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Key Characteristics of the Small Innovative Firm

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Abstract

Despite broad agreement on the strategic role of SMEs (Small and Medium Sized Enterprises) in industrial renewal processes, the lack of systematized and comprehensive information on the nature and level of small innovative firms is striking. This bias is partly explained by an empirical shadow created by the limited availability of good, detailed data for comparable firm-level analyses. Based on extensive matched databases, the purpose of this paper is to provide new insights into the roles of micro and small innovative firms in research-based as well as tradition-based manufacture. The data consists of close to 160 000 observations of manufacturing firms in Sweden over the period 2000-2006, including information on innovation activities captured by patent applications, firm characteristics, international trade and the regional milieu.

Keywords: Innovation, Innovative Firms, Entrepreneurship, Small firms, Intellectual Property Rights, Technology Transfer, Location

JEL: F43, L26, M13, O31, O34

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1. INTRODUCTION

This paper uses patent applications as an indicator of innovative activities and focuses on the characteristics of innovative micro and small firms, with large firms serving as a reference group. It studies how firms' innovation activities vary in accordance with an extensive set of characteristics including observed and unobserved firm-specific information and knowledge spillovers through corporate ownership structure, international trade and the regional milieu. The data material consists of close to 160 000 observations of manufacturing firms in Sweden over the period 2000-2006.

Small innovative firms are considered to be a key factor for entrepreneurial spirit and innovation. Baumol's (2002) hypothesis of a 'David-Goliath' symbiosis between small and large firms and the Schumpeterian 'Mark I' hypothesis (Schumpeter 1934) emphasize the role of small innovative firms in introducing new technology and variety into the economic system. Much research in recent decades also shows that small firms account for a significant share of innovations and employment growth (e.g. Rothwell 1989, Acs and Audretsch 1988 and 1991, Davidsson et al. 1994 and Audretsch 2002).

Indeed, there is a growing and important literature on startups, spin-offs into emerging and knowledge-intensive sectors, such as ICT and pharmaceuticals, and survey-based studies such as the Community Innovation Survey (CIS) data. But the dominance of anecdotal evidence based on individual case-studies and findings from selective and fragmented quantitative information is evident. This bias is partly explained by an empirical shadow created by the limited availability of detailed data for comparable firm-level analyses.

Interestingly, one out of three Swedish manufacturing firms applying for national patent protection is a micro firm (1-10 employees) or a small firm (11-25 employees)[1]; a similar situation is found in many other countries (Iversen et al 2008). Despite the fact that SMEs account for a considerable fraction of the total patent activity, and concerns about their importance in industrial renewal processes, the lack of systematic and comprehensive information on the characteristics of small innovative firms is striking.

Exploiting extensive, matched databases, the purpose of this paper is to provide new insights into the roles of micro and small innovative firms in research-based as well as traditional manufacturing sectors. The data used in this paper originates from Statistics Sweden, the Swedish Custom Office and the Swedish Patent Office (PRV). The basic data set contains compulsory and audited register

[1] To see the truly 'smallness' of firms with 1-25 employees (micro and small), consider that Acs and Audretsch (1988) as well as Acs et al. (1994) define "small firm innovations" as innovations by firms with less than 500 employees. In 2003 the EU commission adopted a definition stating that micro firms are those with 10 or fewer employees, whereas small firms are those with between 11 and 50 employees.

information on firm characteristics based on annual reports for all firms in Sweden. A unique identification number for each firm allows this data to be merged with data on firms' international trade and patent applications, the educational level of the workforce and regional characteristics.

The data material is comprehensive and its richness enables us to evaluate propositions and arguments with regard to the determinants of innovation derived from various strands of innovation literature: the neo-Schumpeterian literature and the resource-based view of the firm (RBV), the theory of agglomeration economies and the literature on international trade as a conduit for knowledge flows.

Section 2 of this paper presents propositions and arguments pertaining to the characteristics of the innovative firm and emanating from different strands of literature. These provide the basis for the selection of variables that are used to contrast innovative with non-innovative firms in the empirical analysis. Section 3 contains the data, variables and descriptive statistics. Section 4 sets out the empirical strategy and Section 5 the results of the econometric analyses of the relationships between our chosen variables and the firms' patent applications. Section 6 concludes the paper by providing suggestions for further research and extensions.

2. THE INNOVATIVE FIRM AND ITS CHARACTERISTICS

The main focus here is on the characteristics associated with innovative small firms. We use patent application as a proxy for the firm's innovative activities. Although patents are typically considered as an output measure in some of the literature we refer to below, it may also be seen as an intermediate product in the innovation process. This is the view taken in this paper.

It should be emphasized that many innovative firms do not apply for patent protection and that a patent application is not an innovation, but only one of many possible innovation indicators. Though the use of patents as innovation indicators has been debated, many scholars argue that it is a proper measure of innovation (Griliches 1990). Acs et al. (2002) compare innovation and patents across US regions and conclude; "the empirical evidence suggest that patents provide a fairly reliable measure of innovative activity" (p.1080).

Which of the characteristics of a firm and its environment are important for innovation? There is no established "general" theoretical model in the literature of the innovative firm. This paper relies on theories, arguments and propositions in three main strands of the literature on R&D, technology and innovation. These are; (i) the Schumpeterian literature and the resource-based view of the firm (RBV), (ii) the literature on agglomeration economies and (iii) the literature on international technology diffusion, which emphasizes international trade as a conduit for knowledge flows.

The three strands offer complementary perspectives on the determinants of innovation. While the neo-Schumpeterian and RBV frameworks stress internal characteristics, the literature on agglomeration economies and international trade puts focus on knowledge and information flows from the local environment and from abroad.[2] An example of the complementarities of the perspectives is that a firm's human capital may affect its capability to internally generate new techniques and products. At the same time it reflects the absorptive capacity as regards knowledge and information flows from either the local environment or from abroad. Next we discuss the three strands of the literature in more detail. We also take up our definitions of, and reasons for using, the variables that we apply in the empirical analysis of the determinants of innovation activity.

