An Exploration into the Determinants of Patent Activities. Some Empirical Evidence for Austria

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1. Introduction

In the last few years the subject of invention and technological change has become one of the most pressing issues of national debate in Europe. The reason underlying the emergence of innovation and invention as a topic of broad public interest is the belief that invention and innovation are the major driving forces of the rise and decline of industries, of regional and national economic growth.

The question how to measure technological change has concerned economists and economic geographers for a long time. However, no widely accepted procedure has been developed so far. Much of the technological change is the product of relatively deliberate economic investment activity which has come to be labeled R & D and one of the few direct reflections of the output of R & D activities is the number and kind of patents granted to different firms. The number of inventions which have been patented is without doubt the most widely used proxy measure of innovative activity though patents are a flawed measure of innovative activity (Pakes and Griliches 1980). Not all innovations are patented and only a small part of the patented inventions will become innovations. In addition, patents differ in their economic impact. The quantity and quality of patenting may depend on chance, how readily a technology leads itself to patent protection, and business decision makers' varying perceptions of how much advantage they will derive from patent rights. Not much is known about differences in the propensity to patent (Scherer 1983).

A patent system provides a form of protection by granting the inventor legal means to prevent others from copying or using the invention without permission for a certain time period (usually fifteen to twenty years). Patent systems require patent documents to provide an 'enabling disclosure' which sufficiently describes the invention to enable others skilled in the same technology field to replicate or make the invention. Thus, patent laws encourage early publication of the invention in return for granting a limited monopoly (Evenson 1984).

This paper examines data on patent applications (1987-1989) in order to identify the determinants which influence patenting activities in the Austrian manufacturing sector. The data used are at the firm level and based on a merger of patent and company data. The paper starts by describing the construction of the sample from the two data sources (section 2). In section 3 some stylized empirical facts about the extent of patent activities in the Austrian manufacturing sector are presented and these are related to characteristics of the establishments. An attempt is made in section 4 to provide a more general conceptual framework for analysing patenting behaviour, while in section 5 the importance of the commonly identified indicators is tested via logit modelling. The final section summarizes some major findings.

2. Sample and Data Description

Before presenting results of the study some attention should be paid to the construction of the sample and data base from the two major data sources. The basic universe of the sample is the set of firms in the Austrian manufacturing sector which existed in the time period of 1987 through 1989 in the statistical information system of the Austrian Research Centre Seibersdorf. This information system which covers all manufacturing firms of Austria with 20 and more employees (see Gheybi et al. 1990 for more details) is actualized every year and provides information on employment size, turnover, product groups (SIC four digit codes), production technology, a short description of the product structure, technology indicators, etc. at the firm level. The manufacturing sector is defined to be firms with the SIC groups as outlined in the appendix.

Owing to the computerisation of the Austrian Patent Office in the 1980s, we were able to obtain a file with data on each individual patent application from 1987 through 1989. For each such patent we have the year it was applied for, the Patent Office number of the patent organisation, the name and address of the patent applicant, an assignment code telling whether the organisation is foreign or domestic, and some information on the technology field of the patent application.

The matching of the Patent Office file with the company data file was a major task in the sample creation. The difficulty of matching is caused by the fact that frequently corporations in the sample may have a slightly different name from that given on the company data file (Co. instead of Inc., or Incorporated and other such changes or abbreviations). To do the matching we proceeded as follows. The names on the Patent Office organisation file were matched by a computer program to the names of the firms in the company file. This program had various techniques for accommodating differences in spelling and abbreviations. The matched list of names was checked for incorrect matches manually. A final file was produced which related the identification number of each firm in the company file to one or more (or none) Patent Office organisation numbers. Using this file, the file with individual patent records was aggregated to the firms level. The final cross section consists of data on firm location, employment, turnover, product groups, production technology, four technology indicators and patents applied for during 1987-1989 for 4559 firms in the manufacturing sector. The technology indicators, unit value of exports in terms of $ per kg at the SITC four digit level, position in the product life cycle, technology intensity (in terms of the world export share of non - industrialised countries at the SITC five digit level) and innovation shift (defined as difference between the product cycles in industrialised and developing countries) have been measured on the basis the UNIDO world export data (1965-1989) to characterize the business segments of the Austrian industry from a technology orientated point of view (see Gheybi et al 1990, Scholz 1977).

