Innovation and Performance in Manufacturing Industries: a Comparison of the Nordic Countries[a]

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Abstract

The availability of new internationally-harmonized innovation survey data collected from OECD countries has created some interesting opportunities for studying the following two key areas: (1) the determinants of innovation behavior at firm level, and (2) innovation as an important factor contributing to the economic growth. This paper looks at the relationship between innovation and productivity in Finland, Norway and Sweden at the firm level. Although these countries enjoy a high degree of political, social and cultural similarities, they differ largely from one another in their productivity growth and national innovation systems. The main objective here has been to examine how an identically-specified econometric model might work when the survey sampling and questionnaire are identical but the national data sets are estimated separately. Findings from the micro-based data in Europe known as Community Innovation Survey (CIS) data were subsequently investigated to see whether or not they contributed to explaining the presence of cross-country differences in aggregated productivity growth. Results reveal major discrepancies between the estimated firm-level results and the aggregated figures. Differences in the country regression results were investigated to see whether they were due to data errors, the econometric model, model specifications, estimation methods or unobservable country-specific effects. The tentative conclusion is that the representativeness of the respondent firms, the model specification and unobservable country-specific effects may partly account for the deviations between macro and micro levels.

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1. INTRODUCTION

The recent availability of new Community Innovation Survey (CIS) data collected by the European OECD countries has created interesting opportunities for studying firm innovation as an important factor contributing to the economic growth of countries being investigated. Access to the rich CIS data allows studies of heterogeneous innovation behavior at different levels of aggregation, such as at firm, industry and country levels. The main feature of the CIS data is that it is the product of the first internationally introduced and harmonized survey on innovation at the firm level. From these data sets two kinds of valuable information in particular have emerged: (1) total expenditure on innovation activities, and (2) the percentage of sales revenues associated with the introduction of new innovative products and services into the market. These two variables act as complements and substitutes to more traditional measures of innovativeness often based on for example, R&D, patents, publications and citations.

Despite the new possibilities introduced by the availability of the CIS data, the most important research results to date mainly concern theoretical and methodological issues in analyzing innovativeness. Hence, less attention has been paid to the generation of results with policy implications and supporting decision making for managers and policymakers. The main challenges remaining are: (a) finding robust theoretical support for dealing with the data, (b) handling the various econometric problems inherent in these sorts of data, and (c) really making the harmonized surveys internationally comparable. Identification of problems and limitations in the data are crucial issues to be resolved via feedback in the data collection stage. While the main emphasis in this study is on cross-country comparisons using CIS data, attention has also been focused on data quality and firm and industry heterogeneity levels.

The level of seriousness with which issues relating to confidentiality are taken varies among OCED countries. The method of aggregating micro-data adopted by Eurostat offers an opportunity to get round some of the confidentiality problems affecting cross-country comparisons. Mohnen and Mairesse (2001) found that the procedure proposed by Eurostat — where each observation is replaced by an average of itself and the two adjacent observations in a ranked order of observations for each variable — does not really affect the observations. One limitation with this method is that complementary data from other sources concerning the individual firms' production, added value, employment, physical capital and human capital cannot be added to common regressions.[1] The averaging method is suitable for single factor or univariate analysis but not for multi-factor or multivariate analysis.

This paper uses an alternative method for making cross-country comparisons. The equations describing the relationship between innovation and productivity are estimated separately using different national data sets but with an identical econometric model. The study has two main objectives. The first being to examine whether differences in aggregated productivity growth between countries can be partly explained by findings

[1] Given that the surveys are representative of the universal firms these data can indeed be matched with various statistics for the representative firm. Using the average firm or pseudo data generated using common time-invariant firm characteristics is an alternative method for avoiding the confidentiality problem (see Deaton, 1985 in the context of household surveys).

from the micro-based CIS data. The second is to investigate whether or not a recent econometric model proposed by Crépon, Duguet and Mairesse (1998), hereafter referred to as the CDM model, has general characteristics appropriate for handling CIS data collected in different countries.