2.1 Internal firm characteristics

The neo-Schumpeterian and the RBV perspectives emphasize internal characteristics, such as R&D, physical capital, human capital and financial structure. A key assertion in the RBV literature is that a firm's competitive advantage depends on internal heterogeneous resources and capabilities (Penrose 1959, Barney 1991). According to this perspective, firms' innovation activities are primarily explained by their internal characteristics. The neo-Schumpeterian literature builds on similar premises, although the role of sector characteristics is typically more explicit, as manifested, for instance, by concepts such as technological regimes (Malerba and Orsenigo 1993).

Consistent with the RBV and the neo-Schumpeterian literature, several studies find that the characteristics of the firms and the sector they operate in are important for explaining a firm's engagement in innovation activities (Kleinknecht and Mohnen 2002, Cohen 1995, Crépon et al. 1998, Pavitt 1984). We will now review a set of characteristics that this literature suggests is important for firms' innovation activity and show how they are defined in this paper. The characteristics include financial resources, physical capital, human capital, size, corporate ownership and sector affiliation.

Profit margin and short term debt

As innovation is often associated with risks and costly investments in knowledge and technology, both internal financial resources and access to external capital are possible determinants of a firm's innovation activity. The theoretical literature suggests that the presence of asymmetric information and moral hazard problems may be particularly serious for SMEs engaged in innovation activities Thus, profitability can be expected to be more important for small and young innovative firms, since they often have limited access to capital markets and difficulties in finding external sources of funds for

[2]It should also be emphasized that the various propositions as regards the characteristics of innovating firms from the different strands of literature considered here are 'open-ended', such that the verification of hypotheses derived from one type of literature does not preclude hypotheses from the others.

their R&D investments (Himmelfarb and Petersen 1994).[3] However, the unsuitability of debt as a source of finance for R&D and other innovation investment has been confirmed across different firm sizes (Hall 2005).

In the analysis we use profit margin, defined as net profit after taxes divided by all sales, as a measure of internal financial means. We also use short-term debt per employee as an indicator of access to external financial resources.

Physical capital and human capital

The empirical literature has convincingly shown that physical capital is a major driving force of economic growth at various levels of aggregation. One explanation is that new knowledge is embedded in capital investments (Hulten 2001). In contrast, the relationship between physical capital and innovation is less obvious. In fact, there is no consensus in the literature on the *short-run* relationship between firms' investment in R&D and other innovation activities and physical capital investments. It is only for the long run that a robust association has been documented (De Jong 2007).

Human capital is regarded as reflecting a firm's capacity to absorb, assimilate and develop new knowledge and technology (Bartel and Lichtenberg 1987, Cohen and Levinthal 1990). Several empirical studies also find that technological change tends to be skill-biased and changes the relative labor demand in favor of highly skilled and educated workers (e.g. Berman et al. 1998, Machin and van Reenen 1998).

We use the stock of capital (corrected for depreciation and new investments) per employee as the capital variable and assume a positive correlation with patent application. We distinguish between two categories of employment, skilled labour and ordinary labour. Skilled labour is defined as employees with at least 3 years of university education and we consider this group as a proxy for R&D. Ordinary labour has less than 3 years of university education and we use this information as the size variable. Recent literature contains mixed results on the relationship between firm size and innovation output.[4] We a priori expect a close and positive association between skilled labour and patent application and we also believe that this link is stronger for small firms compared to large firms.

[3] Scherer (1999) maintains that R&D outlays in large established firms are often of such magnitude that "…they can be financed through routine cash flow and, if need be, can resort to outside capital sources willing to provide funds on full faith and credit without detailed inquiry into the specific uses to which the funds will be put" (ibid. p.72). He argues further that this is one reason why empirical studies of internal cash flow and R&D among larger firms do not find systematic relationships.

[4] One of the stylized facts of innovating firms as reported by Klette and Kortum (2004) is that R&D intensity, for instance, is independent of firm size.

Corporate ownership structure

A further characteristic is corporate ownership structure. We distinguish between individual firms and firms belonging to a corporate group. Three types of corporate groups are analyzed: (i) uninational corporations, (ii) domestic-owned multinational enterprises (MNE) and (iii) foreign-owned MNEs. Following the literature, we assume there are important differences between non-MNEs and MNEs as well as between domestic-owned MNEs and foreign-owned MNEs regarding technological dissemination and innovation. Swedish MNEs can also be expected to have a distinct role in the Swedish "innovation system", since they tend to concentrate their R&D-investments domestically.

By definition, MNEs have established links to several markets and thereby a coupling to several knowledge sources and innovation systems (cf. Dachs et al. 2008). Typically, they also have strong internal capabilities pertaining to the development of proprietary information and knowledge within the corporation (Pfaffermayr and Bellak 2002).[5] Small firms that are part of a MNE (either domestic- or foreign-owned) may thus be expected to be more innovative because of access to the MNE's knowledge and information networks and technology. It is also well known that mergers and acquisitions are an important means by which MNEs expand. One reason why a MNE may acquire a micro firm is that the latter has developed new knowledge and technology pertinent for the MNE. Small innovative firms are often the source of the expansion of technological capabilities in large and established firms (Granstand and Sjölander 1990).

Sector classification and year dummies

A typical argument in the neo-Schumpeterian literature is that the characteristics of a particular sector or industry with which a firm is affiliated may influence its innovation activity. Different sectors have different technology and innovation opportunities and are thus characterized by different technological regimes (Malerba and Orsenigo 1993). Over a sequence of periods certain industries may be characterized by rapid technological progress, translating into high technology and innovation opportunities, which is typically the case in the early phases of a technology's life cycle (cf. Vernon 1966). Small firms tend to have an innovation advantage precisely in high-technology and skill-intensive sectors in which technology and innovation opportunities are high.

Our empirical analysis includes sector dummies based on the overall technology intensity of the sector a firm is affiliated with. We consider four broad OECD classifications; high technology, high-medium technology, low-medium technology and low technology sectors. We also include year dummies to

[5]MNEs have high ratios of R&D relative to sales, a large number of scientific, technical and other 'white-collar' workers as a percentage of their workforce, high value of intangible assets and large product differentiation efforts, such as high advertising to sales ratios (van Marrewijk 2002).

capture unobservable time-varying macro factors, such as general economic conditions, interest rate, inflation, money supply and tax rates, common to all firms.