To interprete data on patenting it is useful to briefly summarize the options to a firm to alter the technology it uses (Evenson 1984):

- **first**, the firm may engage in fundamental research to arrive at results which may improve the efficiency of its more applied research,
- **second**, the firm may engage in applied research designed to invent a new product or process and bring it to the development stage,
- **third**, the firm may engage in testing, pilot production, and plant design work necessary to bring inventions developed by its own applied research into use,
- **fourth**, the firm may purchase inventions or in the case of unprotected inventions imitate them, and engage in strictly adaptive research and development to bring them into use, and
- **fifth**, the firm may purchase semi- or fully developed inventions embodied in machinery, chemicals etc. making only minor modifications of other inventions.

Evidently, activities related to the last option generally do not produce patented inventions. Most patentable inventions are generated by the second type of activities, partly by the first type too. Consequently, patents are viewed in this paper to capture and measure the early stages of the process which lead from novelty/invention through development, testing and engineering to full-scale innovation rather than the whole innovaton process.

3. Some Empirical Evidence on Differences in Patenting

In this section empirical evidence is provided of the extent of patent activities in the Austrian manufacturing sector and this is related to characteristics of the establishments. While empirical studies relating R & D to firm size show considerable ambiguities and inconsistencies in the results (see Cohen and Levin 1989), the few studies relating patents to firms size are considerably less ambiguous. The findings unequivocally suggest that the evidence leans weakly against the Schumpeterian conjecture that the largest firms are especially fecund sources of patented inventions (Scherer 1982, Soete 1979, Link 1980, Loeb 1983, Meisel and Lin 1983 inter alia).

Table 1 provides data on patent applications during 1987-1989 for firm size classes measured in terms of employment (20-49 employees, 50-99 employees, 100-199 employees, 200-499 employees and 500 employees and more) and clearly indicates that the above mentioned results can not be confirmed for Austria. The largest corporations (5.1 per cent of all establishments) generate more patents (58.9 per cent) than do their small and medium sized counterparts. Over all considered, the empirical evidence seems to support the Schumpeterian hypothesis that inventive activities increase with firm size more than proportionately. The ratio of patents per 1000 employees, some sort of patent intensity measure, ranges form 1.7 for the size class 50-99 to 4.5 for the largest establishments. The ratio of 2.7 for the size class 20-49 points to the fact that the relationship between patented inventions and firm size tends to be non-linear in nature, with both larger and smaller firms showing greater patent activities in relative terms. This result is conistent with findings of a more comprehensive study on innovation behaviour of manufacturing firms in Austria in which the relationship between R & D input and firm size has been analysed in more detail (Fischer and Menschik 1990).

Table 2 presents some summary statistics for the firms in the sample, broken down into twenty-three industry categories. The exact industry category assignment scheme used throughout this paper, based on SIC codes, is presented in the appendix. The distribution of patenting activity across these industrial sectors shows high shares of patenting firms in instruments and related products (22.9 percent), machinery (21.8 percent) and vehicles (18.2 percent). Patents in these categories are typically related to technology of production and diffused to other sectors within the economy. The ratio of 1000 employees ranges from 0.0 for leather-producing, 0.2 for clothing and 0.3 for textiles to 6.8 for machinery and 7.1 for non-iron metal and iron producing. The disparity in propensity to patent across industry sectors - revealed by the percentage of patenting establishments in crude terms - may be also due to the fact that the value and cost of individual patents vary greatly across the sectors.