This investigation started out as an attempt to evaluate the significance of innovative activities on productivity performances amongst the Nordic countries. Although the four Nordic countries studied have a high degree of political, social and cultural similarity, they differ largely from one another in their productivity growth and national innovation systems. During the 1990s the annual growth rate in labor productivity in Finland and Sweden was about four times higher than that in Norway and Denmark. Unfortunately the response rate to the second CIS series (CIS II) in Denmark was very low, therefore it was decided to restrict the comparison to Finland, Norway and Sweden only.[3] In addition to the CIS data, data registered in the national bureaus of statistics in these three countries were used. In order to identify and capture the impacts of possible country-specific effects on the firms' innovative activities, their heterogeneity was analyzed by looking at a number of main indicators within R&D, human capital, taxes and other factors characterizing the state of the economies in those countries.

Applying the CDM model to CIS data is attractive in the sense that it takes into account selectivity and simultaneity biases (see Lööf and Heshmati, 2001a, 2001b).

Section 2 of the paper provides a brief discussion on innovation surveys, previous cross-country studies and the results obtained in these. In Section 3, some characteristics of these three Nordic countries are presented based on CIS data and other relevant statistics. Section 4 describes the empirical model, the data and the variable definitions. Section 5 discusses the empirical results and is followed by a cross-country comparison in Section 6. Conclusions are presented in Section 7.

2. INNOVATION SURVEYS AND CROSS-COUNTRY STUDIES

Regardless of their location in Europe, USA or Japan, firms operate on average for somewhat longer than 12 years (Financial Times, 2001). However, the standard deviation for this average is relatively large. Many studies (including for example Olley and Parks, 1996) have found that productivity can help to predict the survival of firms in the marketplace. Furthermore, there is extensive evidence of a robust and positive relationship between productivity and innovation.

One important question for firm management as well as policymakers[4] is whether or not there is some identifiable, unique set of characteristics that make the firm a successful innovator. Some authors express skepticism about the likelihood of finding robust patterns in the incredibly haphazard and complex innovation process at the

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[3] The data is obtained from the second series of the Community Innovation Survey, carried out in Finland and Sweden in 1997 and in Norway in 1998.

[4] The issue of survival of individual firms is not necessarily given high priority by for instance the policymakers. On the contrary, the lesson from the endogenous growth models indicate that long-run growth ought to be positively correlated with the flow or exit of low-productive and less-competitive firms from the market (see Aghion and Howitt, 1998).

micro level. For example Kleine and Rosenberg (1986) argue that requirements for successful innovation vary greatly from case to case, while for example Haltiwanger (2000) stresses the existence of a relationship between technological change on one side, and on the other more intangible and less measurable factors such as organizational change, upskilling, entrepreneurial and managerial ability and the ability to cooperate. It ought to be noted that the direction of the relationship in these studies is not quite clear and that the statistical significance between these kinds of intangibles and productivity is generally not very well documented.

Despite the progress made in the current body of knowledge, a number of issues relating to concepts and measurements still need to be resolved in order to better establish and quantify the determinants of innovation and the relationship between innovation and firm performance. To the list of the above-related factors belong not only how to capture intangible phenomena such as entrepreneurship, organizational innovations and differences in the quality of education, but also the nature and the boundaries of innovating firms.

In order to increase the understanding of innovation activities at the firm level, Eurostat has launched three international harmonized innovation surveys (1993-1994, 1996-1997 and 2001-2002). These surveys known as CIS I, CIS II and CIS III respectively, provide information on the determinants of innovation expenditure and the outcomes of innovation activities as well as the market impacts of innovation as measured by the proportion of sales generated from innovative products and services.[5]

One of the biggest problems when going beyond the descriptive statistics for examining these new data sets, and when using models and relevant econometric methods, is the lack of broadly accepted, formal, and theoretical bases for the empirical work that can accommodate a wide range of quantitative and qualitative CIS variables. This is a problem of general nature common to many branches of empirical macroeconomic growth analysis. In their review of recent theoretical and empirical literature on economic growth, Ahn and Hemmings (2000) found that despite advances in the theory of economic growth, there still remains a large gap between formal models and the informal but often complex mechanisms tested in empirical work. They illustrate the potential problem with models that have successfully endogenized the process of technological progress and accommodated many stylized facts on innovation and growth. However when it comes to the empirical studies, and the choosing of variables in regression analysis, the models provide the researchers with a ‘carte blanche’.