2.2 Location characteristics and agglomeration economies

The literature on agglomeration economies emphasizes the firms' local environment and that the density of firms and the spatial concentration of human capital bring about place-specific external economies of scale that may influence the performance of the firms. Marshall (1920) maintained that concentrations of firms in a similar industry give rise to localization economies in the form of knowledge and information spillovers, labor pooling (advantages of thick markets for specialized skills) and backward and forward linkages. Ohlin (1933) and Hoover (1937) distinguished between urbanization and localization economies, the former pertaining to larger urban regions with a diversified economy.

A main argument in the literature is the local environment as a source of knowledge and ideas (Feldman 1999, Andersson and Johansson 2008). In particular, dense urban environments with richness in knowledge sources are regarded as stimulating face-to-face interaction and localized knowledge flows (Duranton and Puga 2001). These conjectures find support in ample empirical analyses. Innovation activities are more concentrated in space than standard production activities (Audretsch and Feldman 1996), patent citations are geographically localized (Jaffe et al. 1993) and innovations tend to diffuse faster within clusters (Baptista 2000). Moreover, flows of labor and technical personnel between firms tend to be greater in dense locations, thus stimulating the diffusion of competencies and knowledge embodied in people (Almeida and Kogut 1999).

An interesting finding in the literature is that the local knowledge flows appear to be particularly important for small firms. Acs et al. (1994) investigated the sources of innovation inputs for small firms, since they produce innovation output with limited R&D resources compared to large firms. The authors tested the hypothesis that small firms capitalize on flows of knowledge and information from corporate R&D in large firms and universities, and that such flows are stimulated by their geographical proximity. They applied the model developed in Jaffe (1989) in such a way that innovation activity in US states was regressed on industry R&D, university R&D and an index of their geographical coincidence. By partitioning each state's total innovations into those developed by small and large firms, they showed that the geographical coincidence index was only significant for small firm innovations. Although they did not control for characteristics of the firms, as suggested by the RBV and Schumpeterian literature, their findings indicate an importance of local knowledge and information flows for innovation activity in small firms. Ample later studies find that the characteristics of locations pertaining to the potential and frequency of such flows are important, not only for innovations in small firms but also start-up activity. It is now established in the literature that

"…entrepreneurial activity will tend to be greater in contexts where investments in new knowledge are relatively high, since the new firm will be started from knowledge that has spilled over from the source actually producing that knowledge" (Acs et al. 2006, p.12).

In view of the arguments presented above, the empirical analysis includes basic agglomeration measures reflecting the potential for knowledge and information flows as characteristics associated with innovation in the region in which each firm is located. Sweden has one major functional regional (Stockholm) and only two additional metropolitan regions with more than 300 000 inhabitants (Goteborg and Malmo). We include three separate dummies for Sweden's three metropolitan regions with the purpose of ascertaining whether firms located in these regions have a higher propensity to apply for patents and more patent applications than firms located elsewhere in Sweden. The literature on agglomeration economies suggests a positive relationship between innovation and metro-regions. The second agglomeration variable is regional employment fraction, which measures the size of the sector the firm belongs to in the region where the firm is located, as a fraction of the region's total employment in private sectors. It is assumed to reflect the potential for external scale economies associated with sectoral geographic concentration. The sectors are broadly defined and refer to the four OECD sector aggregates in terms of technology level. We expect the employment fraction to positively affect knowledge spillovers and patent activities.

2.3 Networks and linkages to foreign markets

Firms engaged in international trade are regularly claimed to have better access to foreign knowledge and technology, and such access may be important as domestic R&D is often a small fraction of the 'global' R&D stock. The literature on international knowledge spillovers (or technology diffusion) suggests international trade as a conduit for flows of knowledge and technology (see e.g. Keller 2004). Links to customers and suppliers in different markets may foster a firm's accumulation of knowledge about customer preferences, production techniques and technology, and as such stimulate innovation.

An important issue is that a firm's international trade status may be endogenous to the firm's productivity and innovation. Several studies of international trade through the lens of the individual firm find that, conditional on an extensive set of firm characteristics, firms that participate in international trade are more productive (see Greenaway and Kneller 2007a or Wagner 2007 for surveys). Recent evidence from Sweden is provided by Andersson, Lööf and Johansson (2008). The literature offers two non-mutually exclusive hypotheses capable of explaining such a pattern. The first is that firms engaged in international trade have *ex ante* productivity advantages, presumably based on some form of innovation, enabling them to overcome sunk costs associated with foreign sales. The second is 'learning-by-exporting' and rests precisely on the argument that firms that trade internationally have better access to foreign knowledge and technology, which stimulates innovation and productivity.

Much of the literature linking international trade to innovation focuses on imports and technology and knowledge embodied in differentiated intermediate capital goods (cf. Rivera-Batiz and Romer 1991, Coe and Helpman 1995). Domestic firms exploit foreign R&D by importing the intermediate product. From this perspective trade linkages with R&D intensive economies, such as G7 countries accounting for over 80 % of the total R&D investments in the world, are supposed to be an important source of knowledge and technology (Acharya and Keller 2007). Lööf and Andersson (2009) find that the fraction of G7 imports influences productivity at the level of individual firms.

Motivated by the arguments discussed above, our empirical analysis includes measures of the firms' participation in international trade as innovation determinants. These measures are assumed to reflect the potential for international knowledge flows. The first is exports and imports, to and from the G7 countries as fractions of total exports and total imports, respectively. The second variable is the number of export destinations and import origin countries for the firms' export and import flows. Finally, we include dummies to indicate whether a trading firm (i) only imports, (ii) only exports or (iii) imports and exports. The expectations regarding the trade variables are that trade in general and G7 in particular are positively associated with innovation activity in both small and large firms.

3. DATA AND DESCRIPTIVE STATISTICS

3.1 Data

The data source used is this study covers the period 2000-2006 and consists of about 160,000 observations of manufacturing firms in Sweden. The data set is unbalanced. In total 34,742 firms have been observed, of which 40 % are in the sample for all seven years. About 80 % of the firms are observed for three years or longer. Five sources of data have been matched, based on a unique identification number of each firm. The basic data set contains compulsory and audited register information on firm characteristics based on annual reports for all firms in Sweden. This data has been merged with data on (i) educational statistics, (ii) trade statistics, (iii) regional characteristics and (iv) patent applications. All the data originates from Statistics Sweden, the Swedish Customs Office and the Swedish Patent Office (PRV).