Table 3 provides evidence on patent applications disaggregated by six technology intensity classes. Technology intensity is measured in terms of the percentage of the world export share of non-industrialised countries at the SITC four and five digit level and normalised to the interval of zero (very low technology intensity) to six (very high technology intensity). High values point to a high market share of industrialised countries for a product group indicating a high degree of technological competition. Table 3 clearly provides evidence that patent activities (defined as number of patents per 1000 employees) tend to increase with increasing technology intensity.

Table 4 provides evidence on regional discrepancies of patent activities. Four regional types are distinguished: the metropolitan area of Vienna, small and medium sized urban areas, old industrial areas and peripheral regions which represent a variety of historic and current economic trends and conditions within the Austrian economy. Regional disparities in patent intensity - measured in terms of the ratio of patent applications per 1000 employees - may be observed between the metropolitan area of Vienna (4.2 patent applications per 1000 employees) and peripheral regions (2.5). With 3.1 and 3.4 patent applications per 1000 employees old industrial as well as small and medium sized urban areas take on an intermediate position. It is important to note that variations in patenting activities between regional types may be anticipated simply as a result of the different nature of the enterprises and establishments located there. In essence, regional discrepancies may be attributed to size and sectoral effects (see section 5).

4. A Conceptual Framework for the Propensity to Patent

Any explanation of the patenting behaviour of industrial firms has to be based on an understanding of the determinants influencing this behaviour. In this section elements from different theoretical contributions and conclusions from empirical

Table 1: Patenting Activities in the Austrian Manufacturing Industry (1987-1989) by Firm Size

Firm Size	Establishments		Patent Applications		Patenting Firms		Patent Applications per 1000 Employees
	Number	Percent	Number	Percent	Number	Percent	
20-49	2274	49.9	187	9.2	86	3.8	2.7
50-99	1025	22.5	119	5.9	63	6.2	1.7
100-199	604	13.2	160	7.9	59	9.8	2.0
200-499	422	9.3	366	18.1	85	20.1	2.8
500 and more	234	5.1	1196	58.9	81	34.6	4.5
Total	4559	100.0	2023	100.0	374	8.2	3.3

Table 2: Patenting Activities in the Austrian Manufacturing Industry (1987-1989) by Industry Sector

Industrial Sector	Establishments		Patent Applications		Patenting Firms		Patent Applications
	Number	Percent	Number	Percent	Number	Percent	1000 Employees
Mining	125	2.7	5	0.2	4	3.2	0.4
Leather-Producing	16	0.4	0	0	0	0	0.0
Leather-Processing	68	1.5	40	2.0	12	17.7	3.3
Foundry	35	0.8	13	0.5	4	11.4	3.0
Non-Iron Metal	50	1.1	62	2.9	4	8.0	7.1
Machinery	374	8.2	412	20.5	82	21.8	6.8
Vehicles	66	1.4	94	4.4	12	18.2	5.8
Iron and Metal Wares	386	8.5	332	16.4	56	14.4	6.3
Electrical and Electronics	185	4.1	361	17.8	27	14.6	5.5
Instruments and Related Products	70	1.5	41	2.0	16	22.9	3.9
Textiles	213	4.7	9	0.4	8	3.8	0.3
Clothing	422	9.2	7	0.3	6	1.4	0.2
Iron Producing	4	0.1	98	5.1	1	25.0	7.1
Oil Industry	172	3.8	132	6.1	25	14.5	5.8
Stones and Ceramics	222	4.9	34	1.7	14	6.3	1.2
Chemicals	192	4.2	146	7.5	30	15.6	5.3
Glass	46	1.0	2	0.1	2	4.4	0.5
Paper-Producing	62	1.4	20	1.0	7	11.3	1.1
Paper-Processing	60	1.3	15	0.7	8	13.3	1.7
Wood-Processing	732	16.0	41	2.0	24	3.3	0.8
Food, Beverages and Tobacco	647	14.2	20	1.0	13	2.0	0.3
Printing and Publishing	268	5.8	5	0.3	5	1.9	0.2
Others	144	3.2	144	7.1	18	12.5	8.6
Total	4559	100.0	2023	100.0	374	8.2	3.3