Another difficulty identified by Ahn and Hemmings is the widespread use of indicators to represent the hard-to-measure variables and difficulties in interpretation of their coefficients in the regressions. This is highly relevant to the CIS data, which with the exception of quantitative information on innovation input, innovation sales, total sales, employment, export, gross investments (only CIS III) and human capital (CIS III) consists only of indicators.

The restrictions imposed by the national statistical agencies in relation to the use of firm-level data (implied by the confidential nature of the data) result in additional problems in relation to measurements of the new sets of internationally-harmonized

[5] For a detailed discussion of the Community Innovation Survey, please see Archibugi and Pianta (1995).

innovation data. Ideally information ought to be available for facilitating the identification of individual firms contained in the CIS surveys in order to complement the CIS data set with various other statistics at the firm level; such as from the annual accounts, information on education/training levels, R&D subsidies, patents, licenses and so on. For international comparisons, these data should then be pooled in a regression, allowing the researches to model and evaluate both observable and unobservable firm-specific, industry-specific and country-specific effects.

National registers in all three Nordic countries studied in this report facilitate the merging of national data for the firms studied with the CIS data. However, only differences with respect to human capital, measured as the proportion of employees with a university degree plus engineers with post-secondary education have been controlled for here. The main objective has been to examine how an identically-specified model might work when the survey sampling and questionnaire are identical. Eventually this provides evidence that modified versions of the current model could also be used in other countries where CISs have been conducted. Hopefully using the same model specified in a similar manner and on similar data, useful information on the impact of firm-level innovativeness on the differences in productivity will be obtainable.

Due to limitations in the existing data sets, this study is restricted to using sales per employee as a measure of productivity. Lööf and Heshmati (2001b) used different measures of performance and found the level of sales productivity (sales per employee) was an acceptable measure of the level of labor productivity (value added per employee). This section summarizes some evidence from previous studies of the relationship between R&D and productivity and the impacts of country-specific effects on growth.

Evidence based on firm and industry-level data points to the presence of a positive and strong relationship between R&D and productivity. At the firm level Mairesse and Cuneo (1985) found that the estimated elasticity of performance with respect to R&D capital in France, was in the interval of 0.09-0.26. The corresponding elasticities produced by Sassenou (1988) for Japan, and Griliches and Mairesse (1990) for the US were 0.14-0.16 and 0.27-0.41 respectively. However, as many researchers have pointed out, it is not innovation input, but rather innovation output that increases productivity. R&D is identified as just one and often a minor part of firms' expenditure on innovation. In the CIS survey, innovation investment is broken down into seven different investment categories. For example the Swedish data used in this study shows that the traditional innovation input measure, internal R&D corresponds to 1.5% of total sales, while all seven categories together correspond to 3.3% of total sales. The CIS data also provide a direct measure of innovation output, defined as the proportion of sales due to innovative products and services.

It should be noted that the two CIS measures innovation input and innovation output exhibit several shortcomings. For example they are based on the subjective opinion of respondents to the survey. Furthermore, innovation is a heterogeneous phenomenon showing large variations between industries and firm sizes. These measures are new and rather unfamiliar for many firms. Despite the limitations encountered above, experience from working with CIS data indicates that these measures provide reasonable estimates, both comparable across countries and successive surveys.

Comparing the proportion of innovative sales from the innovative firms in this study shows large similarity between all three countries. The average proportions are 36%, 34% and 33% for Norway, Finland and Sweden respectively. These figures are however somewhat higher than those reported by Mohen and Mairesse (2001). Based on CIS I data, they found an average proportion of observed innovative sales of 34.7% in high-R&D sectors and 22.3% in low-R&D sectors. The results were based on data from seven European countries.[6] The measure of innovation sales they found was somewhat narrower though. This is defined as the percentage of sales due to products new to the firm, but not new to the industry. In this study the sum of both components was used as the measure of innovation output.