To the best of our knowledge, this data is almost unique in terms of the extensive information on patenting firms in general and patenting micro firms and small firms in particular. In total the data comprises close to 8,000 patent applications from about 2,000 Swedish manufacturing firms, representing more than 95 percent of all national patent applications by Swedish manufacturing firms during the period 2000-2006.

3.2 Descriptive statistics

Table 1 presents the summary statistics of key firm characteristics over the period 2000-2006, as motivated and defined in Section 2. The sample is separated into three size-classes: 1-10 employees, 11-25 employees and more than 25 employees. Several things stand out. First, the fraction of patent applicants differs considerably across the size-classes. While only 0.3 % of the micro firms applied for one or more patents during the period, the corresponding fraction for "large" (more than 25 employees) is 6 %. Second, within the three size-classes, patenting firms have 3-5 times more skilled labour than non-patenting firms. Third, innovative firms (all size classes) are more profitable and have better access to bank loans. Fourth, a considerably larger fraction of patent applicants is associated with a Swedish MNE compared to non-patenting firms. Finally, patenting firms tend to be more capital-intensive and technology-intensive than other firms.

Table 2 shows the descriptive statistics for the trade variables applied in the regression analysis. Two interesting things should be noted. First, patenting micro firms have a six times larger G7 fraction in their export-basket compared to other micro firms. They also import more from G7 and are much more globally oriented than other micro firms. Second, G7 and the international market are of great importance for all patent applicants, but the difference between patent applicants and others is smaller for large firms compared to small firms. Overall, patenting firms are more internationalized than non-patenting ones.

Table 3 reports descriptive statistics for regional characteristics over the period 2000-2006. Only minor differences are found between patent applicants and others. Based on the previous literature on agglomeration economies and innovation, one would expect patenting firms to be more frequent in the metropolitan areas of Sweden. Surprisingly, it is shown that patenting firms are not overrepresented in the three metropolitan regions of Sweden. Moreover, the statistics associated with the variable 'Emp-share LA region', which measures the size of the sector in the region where the firms are located, also suggest that patenting firms are not overrepresented in regions where the sector to which the firms belong is large.

4. EMPIRICAL STRATEGY

We use two measures of patent applications: (i) an indicator variable showing whether firm *i* has applied for a patent in year *t*, (ii) count-data reporting the number of patent applications by firm *i* in year *t*. An application may have several applicants from different firms, motivating adjustment with weights. However, this requires assumptions of the particular contribution from each of the firms. Since our sensitivity analysis only shows marginal differences between weighted and non-weighted applications in the econometric regressions, we apply the former.

In order to estimate the relationship between innovation activity, as evidenced by patent applications, and the determinants in Section 2, we apply two classes of non-linear estimators. The first is a binary outcome model and the second is count-data models. In the first model a dummy variable indicates whether the firm applied for a patent in a given year. The descriptive statistics show that the average fraction of patent applicants is 0.3% for micro firms, 1.1% for firms with 11-25 employees and 5.9% for larger manufacturing firms. In the count data models, the dependent variable is the number of patent applications by each firm. The typical small firm engaged in patent activities made 1 application and the typical firm with more than 25 employees made 5 applications or more over the period 2000-2006.

The general model is a firm-specific-effects model and may be expressed as:

$$y_{it} = \alpha_i + \mathbf{x}'_{\mathbf{it}}\boldsymbol{\beta} + \varepsilon_{it} \qquad (1)$$

where y_{it} denotes patent application by firm *i* in year *t*, $\mathbf{x}_{\mathbf{it}}$ a vector of regressors, α_i firm-specific effects that may be fixed-effects (FE) or random-effects (RE), and ε_{it} an idiosyncratic error. When a pooled model is applied on the panel data we assume that the regressors are exogenous and ignore the unobserved firm-specific effects.

The first empirical model we consider is a logit firm-specific model with which we show the probability that a firm will apply for a patent. This binary model specifies that

$$\Pr(y_{it} = 1 | x_{it}, \beta, \alpha_i) = \Lambda(\alpha_i + x'_{it}\beta) \qquad (2)$$

where α_i may be an FE or RE and $\Lambda(z) = e^z(1+e^z)$

The literature suggests several alternative estimators for count-data estimations. The leading example is negative binominal models (Cameron and Trivedi 2008). Some of the standard complications in analyzing count data include the presence of unobserved heterogeneity due to omitted variables, an “excess” of zero observations and overdispersed data. The dependent variable *patent application* in our data is considerably overdispersed because the sample variance is 42 times the sample mean. Our strategy for dealing with these issues is to employ (i) the pooled zero-inflated negative binominal estimator in order to account for the large fraction of zero patent applications among the observed firms as well as overdispersion, and (ii) the panel-data negative binominal estimator to account for both the overdispersed data and the unobserved firm-specific effects. The preferred count-data estimator is the panel-data application of the negative binominal model.

A crucial issue is whether the fixed-effects (FE) or the random-effects (RE) is the appropriate model for our panel-data logit and negative binominal estimators. In the FE model, the unobserved firm-specific effects α_i in (1) are permitted to be correlated with the regressors $\mathbf{x}_{it}$. In the RE model it is assumed that α_i is purely random, implying that it is uncorrelated with the regressors. We find that the more relevant model for our data is the RE model. This estimator, which corrects for the panel complication that the observations are correlated over time for a given firm, makes it possible to estimate the coefficients of both time-invariant and time-varying regressors and can handle a large amount of zero observations of the dependent variables.

5. RESULTS

We now turn to the results of the binary and count-data models. The two dependent variables are the propensity to apply for a patent and the number of patent applications. Our focus is on micro and small firms and the coefficient estimates for these two groups are contrasted with the results for firms with more than 25 employees.

As a point of departure we first consider the persistency in the sample from year to year: In the data, more than 99% of small and large firms that *did* not apply for a patent one year did not apply the next. Looking then at *the applicants*, 50% of firms with more than 25 employees that applied one year also applied the next year. The corresponding figure for micro firms is 17%.

Estimates for the variables in the basic model are found in Table 4. This model is based on the neo-Schumpeterian literature and the resource-based view of the firm (RBV) and includes financial resources, physical capital, skilled labour as a proxy for R&D, firm size, corporate ownership structure, sector classification and year dummies. The basic model is augmented in Tables 5 and 6 with export variables and import variables, respectively. Our last results are in Table 7, which shows the estimated impact of location characteristics using the variables in the basic model as covariates.