Table 3: Patenting Activities in the Austrian Manufacturing Industry (1987-1989) by Technology Intensity

Technology Intensity	Establishments Number	Establishments Percent	Patent Applications Number	Patent Applications Percent	Patenting Firms Number	Patenting Firms Percent	Patent Applications per 1000 Employees
Less than 1.00	640	14.1	64	3.2	24	3.8	1.3
1.00-1.99	671	14.7	231	11.4	37	5.5	1.4
2.00-2.99	1198	26.3	528	26.1	100	8.4	2.1
3.00-3.99	1221	26.8	535	26.4	122	10.0	3.4
4.00-4.99	645	14.1	513	25.4	64	10.1	3.9
5.00-6.00	184	4.0	152	7.5	27	14.7	4.2
Total	4559	100.0	2023	100.0	374	8.2	3.3

Table 4: Patenting Activities in the Austrian Manufacturing Industry (1987-1989) by Regional Type

Regional Type	Establishments Number	Establishments Percent	Patent Applications Number	Patent Applications Percent	Patenting Firms Number	Patenting Firms Percent	Patent Applications per 1000 Employees
Metropolitan Area of Vienna	1086	23.8	645	31.9	93	8.6	4.2
Small and Medium Sized Urban Areas	2297	50.4	1000	49.4	196	8.5	3.4
Peripheral Regions	1011	22.2	269	13.3	64	6.3	2.5
Old Industrial Areas	165	3.6	109	5.4	21	12.7	3.1
Total	4559	100.0	2023	100.0	374	8.2	3.3

research will be immediated into a conceptual framework for analysing determinants for patenting behaviour.

In assessing factors which influence patenting behaviour it is necessary to go beyond the characteristics of the firm. It is increasingly recognized that the environment in which the firm operates, more or less strongly influences - sometimes facilitates and sometimes retards - invention activities. Such acceleration and retardation effects relate not only to the sectoral, economic and technical environment of the firm, but also to the locational and to the political-institutional framework in which the firm has to operate (Fischer 1991, Tödtling 1990, see figure 1).

It may be assumed that four major types of determinants influence invention and patenting behaviour (see Fischer and Menschik 1990):

- **First**, factors related to the firm's potential for invention activities (i.e. so-called internal factors),

- **Second,** factors related to the firm's interaction with its locational and/or regional environment (i.e. invention-relevant locational or regional influences),