3. THE DATA

3.1 The Nordic countries in an international perspective

This study focuses on the impacts of innovation on productivity in manufacturing firms in Finland, Norway and Sweden. Table 1 shows large variations in the aggregated manufacturing productivity growth between Sweden and Finland at one end and Norway at the other. Regardless of whether the Finnish and Swedish growth rates are measured per employed person or per hour of work, they occupy a position at the top of the list of the 12 OECD countries between 1988 and 1998. The rate of productivity growth in Norway was as can be seen at the lower end of the list.

Column 3 in Table 1 shows gross expenditures on R&D for the 12 countries as a percentage of gross domestic product (GDP). The ratio is very high in Sweden (3.7) and Finland (2.7), while it is relatively low in Norway (1.7) in both an international and a Nordic perspective.

Patents are used widely as indicators of firm innovativeness, though they do not necessarily reflect innovation. Taking residential patent applications in relation to the size of the population, Column 4 shows an extremely large coefficient of innovativeness for Japan. This can be partly explained by the unusual patent strategy in use by many Japanese firms. Comparing the other 11 countries in Table 1, the highest coefficients can be seen in Germany, Sweden, Finland and the USA. A measure of innovativeness by patents in Norway is about 40% lower than in the two other competing Nordic countries.

Recent research has emphasized the importance of national systems of innovation and their differences across OECD countries in terms of national institutions, their relationships, resources and specialization. Hall and Jones (1999) discuss the importance of institutions and governments in providing environments that encourage capital accumulation, skills acquisition, invention and technology transfers. Putnam (1993) argues that certain aspects of relationships between individuals, such as trust, values in common, norms, informal networks and levels, and social interactions are favorable for competitiveness. However entities such as institutions, social capital and cultural climate are not readily measurable, and the formal empirical investigations of their statistical relationship with growth in cross-country regressions have not yet

[6] Belgium, Denmark, Germany, Ireland, Italy, the Netherlands and Norway.

produced any unambiguous results, as observed by many investigators including Helliwell (1996) and Keefer and Knack (1997).

World Values Surveys and World Competitiveness Executive Opinion Surveys represent two attempts to capture hard-to-measure conditions for competitiveness. Keefer and Knack (1997) constructed a trust index based on the question, “Generally speaking, would you say that most people can be trusted, or that you can’t be too careful in dealing with people?”. The average index value was found to be 39 for the 23 OECD countries involved (on a scale of 0 to 100), with Norway topping the list with 61, followed by Finland and Sweden with 57. This can be compared with 45 for the USA, 41 for Japan and only 25 for France.

Using the World Competitiveness information along with some arbitrary though important indicators for the prevailing national conditions, the overall picture displayed in Table 2 shows that the environment for production is fairly competitive in the Nordic countries compared with France, Japan and the USA. The underlined values in Table 2 indicate the highest value amongst these six countries (where high numbers indicate high competitiveness). The results show that the conditions are particularly favorable in Finland (with six underlines) when bureaucracy, corporate creditability, technology cooperation, basic research and economic literacy are taken into consideration. Norway's competitive advantages lie in its industrial relations and political systems, while Sweden’s relative strengths are industrial relations and financial resources. Personal taxes are an area where executives in Finland and Sweden regard the prevailing situation as hampering production.

3.2 Institutional differences between Finland, Norway and Sweden

Table 3 contains selected descriptive statistics on a number of parameters including macroeconomic conditions, economic structure, human capital, R&D and aggregated productivity growth in the manufacturing industry in the three Nordic countries Finland, Norway and Sweden. These factors are important for the productivity growth and innovation activities of firms. Panel A in Table 3 shows that Norway with its population of 4.4 million is the richest country in terms of GDP per employed person. As a percentage of the corresponding US figures adjusted for purchasing power parity (PPP), this figure was 92% in Norway in 1996 compared to only 74% in Finland (population of 5.1 million) and 73% in Sweden (population of 8.9 million).