The tables are organized in the following way: the first column reports the results for micro (1-10 employees), small (11-25 employees) and larger firms (more than 25 employees), using the logit panel model with random firm-specific effects. Columns 2 and 3 report the count data results for the three size-groups. Column 2 presents the results of the pooled zero-inflated negative binominal model, while the results of the panel data negative binominal model, which controls for random firm-specific effects, are displayed in column 3.

5.1 Basic model

Based on the innovation literature, we expect profit to be a more important determinant than debt in our innovation equations. We also suppose the link between *profit margin* and innovation activity to be relatively stronger for smaller firms than larger ones, and the opposite for the relationship between external debts, measured as *short-term debt* per employee. However, very few studies have systematically analyzed the importance of various financial resources for very small innovative firms. Thus, the general findings from previous research are not necessarily applicable to our data.

The upper part of Table 4 shows that the probability of applying for a patent (logit model) as well as the number of applications are neutral with respect to profitability and external debt for micro firms. For firms with 11-25 employees, however, the preferred negative binominal panel-data estimator shows a positive and strong correlation between the number of patent applications and profitability, albeit just outside the 5% significance level. No relationship between the financial resources of the firm and the probability of applying for a patent can be found for this group. Looking then at larger firms ($\geq$ 25 employees), it is evident that the estimates associated with contemporaneous profit margins are positive and significant for all three estimators. Ignoring the zero-inflated negative binomial results, short-term debt appears to be irrelevant for patenting activity within the largest size-group.

The lack of correlation between the financial situation and the innovation indicator for micro firms is puzzling. A possible explanation might be internal support within the corporate group. The descriptive statistics in section 2 show that 30% of innovative micro firms belong to a domestic-owned or foreign-owned group.

The relationship between *physical capital* per employee and patent applications for micro firms and for the larger firms is insignificant. Conflicting results are reported for the two count-data estimators for firms with 11-25 employees, but, guided by the preferred estimator controlling for unobserved firm-specific effects, we conclude that tangible capital is not closely associated with innovation activity for any size category.

We next consider the estimated coefficients for *skilled labour* (employees with 3 years of education or more). First, the logit model for whether a firm applies for a patent shows that the coefficient is significantly different from zero at the 1% level for micro and small firms. By contrast it is only significant at the 10% level for larger firms. Notably, the magnitude of the skill-coefficient is considerable larger for micro firms compared to other firms. Second, the output-pattern of the count-data models is almost identical to the binary outcome. At the margin, one more skilled worker is considerable more important for micro firms than for other firms. It is also notable that the count estimate for larger firms is highly significant in the zero-inflated model and non-significant in the panel model.

Ordinary labour is considered to be an additional size-variable in the analysis. Our classification of the firms into three different groups partly accounts for the size-effect. The estimated size-coefficients for the two panel-data models are small and non-significant for micro firms, small and only weakly significant for firms with 10-25 employees and small and highly significant when the largest size group is considered.

The *corporate ownership structure* is assumed to be associated with knowledge spillovers and domestic multinational firms have been found to be of particular importance in the so-called national innovation system in Sweden (Johansson and Lööf, 2008). This paper confirms previous findings and shows that the membership in a domestic MNE group is positively correlated to our measures of patent activity for large firms, small firms and micro firms as well. Only among large firms do we find a link between foreign ownership and patent application in Sweden, which suggests an international technological diffusion.

The results for the smaller firms are interesting. Affiliation to a domestic-owned MNE increases the innovation capacity. MNEs tend to concentrate their R&D activities to the home country partly because of strong complementarities between the knowledge base of the MNE and the technological competencies of the "innovation system" in the home country (Patel and Pavitt 1991). Naturally, this system of innovation includes small innovative firms. Given that MNEs often buy small innovative firms in order to acquire knowledge and technology, we interpret the results as meaning that domestic MNEs are better equipped than foreign MNEs to scan the Swedish market and accumulate information about small innovative firms as potential members of their corporate group. Notably, membership in a uninational group is negatively associated with national patent application.

Finally, consistent with ample previous studies, the estimated coefficients for the sector dummies show that innovation activity in the form of patent applications is more likely for firms active in high-technology sectors. The results in Table 4 verify that this is also the case for small and micro firms.

5.2 International trade characteristics

We now consider the basic model in Table 4 augmented with variables reflecting each firm's participation in international trade. These variables are motivated by the literature on trade as a conduit for international knowledge flows. The estimates in the upper part of Table 5 indicate that a firm's fraction of exports to the most R&D-intensive countries in the world, *G7-exports*, is closely correlated with innovation activity. The binary model and the two count models show a very robust pattern for micro firms and large firms. The propensity to apply for a patent and the patent count increase considerably with G7-trade. These results are consistent with the literature on 'learning-by-exporting' and international technology diffusion. Interestingly, no significant association between innovation activity and G7 exports is found for firms in the size group 11-25 employees.

The three estimators produce very similar binary and count estimates for small and large firms regarding the number of *export destinations*. Patent application is an increasing function of international presence on different markets. Among micro firms, though, the number of destination countries is insignificant.

The lower part of Table 5 presents coefficient estimates for three categories of dummy variables: firms with only exports, firms with only imports and firms with both exports and imports. The typical trading firm is engaged in exports as well as imports. Firms that both export and import are also significantly more likely to be innovative, as approximated by patent applications; this holds across all three size-classes. These firms have a two-pronged international link to both customers and suppliers in different countries and thus many potential channels open for knowledge and information flows from abroad.

Surprisingly, in contrast to G7-exports, we do not find that the fraction of G7 countries of the firm's total imports has any impact on patent applications among small firms with 1-10 employees (Table 6). The coefficient estimate for *G7 imports* is significantly different from zero only for large firms. The results of the number of import origins and the three dummy variables are similar to those in Table 5. With the panel logit model the number of origin markets for imports is significant and positive for firms of all size-classes. In the count data models, however, this variable is significant only for firms with more than 10 employees. Finally, the results confirm the strong association between innovation activity and a firm's engagement in export and imports.