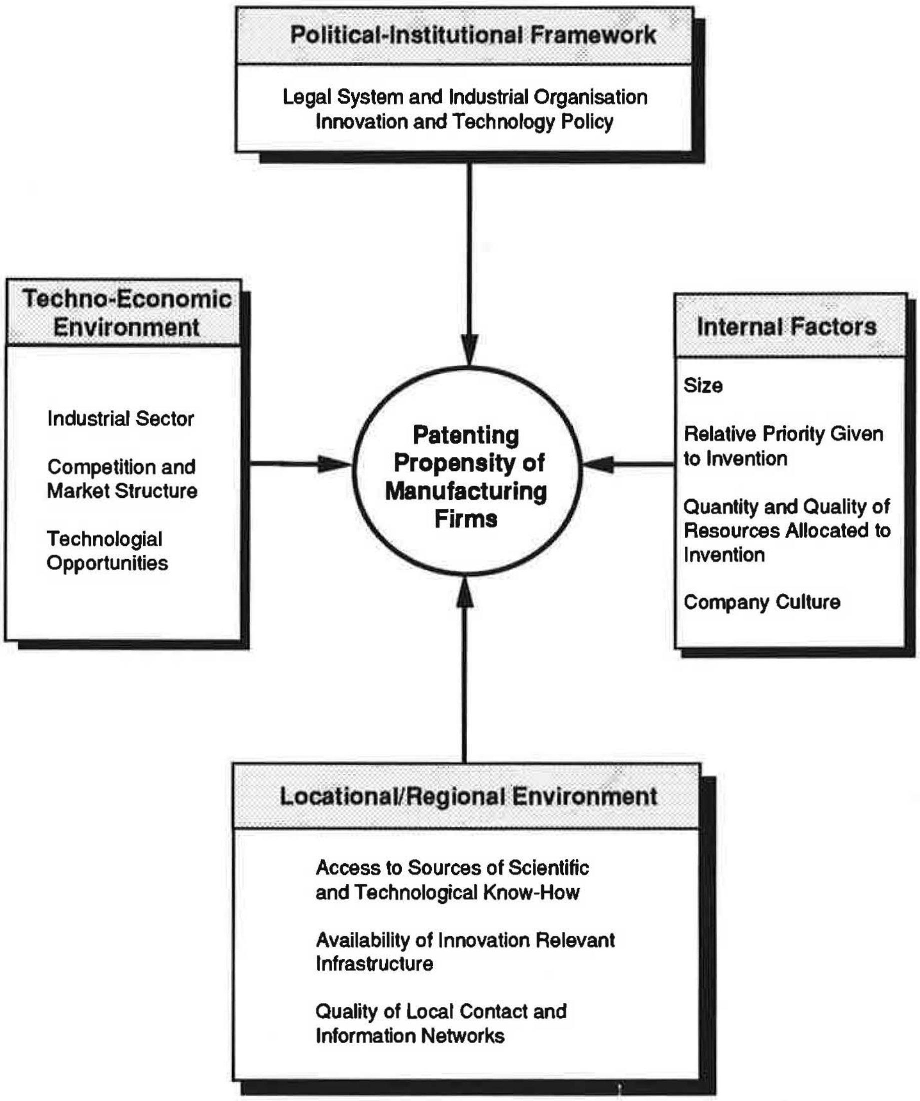
- **Third**, factors related to the firm's interaction with its sectoral, technical and economic environment (i.e. invention-relevant influences of the techno-economic environment), and

- **Fourth**, factors related to the political-institutional context in which the firm has to operate

The various factors which might conceiveably influence invention and patenting activities add up to a formidable list. The most important factors will be briefly discussed in the following (see Fischer 1991).

Internal factors relating to the behaviour and structure of the firms play a crucial role in influencing invention and patenting activities, as well as in explaining differences in patenting behaviour. The relationship between establishment size and invention/innovation has been the matter of a long standing debate (see Freeman 1982, Galbraith 1985, Hageedoorn 1989, Cohen and Levin 1989). Some

Figure 1: A Conceptual Framework for Patenting Behaviour at the Firm Level



scholars like Galbraith (1985) argue in the Schumpeterian tradition that large size is a prerequisite for economic progress via invention and innovation, and emphasize the pre-leading role which large companies play. This view is largely based on the rationale that larger firms show a greater ability to raise capital necessary for invention projects and to spread risks over a portfolio of projects. They have a greater capacity to manage information and to maintain large R & D facilities, and can afford the managerial and technical specialists which are often needed to arrive at patented inventions.

The supremacy of large firms has been questioned by many. Scholars like Rothwell and Zegveld (1982) stress the specific role of smaller firms, especially of high tech firms, in the process of technological change and point to several comparative advantages in innovation which may be ascribed to them, their ability to react quickly to keep abreast of fast-changing market requirements, their lack of bureaucracy, their great flexibility of internal communication networks and their ability to adapt changes in external environments (see also Sweeney 1983, Rothwell 1986). As a consequence, there are good reasons to assume a non-linear U-shaped relationship between patented invention and firm size, with both large and small firms sharing greater patent activities.