The import and export intensities are about the same for all three, while using the export/import ratio for four different high-technology sectors indicates the existence of some differences. Sweden specializes foremost in pharmaceutical production, electronics and aerospace technologies; Finland specializes in high technology in the electronics industry, and Norway specializes in manufacturing outside areas traditionally defined as high technology. Norway is the world’s third-largest oil exporter and has developed major competitive advantages within various branches and sub-sectors of the oil-cluster

The design of the tax systems in all three countries is similar. Northern Europe is a high-tax area, particularly when it comes to taxes on labor. Marginal tax on personal income is above the 50% level, while the employers’ social security contribution as a percentage of the payroll varies from just over 10% of the gross wage in Norway to 33% in Sweden. The corporate tax and capital tax rates are about 30% in all three countries, which is similar to many other OECD countries in Europe. Sweden has the world's largest ratio of total taxes and fees as a proportion of GDP, at 52%. The corresponding figures for Finland and Norway are 47% and 42% respectively.

The percentage of the population of working age with higher tertiary education is highest by a substantial margin in Norway at 25%, compared with 15% in both Finland and Sweden. However, considering the percentage with lower tertiary education and higher, the figures are about the same for all three countries.

Panel B in the same table provides R&D figures for the three countries. The per capita expenditure is most sizable in Sweden, while the R&D intensity, expressed in terms of R&D personnel as a proportion of the labor force is greatest in Finland. Some 43% of the gross expenditure on R&D (GERD) is financed by government in Norway, compared with 31% in Finland and 25% in Sweden. The performance of R&D activities within higher educational as well as the government sectors are relatively more important in Norway than in Finland and Sweden. Hence, the consumption of GERD by the business sector is lowest in Norway, 57%, compared to 66% in Finland and 74% in Sweden. The figures for patent applications show that Sweden has considerably more external patent applications than the other two competing countries, and that Norway has significantly fewer national patent applications.

A decomposition of the industrial structures in Column A of Panel C in Table 3 shows that the industry classification fabricated metal products and machinery is larger in Sweden as a proportion of total manufacturing compared to the other two countries. The food, drink and tobacco industry and basic metal are proportionately largest in Norway, while paper and printing is more important in Finland than in both Sweden and Norway.

Column B of Panel C in Table 3 shows the different industries' annual productivity growth in manufacturing during 1990 to 1997 and the growth of total manufacturing. The aggregated growth was 6.1% in Finland, 5.2% in Sweden and 1.1% in Norway. In seven out of nine different industries, the Norwegian productivity growth was considerably lower than the Swedish and Finnish growth rates. Hence, the main explanation for the weak productivity growth in Norway in the context of a Nordic comparison is essentially not the structure of manufacturing when 2-digit NACE codes are considered. With exactly the same structure of the manufacturing industry as Sweden, the annual growth rate for 1990-1997 in Norway would have only increased from 1.1% to 1.2%.

3.3 Findings from the descriptive statistics

Table 4 provides descriptive summary statistics for the total samples and for the innovative sub-sample separately. Panel A shows that the number of included manufacturing firms tallies 1,062 in Finland, 1,315 in Norway and 746 in Sweden. Comparing the mean and median values for sales as well as employment respectively indicates a large degree of asymmetry in the size distribution as expected, with the mean values being 2-4 times larger than the medium values. The analysis is limited to firms with a minimum of 20 and a maximum of 5,000 employees in 1996 in Norway and Sweden, while the corresponding limits in Finland for the same year are 10 and 10,000. This leads to different medians of 50 employees per firm in Sweden, 44 in Norway and 27 in Finland.

Comparing the factor intensity[7] for the three countries shows that the proportion of labor-intensive firms is largest in Norway, and since the proportion of capital intensive firms are about the same in all three countries, this means that Norway has smallest proportion of knowledge-intensive firms.

Turning to the innovation indicators, these show that 46% of the Swedish firms introduced at least one technologically new or essentially improved product on the market during 1994-1996.[8] The corresponding figures for Norway and Finland are 35% and 24% respectively. Four out of ten Norwegian firms launched one or more process innovations compared with 36% of the Swedish firms and 20% of the Finnish firms. The proportion of firms that applied for a patent during the period considered was considerably lower in comparison with the two indicators on innovativeness presented above, being 19% in Sweden, 12% in Finland and 8% in Norway.