Overall, the results in Tables 5 and 6 suggest that the variables reflecting a firm's participation in international trade are significantly related with innovation activity. This is consistent with the hypothesis that links to foreign markets are a conduit for international knowledge flows, which stimulate innovation. The new finding is the important role of G7 for exporting micro firms.

5.3 The regional milieu

The literature has convincingly shown that there is a positive inter-relationship of agglomeration and innovation and productivity (see Section 2.2). Using cross-sectional CIS data for Sweden, Johansson and Lööf (2008) find that there is a "Stockholm-effect" as regards productivity. Everything else equal, firms in Stockholm are more productive than in the rest of Sweden. Based on arguments in the literature on agglomeration economies, we now ask if there is a link between location and patent activity similar to the one established for location and productivity.

Table 7 reports the estimated coefficients associated with the variables reflecting agglomeration phenomena, i.e. the dummy variables for Sweden's three metropolitan regions and the size of the sector in the region. The latter variable is assumed to reflect the potential for external scale economies associated with sectoral geographic concentration and may be considered as a specialisation indicator.

Starting with the metropolitan-variables, Table 7 shows no "Stockholm-effect" as regards firms' patent activities. The estimated parameter is insignificant for all size-classes. For small firms the results actually suggest a negative relationship between the propensity to apply for patents and location in Gothenburg or Malmo. The count data coefficient for large Malmo-firms, however, is positive and significant at the 5% level. Looking then at the importance of specialization, the results shown at the bottom of Table 7 indicate an interesting difference between micro firms and small firms on the one hand, and micro firms and larger firms on the other. The coefficients from the binary model and the count data models also suggest that only larger firms with more than 25 employees benefit from location in a region with the same specialization as the observed firm.

Based on a large and expanding literature on the advantages of agglomerations, we expect the metropolitan variables to be correlated with patent application for the two smaller size-groups as well. How can the surprising results be explained? One plausible interpretation is that we show that the finding for innovative firms in general is not applicable to very small firms. This group of firms is distinguished in many respects and, due to the lack of systematic studies, we implicitly assume that what is true for large innovators is also true for small innovators. Another possible explanation might be our choice of innovation proxy, i.e. patent applications. We consider applications not adjusted for quality (by citations and oppositions, etc). Recent research on Swedish data shows that the concentration of quality-adjusted patents to metropolitan regions is much higher than for raw counts of patents (Ejermo 2007). However, since we are controlling for factors such as technology intensity, research intensity (captured by skilled labours) and firm size, the differences in quality are at least partly accounted for in the regressions.

6. SUMMARY AND CONCLUSIONS

One out of three Swedish manufacturing firms applying for national patent protection is a micro firm (1-10 employees) or a small firm (11-25 employees). The situation is similar in other countries and reflects the importance of small firms in national innovation systems. Yet, despite broad agreement on the strategic role of SMEs in industrial renewal processes there is a lack of systematized and comprehensive information about the nature and level of the small innovative firm. In particular, there is a ‘knowledge gap’ as regards characteristics of the small innovative firm. This bias is partly explained by an empirical shadow created by the limited availability of detailed data on small firms for comparable firm-level analysis.

Based on extensive, matched databases and unique identification of each firm, this paper adds to the understanding of the roles of micro firms and other very small innovative firms in research-based as well as tradition-based manufacture. We use patent applications as an indicator of innovative activities and explain variations of innovation across firms with an extensive and almost unique set of information on individual observations. The focus is on micro and small firms while firms with more than 25 employees serve as a reference group. The data consists of close to 160 000 observations of manufacturing firms in Sweden over the period 2000-2006.

Several interesting findings are reported in the descriptive statistics. First, the fraction of patent applicants differs considerably across the size-classes. While only 0.3 % of the micro firms applied for one or more patents during the period, the corresponding fraction for “large” (more than 25 employees) is 6 %. Second, within the three size-classes, patenting firms have 3-5 times more skilled labor than non-patenting firms. Third, innovative firms (both small and larger) have larger profit margins and better access to bank loans. Fourth, a substantially larger fraction of patent applicants is associated with a Swedish MNE compared to non-patenting firms, and patenting firms tend to be more high technology-intensive than other firms. We also find a large degree of persistency in the sample. More than 99% of both small and large firms that did *not* apply for a patent one year did not apply the next year. Considering patent applicants, 50% of firms with more than 25 employees that applied one year also applied the next year. The corresponding figure for micro firms is 17%.

Based on patent applications, the empirical analysis applies non-linear binary and count-data models to explain innovative activity across firms. We evaluate propositions and arguments in three strands of the innovation literature. The first is the neo-Schumpeterian literature and the resource based view of the firm (RBV), suggesting the importance of firm characteristics such as firm size, physical capital, human capital, R&D, internal and external financial sources and industry classification. The second strand is the branch of trade literature focusing on technological diffusion across borders through trade and foreign direct investments. A third strand is the literature on agglomeration economies suggesting the importance of proximity, clustering and face-to-face contacts for localized knowledge spillovers.

The following facts emerge: (i) The probability of applying for a patent and the number of applications are neutral with respect to profitability, access to external financing, and physical capital among micro firms (1-10 employees) and small firms (11-25 employees), (ii) at the margin, one more skilled worker is much more important for micro firms than for other firms, (iii) the patent performance of all size-categories of firms is closely correlated with a domestic multinational firm, (iv) the propensity to apply for a patent and the number of applications are an increasing function of the extension of exports to G7, the most R&D-region in the world, and (v) controlling for observable and unobservable firm characteristics, no positive agglomeration-impact on patent application can be found for micro firms or small firms.

The summarizing finding is that we provide new insights into the roles of innovative micro firms. Successful results of their innovation activities are closely associated with links to both domestic multinational firms and customers in the G7-region. A skilled labour force is crucial but we do not find a significant role of either location or financial means. A possible explanation for the latter finding might be internal support within the corporate group. We also show that innovative micro firms are distinguished from other innovative firms in several respects.