Organisation-specific factors which influence the quality and quantity of new knowledge generated are the relative priority given to invention in the organisation's strategy-making, the quantity and quality of resources allocated to invention, the organisation's culture which may be defined as patterns of activities, interactions, norms beliefs, attitudes, products and the technological standard. Spatially sensitive organizational factors which influence resource allocation to invention are those related to the organisational structure of multi-site companies. Headquarters are more likely to comprise invention activities than branch plants or subsidiaries.

Among the **spatial factors** influencing the knowledge generated during invention processes, the quality of local/regional networks and infrastructure through which linkages are established may be considered to be essential. Scientific research increasingly depends on network linkages and diffusion, especially between researchers dealing with complementary aspects of an invention program (Suarez-Vila and Vela 1990). The major bottlenecks for small firms in peripheral and rural regions which are poor in terms of the environmental complexity needed for invention projects are found in the area of human capital, information provision and risk capital. Larger firms and particularly multi-site firms can overcome such limitations more easily.

In general the industrial sector in which a firm operates is considered as a major factor influencing its potential to invent and innovate (see Oakey et al. 1980, Fischer and Menschik 1990). Closely related to the industrial sector are other determinants such as technological opportunities, and market pressure and structure. Technological opportunities may be defined as the extent of basic scientific knowledge in industry (see Dosi 1984). Evidently, technological opportunities vary with time and among industries. New growth industries like electronics, biotechnology, aerospace, chemicals and allied industries offer more technological opportunities than other more mature industries like textiles and clothing. If one looks at the empirical work on the relationship between market structure and invention activities one can find some consensus, but only at a level of high generality, in so far that market concentration has a favourable impact on knowledge production in certain industry-specific situations.

Finally, the legal systems in different countries influence the type of inventive activities undertaken by firms and the patentability of inventions. Some countries pursue policies which encourage the holding of inventions in trade secrecy. When industrial organisation structures effectively discourage competition, corporations may have little incentive to sell new technology in direct form and may attempt to capture rents through the sale of new technology embodied in products. This tendency may be reinforced by trade secrecy laws which provide penalties for the pirating of trade secrets (Evenson 1984).

5. Logit Analysis and Results

Litttle is known how the determinants discussed in section 4 interrelate with each other and influence patent activities. As a first step in identifying the key determinants of patent activities the data were analysed by means of logit analysis. Logit modelling attempts to overcome the difficulties inherent in bivariate analysis with the rigour of multiple regression modelling for categorical data with a dichitomous response variable (see Fischer and Nijkamp 1985, Wrigley 1985 for more details).

Patent application makes up the dichotomous dependent variable of the form yes/no. The following independent variables were incorporated into the analysis:

- Establishment employment size (natural logarithm),
- Technology intensity (measured by the percentage of world export share of non-industrialized countries at the SITC five digit level),
- High-tech firm (using the definition of Glasmayer et al. 1983 at the SIC four digit level),
- Industrial sector (23 different categories, see appendix),
- Location (metropolitan area of Vienna, small and medium sized urban area, old industrial area, peripheral region).

Table 5 indicates the degree to which establishment characteristics and environmental characteristics increase or decrease the probability (strictly the log-odds) of patent application. There is no intention that the result presented in the table should in any sense represent an optimal model. Rather, the intention is to demonstrate which variables are important and to identify wether the magnitudes and directions of the relationships are similar and otherwise. Although t-values are given as well as the parameter estimates, it should be noted that the most reliable way to evaluate the significance of the estimates is through the change in log-likelihood associated with each parameter. For variables with more than two categories the significance of any one parameter will depend on its relationship to categories other than the reference category which is what the t-value reflects. All the significant coefficients (0.05 level of significance) have the anticipated sign. However, not all the coefficient estimates are significantly different from zero. The logit model fits reasonably well the data, in terms of rho-squared bar at market shares of 0.16 and a prediction success of 94 percent.

