran estimates for each of these two samples. The aim was to check if different strategies, as far as foreign R&D location is concerned, entail different relationships between technological diversification and technological internationalisation. Thus we ran two regressions based on Model 1. For the first, the sample of firms is made up of those implementing strategy 2 (Model 1-S2), and for the second, those involved predominantly in strategy 3 (Model 1-S3).

Table 6 gives the regression results. The important finding is that the goodness of fit is better (in terms of R^2) for the estimation carried out with the firms which conducted strategy 3 (final column), and the coefficient related to INT (i, t) is significantly positive. By contrast, the value for this coefficient is not significantly different from zero (at the 95 per cent level of confidence) for the firms conducting strategy 2. If anything, the value is negative, albeit with a low t-value. This result is striking since in both models, in general the coefficients related to

[14] A dominant strategy is the one that encompasses the greatest number of patents.

other explanatory variables have the same sign and the same level of significance (except for the dummies taking into account the country fix-effects).

Table 6. Technological diversification and internationalisation strategy.
Here the dependent variable is DIV= 1-Her

	Model 1-S2	Model 1-S3
Log Int(i,t)	-0.56 (-1.23)	1.58 *** (3.22)
Log Tecsize(i,t)	16.88 *** (7.90	15.45325 *** (8.710)
Tecgroup1	7.58 (1.38)	14.07 *** (2.81)
Tecgroup2	16.82*** (2.76)	5.11 (1.00)
Tecgroup3	13.46 ** (2.49)	21.83*** (4.65)
Tecgroup4	18.84*** (3.38)	26.77 *** (5.43)
Tecgroup5	11.03 ** (2.03)	21.42*** (4.43)
Europe	3.40 (0.33)	-15.36 ** (-2.54)
USA	2.82 (0.27)	-15.93*** (-2.64)
Japan	8.27 (0.79)	-14.40** (-2.21)
Period effects	-4.99 *** (-2.72)	-3.85 ** (-2.25)
Intercept	23.45** (11.78)	35.52 *** (4.62)
N	268	406
R squared	0.3023	0.3935
Adjusted R squared	0.2724	0.3766
F-statistic	10.09 ***	23.24 ***

Method of estimation: OLS. t-statistics in parentheses.
*, **,*** indicate the parameter is significantly different from zero at the 10%, 5%, 1% probability thresholds.
OLS estimates, t-statistics values between parentheses.
Tecgroup1: Electronics and Electricity. Tecgroup2: Instrumentation. Tecgroup3: Chemicals and Pharmaceuticals. Tecgroup4: Industrial processes. Tecgroup5: Machinery and engineering.

These estimates show that as large multinational firms become more diversified (less specialised) in terms of technological competencies, the level of technological internationalisation increases when they follow a home-base-augmenting FDI in R&D

strategy (strategy 3) once we control for other potential intervening factors.[15] From this analysis we draw the conclusion that the relationship between the firm degree of technological internationalisation and firm technological diversification changes according to the strategy followed by the firm. In other words the strategy implemented by a firm matters. There is another consequence. If our results are then the taxonomy regarding R&D internationalisation strategy that has been elaborated previously (Patel and Vega, 1999, Le Bas and Sierra, 2002), with no reference to technological diversification, is now reinforced. It is also relevant for explaining the trend of technological diversification. It is too early to set out a definitive explanatory framework for explaining the reasons why the relationship works with one internationalisation strategy and not with the other. Placing our analysis in the framework of the evolutionary vision of the MNCs, as pictured by Kogut and Zander (1993), would indicate that what is important is the organisation that could transfer knowledge across borders. In the context of strategy 3 dynamic learning (more exploration than exploitation) is very important. Technological knowledge diversification may be the only means for the firm to absorb new knowledge from its foreign locations and transfer it internally.[16]

[15] To some extent the reverse would seem true. The firms following strategy 2 (the home-base exploiting FDI in R&D strategy) become less specialised as the level of technological internationalisation increases.

[16] More generally it would seem important to explicitly take into account the costs of technological diversification at the firm level.

6. Conclusions.

The possible relationship between technological diversification and technological internationalisation is the issue at the heart of this study. The results of simple regression show that technological diversification is very weakly explained by technological internationalisation. By contrast Cantwell and Piscitello (2000) point out that an important impact of technological diversification on technological internationalisation exists for the 1990s.[17] We undertook a multiple regression analysis in order to validate this finding. Adding other regressors and remaining in the context of pure cross-sectional model, the Cantwell and Piscitello result is much less striking. An additional factor has a significant influence on technological diversification: the size of the technological activity at the firm level, controlling for the effects of technological groups and countries. To test for the presence of a causal effect, we estimate a dynamic cross-sectional model. This yields information that a causal effect of technological internationalisation on technological diversification is statistically rejected.

In the final part of the paper we investigated a further perspective, namely we explored the links between the *type* of technological internationalisation strategy implemented by the firms, and the level of technological diversification and the scale of technological internationalisation. We expected that the relationship between the two variables would have a different configuration for each strategy. As a first attempt our results are encouraging. The estimates show MNCs become more diversified (less specialised) in terms of technological competencies as the level of technological internationalisation increases when they follow a home-base-augmenting FDI in R&D strategy (strategy 3). We could not find a statistically valid pattern for those of MNCs that conduct a different strategy (strategy 2, the so-called home-base- exploiting strategy). This important result has not been previously reported in the literature dealing with the interwoven relationships between technological diversification and technological internationalisation. This paper does not yet suggest a relevant framework for explaining the complex mechanisms underlying these two important firm-level processes but provides input for building one.

[17] There are many possible reasons why we can obtain results that are a little different from Cantwell and Piscitello's (2000) findings, even when we use the same indicators for the main variables, the same type of equations to be estimated and patent data for the same time period. Two important reasons have to be stressed. Firstly, Cantwell and Piscitello use US patents data (versus European patents) for 166 largest European and US firms (versus 345 largest world-wide firms as far as patenting is concerned). They did not account for technology groups and country-specific effects.

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Annex

List of the 30 technological fields and the dummies for the technology groups.

N°	Technological field
1	Electrical components Electronics
2	Audio-visual sector
3	Telecommunications
4	Information technology
5	Semi-conductors
6	Optical instruments
7	Analytical, measurement & control instruments
8	Medical equipment
9	Organic chemistry
10	Macro-molecular chemistry
11	Pharmaceuticals - cosmetics
12	Biotechnology
13	Food and agricultural products
14	Technological processes
15	Surface treatment
16	Materials handling
17	Thermal processes
18	Materials - Metals
19	Chemical processes - Oil
20	Environment - Pollution
21	Machine tools
22	Motors - Pumps - Turbines
23	Mechanical components
24	Product handling - Printing
25	Agricultural machinery - Food processing
26	Transport
27	Nuclear technology
28	Space - Arms
29	Household equipment & consumer goods
30	Building and public works

Dummy for technology groups (technological sectoral characteristics).

TECGROUP 1 : technological fields 1 to 5
TECGROUP 2 : technological fields 6 to 8
TECGROUP 3 : technological fields 9 to 13
TECGROUP 4 : technological fields 14 to 20
TECGROUP 5 : technological fields 21 to 28