The most important pieces of information contained in the surveys are (1) innovation investments as a proportion of total sales, and (2) the percentage of sales associated with innovative products. The total expenditures on innovative activities corresponded to 3.3% of the totals sales for the average manufacturing firm in Sweden, 2.5% for the average Norwegian firm and a surprisingly lower mean of 1.9% for manufacturing firms in Finland. When the total sample is considered, innovation sales expressed as a percentage of total sales are 15.1% in Sweden, 11.4% in Norway and 8.0% in Finland.

Variable human capital, defined as the proportion of employees with a university degree or a post-secondary education for engineers, is about the same size in all three countries. However, there are larger proportions of engineers in Finland and Sweden. Possible double counting of R&D expenditures were adjusted for in the regressions by subtracting R&D personnel from the skilled group defined as engineers.

Panel B in Table 4 presents the same statistics as Panel A, but only for the innovative sample. In order to be innovative according to the definition used here, the firms must invest in innovation activities and introduce new products and processes to the market. This results in 485 innovative firms in Norway, 407 in Sweden and 323 in Finland.[9]

The innovative firms are generally of larger size than the non-innovative firms in all of the three sample countries, irrespective of whether or not size is measured in terms of sales or employment. The typical innovative firm has a larger proportion of highly-educated personnel compared with the non-innovative firms.

Interestingly, typical innovative firms are rather similar in all three countries when innovation input and innovation output, defined as a percentage of total sales are considered, though there are considerable differences in the percentage of innovative

[7] The following definitions and classifications of factor intensity have been used: (i) capital-intensive manufacturing consists of a two-digit international system for industrial classifications (ISIC) 10-14, 16, 21, 24 and 27 excluding 24.4-5, (ii) knowledge-intensive manufacturing includes ISIC 24.4-5, 28, 29, 30-33, 34-35, and (iii) labor-intensive manufacturing consists of ISIC 15, 17-19, 20, 22, 25, 26 and 36-37.

[8] Unger (2000) reports that the average level of product innovativeness among EU members is 48% in the CIS-II data set.

[9] It should be noted that the innovative sample is not weighted, here resulting in an over-representation of the innovative sample in comparison with a case where the innovative sample is weighted.

firms between the three countries. Innovation input corresponds to 7.6% of sales in Norway, 7.1% in Finland and 6.1% in Sweden. The proportion of innovative sales to total sales for innovative firms is 36% in Norway, 34% in Finland and 33% in Sweden.

Panel A in Table 5 shows the percentage of the Nordic firms reporting various sources of obstacles to innovation activities. When considering the total samples, it can be seen that risks and costs are the two dominating factors hampering innovation in Finland, while organizational rigidity and lack of qualified labor are the most important hampering factors found in Norway. Lack of qualified labor and over-perception of risks are amongst the factors having a negative impact on innovation activities in Sweden.

Focusing only on innovative firms reveals that about one third of sample firms in Norway and in Sweden perceive the lack of qualified labor and organizational rigidity as obstacles to innovation. The Swedish as well as the Finnish firms also find that risks and high costs impede their innovative activities. Analysis of various sources of investment and decomposition into internal and external sources, along with support by various government agencies would shed light on the importance of capital to innovation activities among firms.

Panel B in Table 5 presents factors of crucial importance to the innovative firms' innovation strategies. Dividing the firms into innovative and non-innovative firms, the opening up of new markets, increasing market share and improved product quality are among the most frequently given reasons for innovation in Finland, Norway and Sweden when the innovative samples are considered. However these strategies are most noticeable in Norway and least in Finland.

Customers and internal knowledge within the firm itself dominate as crucial sources of information for innovation foremost in Norway and Sweden and to a lesser degree in Finland. Only a small proportion of Nordic firms consider knowledge received from patent disclosures, universities, computer-based information networks and consultants as very important for developing their products and processes. Panel C in Table 5 shows that the Norwegian firms exchange knowledge with suppliers, competitors and other firms more often within the same group than do their Finnish and Swedish counterparts.

Panel D in Table 5 indicates that innovative cooperation with their national universities is much more common in Finland than in Norway and Sweden. This panel also shows that innovative Finnish firms have a higher propensity to cooperate with government and non-profit research institutions than innovative firms do in Norway, and much more readily those in Sweden. Finally, national cooperation appears to be more common than international cooperation in innovation, with the exception of other enterprises within the same group and competitors. In the two latter cases, no differences were found between the propensity to cooperate with national or international partners.