The research in this paper can be extended in several ways. There is a need to better understand our puzzling results regarding the importance of profitability, external financing and the local milieu for patent applications among firms with less than 25 employees. Moreover, this paper focuses on the association between various characteristics and innovation activity and does not try to assess the direction of the relationships. One area for future research is thus to assess causality issues associated with the characteristics considered in this paper. For instance, is the significant relationship between affiliation to a domestic MNE and innovation in small firms due to the fact that domestic MNEs are successful in acquiring already innovative firms, or is it due to such an affiliation stimulating innovation in small firms? Similar questions apply to the firms' participation in international trade. Another area for further research is to extend the analysis beyond manufacturing firms. We have focused on small firms in manufacturing sectors, but there is plenty of evidence that innovation in service sectors, especially small knowledge-intensive business services (KIBS), plays an important role in the contemporary economy, which to a large extent is characterized by advanced services.

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TABLE SECTION

Table 1
Summary statistics. Firm characteristics over the period 2000-2006

	1-10 Emp		11-25 Emp		26- Emp	
	All	Pat	All	Pat	All	Pat
Observations	112,684	374	22,812	261	22,298	1,315
Patent applicants	0.3 %	100 %	1.1%	100 %	5.9%	100 %
Patent applications	<0.1	1.3	0.2	1.3	0.3	5.1
Employment	3.7	4.3	16.2	17.3	170.3	617.2
Ordinary labour	3.5	3.3	15.4	15.1	148.4	488.7
Skilled labour	0.2	1.0	0.8	2.2	21.9	128.5
Profit margin	4.6 %	5.1 %	2.5%	3.1%	2.7%	6.5%
Short term debt per emp[1]	25.1	45.5	28.8	44.1	39.5	65.5
Non-affiliate	82.5%	67.2%	49.2%	36.4%	14.9%	6.0%
Uninational	14.1%	18.5%	35.7%	31.4%	28.8%	7.7%
Swedish MNE	1.9%	10.0%	9.3%	23.8%	31.8%	49.5%
Foreign MNE	1.5%	4.3%	5.8%	8.4%	25.5%	36.8%
High technology	6.8%	22.6%	5.4%	16.4%	6.1%	16.9%
High med. technology	16.7%	32.0%	21.1%	38.3%	29.2%	46.8%
Low med. technology	33.5%	29.0%	35,6%	31.0%	30.5%	24.7%
Low technology	43.0%	16.4%	37.8%	14.1%	34.2%	11.6%

Note
(1) 1000 Euros

Table 2

Summary statistics. Trade characteristics over the period 2000-2006

	1-10 Emp		11-25 Emp		26- Emp	
	All	Pat	All	Pat	All	Pat
G7-exports/total exports, %	3.3	19.9	10.6	27.5	24.5	39.8
Export countries	0.7	3.0	3.4	12.6	14.7	36.5
Only exports, no imports, %	10.6	14.5	17.5	13.0	7.8	1.9
G7-imports/total imports, %	5.7	21.9	14.6	31.0	30.7	46.0
Import countries	0.5	1.5	1.9	4.3	7.9	17.4
Only imports, no exports, %	6.7	0.8	7.8	4.5	5.1	0.8
Exports and imports, %	12.4	45.4	41.5	74.3	78.7	96.5

Table 3

Summary statistics. Regional characteristics over the period 2000-2006

	1-10 Emp		11-25 Emp		26- Emp	
	All	Pat	All	Pat	All	Pat
Stockholm	19.8	21.0	14.4	17.6	11.0	14.9
Gothenborg	9.8	10.8	8.8	5.7	8.4	9.4
Malmo	6.1	5.4	5.8	4.6	6.2	7.3
Emp-share LA region	11.2	10.9	12.5	11.4	13.8	13.5

Table 4
Patent application
Basic model

Model	Logit			Zero-inflated Negative binominal			Negative binominal		
Dep variable	Application dummy			Number of applications			Number of applications		
Firm size	1-10	11-25	26-	1-10	11-25	26-	1-10	11-25	26-
Profit marg	-0.287	0.820	1.940 A	0.168	0.504	2.421A	-0.175	1.250 C	0.998 A
	(0.489)	(0.257)	(0.000)	(0.645)	(0.474)	(0.000)	(0.646)	(0.060)	(0.000)
Short Debt	0.001	0.000	0.000	0.002	-0.001	0.007 A	0.001	0.001	0.000
	(0.380)	(0.875)	(0.397)	(0.132)	(0.537)	(0.000)	(0.163)	(0.359)	(0.923)
Phys cap	0.000	-0.000	0.000	0.001	0.006 A	0.000	0.000	0.001	0.001
	(0.920)	(0.965)	(0.587)	(0.235)	(0.007)	(0.688)	(0.836)	(0.631)	(0.212)
Skilled lab	0.753 A	0.221 A	0.000 C	0.584 A	0.124 B	0.002 A	0.600 A	0.191 A	-0.000
	(0.000)	(0.000)	(0.091)	(0.000)	(0.016)	(0.000)	(0.000)	(0.000)	(0.414)
Ordinary lab	0.014	0.036 C	0.001 A	-0.1957 A	-0.065 C	0.000 A	0.003	0.032 C	0.000 A
	(0.640)	(0.076)	(0.000)	(0.000)	(0.084)	(0.003)	(0.913)	(0.071)	(0.000)
Dom-UNI	0.131	-0.026	-0.404 C	0.204	0.130	-0.617 A	0.152	-0.077	-0.420 B
	(0.501)	(0.897)	(0.076)	(0.184)	(0.417)	(0.000)	(0.375)	(0.678)	(0.024)
Dom-MNE	1.053 A	0.720 A	1.118 A	0.814 A	0.681 A	0.712 A	1.076 A	0.528 A	0.904 A
	(0.001)	(0.004)	(0.000)	(0.002)	(0.001)	(0.000)	(0.000)	(0.021)	(0.000)
For-MNE	0.251	0.111	1.125 A	0.280	0.276	0.359 B	0.167	0.124	0.869 A
	(0.529)	(0.753)	(0.000)	(0.399)	(0.323)	(0.017)	(0.621)	(0.689)	(0.000)
High Tech	2.252 A	1.835 A	3.021 A	1.797 A	2.074 A	2.427 A	2.022 A	1.800 A	1.799 A
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
High-med	1.774 A	1.697 A	2.147 A	1.603 A	1.497 A	1.727 A	1.583 A	1.612 A	1.546 A
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Low medium	1.090 A	0.994 A	1.297 A	0.977 A	0.945 A	1.172 A	0.940 A	0.962 A	0.947 A
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Obs	112 684	22 812	22 298	112 684	22 812	22 298	112 684	22 812	22 298