Table 5 clearly indicates the influence of the establishment and environmental characteristics taken into consideration on the propensity to patent through varying levels of significance and the magnitude of the explanatory variables. The analysis confirms that establishment size has an important influence on patent behaviour. The parameter estimate indicates that as the firm size increases so the odds of patenting increases. Establishments belonging to machinery, instruments and related products appear to be more inclined towards patenting than firms in other industry categories. By way of contrast, textiles and clothing, as well as food, beverages and tobacco exhibit strongly negative effects on patenting activities indicating both the low level of technological opportunities in these industry sectors as well as the relative weak technological performance of the firms.

Table 5: Results of the Logit Analysis (t-values in parentheses)*

Variable	Parameter Estimates	
Size (log employment)	0.75	(14.29)*
Technology Intensity	0.14	(5.76)*
Small and Medium Sized Urban Areas	0.21	(1.56)
High Tech Firms located in the Agglomeration of Vienna	0.56	(3.43)*
Machinery	0.98	(6.32)*
Instruments and Related Products	0.94	(4.78)*
Textiles and Clothing	-0.78	(-5.19)*
Food, Beverages and Tobacco	-1.07	(-4.43)*
Constant	-6.22	(-16.85)*
Log - Likelihood at Zero	1279.65	
Log - Likelihood at Constant	1214.45	
Log - Likelihood at Convergence	1029.16	
Rho - Squared at Market Shares (adjusted)	0.16	
Prediction Success (in %)	93.99	
Number of Observations	4559	

* significant at the 0.05 level

The parameter results of the indicator technology intensity, as measured by the percentage of world export share of non-industrialized countries at the SITC five digit level, show a clearly positive influence on the odds of patenting for Austrian firms. This indicates the pressure to invent/innovate for industrial firms which act in market segments which are characterised by a high competition with other industrialised countries.

Regionally, establishments located in small and medium sized urban areas have significantly higher levels of patenting activities than the others located in peripheral regions and old industrial areas, but also in the metropolitan area of Vienna (here with the exception of high tech firms).

6. Summary and Conclusions

The computerisation ot the Austrian Patent Office in the mid 1980s has made it possible to analyse patenting behaviour at the firm level over a certain time period. This makes patents an easily accessible and reasonable proxy for the early stages of the innovation process.

In this paper we have reported results of an attempt to identify determinants of patenting behaviour of manufacturing firms, merging patent and company data from different information sources. The results achieved so far seem to confirm the Schumpeterian hypothesis that inventive activities increase with firm size more than proportionately. In addition, we have seen that patenting is done across nearly all manufacturing industries with much higher intensities in such technologically progressive industries as instruments and related products, motor vehicles and machinery.

Important determinants influencing positively patenting behaviour have been identified to be the competition situation of different market sectors as well as sectoral effects. Moreover, the results of the logit analysis reveal that variations between the four regional types, to the extent that they exist at all, are largely attributable to different structural (size and sectoral) effects even though firms located in small and medium sized urban areas have significantly higher levels of patenting activities than others.

One obvious way to improve the value of the patent data used is to differentiate between patents according to their quality. Patent data disaggregated by the quality of patents may help to evaluate and explain the pattern of relative technological strenghts and weaknesses of firms and, thus, contribute significantly to our understanding of the nature of inventive activities. Future research efforts have to be undertaken into this direction.

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APPENDIX

Industrial Sector	SIC-Codes
Mining	1011-1499
Leather-Producing	3111 and 3131
Leather-Processing	3142-3199 and 3361-3369
Foundry	3321-3325
Non-Iron Metal	3331-3357
Machinery	3511-3599
Vehicles	3711-3799
Iron and Metal Wares	3411-3499
Electrical and Electronics	3612-3699
Instruments and Related Products	3811-3873
Textiles	2211-2299
Clothing	2311-2399
Iron Producing	3312
Oil Industry	2911-3079
Stones and Ceramics	3241-3299
Chemicals	2812-2899
Glass	3211-3231
Paper-Producing	2611-2631
Paper-Processing	2641-2661
Wood-Processing	2411-2599
Food, Beverages and Tobacco	2011-2141
Printing and Publishing	2711-2795
Others	3911-3999

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