The next section contains a discussion on an econometric model and estimation methods utilizing information gathered on the issues of obstacles, strategy, sources of information and cooperation, as well as innovation input, innovation output, exporting, firm size, human capital and others factors. The objective is to specify a model that allows separation and estimation of the impacts of these variables on firm productivity.

4. THE MODEL

The theoretical framework of this study is a Cobb-Douglas production function explaining variation in productivity growth by a number of standard inputs and the traditional R&D investment variable substituted by the broadened definition of innovation investment variable. The main focus here is on whether innovation contributes to the explanation of differences in productivity growth among firms, when controlling the variable of observable factors relevant to firm performance. The contribution of innovation to productivity is expected to be positive.

The empirical model used here is a modified version of the model introduced by Griliches (1995) and further developed by Crépon, Duguet and Mairesse (1998).[10] The model, referred to as the CDM model, includes four equations and three established relationships including the innovation input (Equation 2) linked to its determinants, the knowledge production function (Equation 3) relating innovation output to innovation input, and the productivity equation (Equation 4) relating innovation output to productivity growth. Equation (1) expresses the firms' propensity to innovate. The CDM model is represented by the following equations:

(1) $$g^* = \beta_0^0 + \sum_n \beta_n^0 x_n^0 + \varepsilon^0$$

(2) $$k^* = \beta_0^1 + \sum_m \beta_m^1 x_m^1 + \varepsilon^1$$

(3) $$t = \beta_0^2 + \beta_k k + \beta_{MR} MR + \sum_l \beta_l^2 x_l^2 + \varepsilon^2$$

(4) $$q = \beta_0^3 + \beta_t t + \beta_{-1} q_{-1} + \sum_k \beta_k^3 x_k^3 + \varepsilon^3$$

where g^* is a latent (unobserved) innovation decision variable, k^* represents latent innovation input or R&D expenditure, t is innovation output, q is productivity and MR is the inverted Mill's ratio introduced to correct for possible selection bias, β_k is the elasticity of production with respect to changes in R&D, x^1, x^2 and x^3 are M, L and K vectors of primarily standard input variables such as human capital, physical capital, material and energy and other variables explaining the innovation input, innovation output and performance of firms, and β^j is the corresponding vector of input elasticities and other determinants.

As not all firms make an investment in innovation, a two-step investment decision procedure has been applied. In the first step, based on Equation (1), firms decide whether to engage in research or not. This decision is modeled as a probit model. The second stage based on Equation (2), is modeled as a tobit model, where firms decide how much to invest in research, conditional on having already decided to make an investment in innovation. The two models differ in the way that the dependent variable is defined. The dependent variable (g) in the probit model equals 1 for a firm engaged

[10] The basic CDM model and its various generalizations estimated using different estimation methods is found in Lööf and Heshmati (2001a, 2001b).

[11] The basic CDM model and its various generalizations estimated using different estimation methods is found in Lööf and Heshmati (2001a, 2001b).

in innovation investment, otherwise it is 0. In the tobit model, *k* represents the level of innovation ivestment. The vectors x^0 and x^1 are partially overlapping.

One possible problem with the production-function approach is that explanatory variables are often determined jointly with the dependent variable; in other words they are not exogenously given. The last steps of the CDM model highlight this simultaneity problem. The innovation output (*k*) is endogenous in the knowledge production function equation (Equation 3), and knowledge capital or innovation output is endogenous in the productivity equation (Equation 4). To overcome the problem of endogenous explanatory variables, the CDM model accounts for simultaneity bias by relying on the instrumental variable approach. In the estimation a two-way casual relationship between productivity and innovation has been allowed for.

In this paper, an innovation investor is defined as an enterprise that claims to have invested in innovation activities in 1996. Equation (2) expresses the amount of innovation investment per employee, where a firm invests in innovative activities. Equation (3) expresses variations in the amount of innovation output (innovation sales) per employee among the innovative firms. This measure is obtained by multiplying the proportion of sales of innovative products, defined as technologically new or improved products introduced between 1994-1996, by total sales and then dividing the sum by the number of employees. Finally, Equation (4) expresses variations in productivity defined as sales per employee.