Notes
C significant at 10%; B significant at 5%; A significant at 1%.
p values in parentheses.
(1) Reference is domestic non-affiliate firms
(2) Reference is low technology firms

Year dummies included

Table 5

Patent application

Basic model augmented with export and other trade characteristics

Model	Logit			Zero-inflated Negative binominal			Negative binominal		
Dep variable	Application dummy			Number of applications			Number of applications		
Firm size	1-10	11-25	26-	1-10	11-25	26-	1-10	11-25	26-
G7-export	0.702 ^{A}	0.363	0.723 ^{A}	0.895 ^{A}	0.225	0.395 ^{A}	0.535 ^{B}	0.197	0.426 ^{A}
	(0.006)	(0.243)	(0.001)	(0.000)	(0.383)	(0.006)	(0.014)	(0.479)	(0.006)
Exp-c	0.023	0.071 ^{A}	0.044 ^{A}	0.013	0.062 ^{A}	0.026 ^{A}	0.018	0.064 ^{A}	0.026 ^{A}
	(0.166)	(0.000)	(0.000)	(0.366)	(0.000)	(0.000)	(0.258)	(0.000) ***	(0.000) ***
Export dum	1.009 ^{A}	1.038 ^{A}	1.192 ^{B}	0.926 ^{A}	0.690 ^{B}	-0.239	0.976	0.936	0.867
	(0.000)	(0.002)	(0.016)	(0.000)	(0.011)	(0.387)	(0.000) ***	(0.002) ***	(0.029) **
Import dum	0.756 ^{A}	0.808 ^{C}	1.029 ^{C}	0.677 ^{A}	0.496	-0.474	0.731	0.593	0.611
	(0.002)	(0.051)	(0.061)	(0.002)	(0.174)	(0.147)	(0.001) ***	(0.118)	(0.179)
Expimp dum	1.414 ^{A}	1.071 ^{A}	1.401 ^{A}	1.304 ^{A}	0.880 ^{A}	-0.061	1.375 ^{A}	0.992 ^{A}	1.219 ^{A}
	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.755)	(0.000)	(0.000)	(0.000)
Obs	112 684	22 812	22 298	112 684	22 812	22 298	112 684	22 812	22 298

<u>Notes</u>

C significant at 10%; B significant at 5%; A significant at 1%.

p values in parentheses.

Additional covariates included are profit margin, short-term debt per employee, physical capital per employee, skilled labour, ordinary labour, corporate ownership structure, sector dummies and year dummies. See Table 4.

Table 6
Patent application
Basic model augmented with import and other trade characteristics

Model	Logit			Zero-inflated Negative binominal			Negative binominal		
Dep variable	Application dummy			Number of applications			Number of applications		
Firm size	1-10	11-25	26-	1-10	11-25	26-	1-10	11-25	26-
G7-imports	0.201	0.135	0.579 A	-0.063	0.084	0.581 A	0.072	0.007	0.497 A
	(0.385)	(0.601)	(0.001)	(0.771)	(0.705)	(0.000)	(0.717)	(0.974)	(0.000)
Imp-c	0.039 B	0.068 A	0.084 A	0.041	0.062 A	0.052 A	0.039	0.053 B	0.045 A
	(0.329)	(0.006)	(0.000)	(0.251)	(0.005)	(0.000)	(0.325)	(0.021)	(0.000)
Export dum	1.171 A	1.332 A	1.565 A	1.086 A	0.959 A	-0.070	1.102 A	1.191A	1.067 A
	(0.000)	(0.000)	(0.002)	(0.000)	(0.000)	(0.799)	(0.000)	(0.000)	(0.007)
Import dum	0.616 B	0.595	0.655	0.613 A	0.312	-0.866 A	0.635 A	0.420	0.324
	(0.019)	(0.164)	(0.245)	(0.010)	(0.412)	(0.009)	(0.007)	(0.281)	(0.482)
Expimp dum	1.509 A	1.413 A	1.430 A	1.496 A	1.209A	-0.194	1.467 A	1.334 A	1.190 A
	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.323)	(0.000)	(0.000)	(0.001)
Obs	112 684	22 812	22 298	112 684	22 812	22 298	112 684	22 812	22 298

Notes
C significant at 10%; B significant at 5%; A significant at 1%.
p values in parentheses.
Additional covariates included are profit margin, short-term debt per employee, physical capital per employee, skilled labour, ordinary labour, corporate ownership structure, sector dummies and year dummies. See Table 4.

Table 7
Patent application
Basic model augmented with regional characteristics

Model	Logit			Zero-inflated Negative binominal			Negative binominal		
Dep variable	Application dummy			Number of applications			Number of applications		
Firm size	1-10	11-25	26-	1-10	11-25	26-	1-10	11-25	26-
Stockholm[1]	-0.166	-0.461	-0.123	-0.075	-0.076	0.167	-0.107	-0.277	0.021
	(0.418)	(0.110)	(0.587)	(0.637)	(0.709)	(0.164)	(0.555)	(0.269)	(0.889)
Gothenborg[1]	-0.217	-1.012 A	-0.104	-0.211	-1.033 A	0.045	-0.233	-1.025 A	-0.241
	(0.390)	(0.009)	(0.674)	(0.290)	(0.001)	(0.747)	(0.310)	(0.004)	(0.155)
Malmo[1]	-0.558	-0.894 B	0.425	-0.514 C	-0.785 B	-0.065	-0.493	-0.628	0.452 B
	(0.102)	(0.048)	(0.110)	(0.056)	(0.027)	(0.677)	(0.111)	(0.112)	(0.021)
Emp-share	1.283	-1.104	1.325 C	0.946	-0.456	0.743 B	1.071	-0.769	1.029 B
	(0.152)	(0.342)	(0.069)	(0.175)	(0.605)	(0.047)	(0.167)	(0.459)	(0.036)
Obs	112 684	22 812	22 298	112 684	22 812	22 298	112 684	22 812	22 298

Notes
C significant at 10%; B significant at 5%; A significant at 1%.
p values in parentheses.
(1) Reference alternative is Rest of Sweden
Additional covariates included are profit margin, short-term debt per employee, physical capital per employee, skilled labour, ordinary labour, corporate ownership structure, sector dummies and year dummies. See Table 3.