The explanatory variables introduced to explain the firms’ propensity and ability to innovate are numerous and include the following: industry "dummies", firm size measured as the logarithm of the number of employees, a logarithm of export per employee, a dummy variable for patent applications during 1994-1996, the proportion of administrators and non R&D-engineers in the workforce, the factor intensity (knowledge, labor and capital) dummy variables, and finally a set of control variables indicating whether turnover in 1996 increased or decreased by 10% or more due to recent establishments, mergers with another enterprises or part of it, or sales or closures of part of the enterprise during 1994-1996.

When explaining the amount of innovation, an additional number of indicators to the list of explanatory variables above were utilized. These included a number of indicators of very important reasons and sources of information for innovation, perceived obstacles to innovation, and firms' national and international cooperation in innovation.

The measure of innovation output has been classified into two distinct groups: all innovations and radical innovations. Radical innovation is a subset of all innovations, and is defined as innovations new to both the markets and to the firm. Estimations are modeled separately for the two categories of innovation. The underlying assumption is that radical innovations differ from other innovations. The difference is due to the presence of a weaker correlation of radical innovation with recent R&D investment and returns to R&D. Innovation output is defined as the logarithm of innovation sales per employee, and is explained using the following: predicted innovation investments, feedback effects from predicted productivity, Mill’s ratio predicted from the propensity to invest equation, 17 industry dummies, three factor-intensity dummies, a dummy for process innovation, and additional indicator variables representing reasons for innovation through a number of strategy variables. These strategy variables include product strategies that are offensive (proactive) and defensive, a strategy for reducing the costs of labor, material or energy consumption and a strategy for increasing flexibility in the production process.

The additional variables include a number of composite dummy variables indicating moderate and very important sources of information for innovation, cooperation in innovation, firm size, and control variables for recent establishments, mergers, acquisitions and plant closures.

Variations in the productivity variable, defined as the logarithm of sales per employee are expressed by the following: a logarithm of predicted innovation sales per employee, human capital, industry and factor-intensity dummies, a dummy for process innovation, important sources of knowledge for innovation, composite effects, factors hampering innovation, dummy variables for establishments, mergers and closures and finally the firm size.

Equations (3) and (4) are estimated together in a 3SLS simultaneous equation system as well as in a 2SLS model. The 2SLS model can be distinguished from the 3SLS model by the incorporation of feedback effects from productivity to innovation output in 3SLS. In total, four different models were used for estimations, distinguishable from one another by the way innovation is defined, namely radical or all innovations, and by the different estimation methods 2SLS and 3SLS. These alternative model specifications and estimation methods are undertaken for the purposes of sensitivity analysis. This certainly results in variations in the estimated results and subsequent difficulties in interpretation of the result. Despite these difficulties, it is believed that the benefits of the procedure outweigh the disadvantages. The differences serve to indicate heterogeneity and potential sources of improvements in performance.

One serious limitation of this regression analysis is that physical capital is not controlled for, which means that the estimated impact of innovation output on productivity will be overestimated, according to findings by Lööf and Heshmati (2001b).[12]

5. THE EMPIRICAL RESULTS

Regression results for the CDM model outlined in Section 4 are reported in Tables 6 to 11. The model was used separately for each of the three Nordic countries and the two definitions of innovation output, namely total innovative sales and sales limited to radical innovations respectively.

The probit equation for innovation determination (Equation 1) for the total samples found in Table 6, shows that the probability of engagement in innovative activities is positively related to an increase in firm size, export intensity and previous involvement in research approximated by patent applications. The control variables for recent establishments, mergers with another firm or part of it, or sales or closures of part of the firm are not statistically significant (5% level of significance).

The section that follows will present the tobit model of innovation (Equation 2) and the 3SLS equation of innovation output, defined as innovation sales (Equation 3) and

[12] The accumulation of physical capital is one of the main sources of economic growth. Jorgenson (1990) found that the contribution of physical capital accounts for more than 40% of the growth in the US during 1947-1985. In allowing for quality differences in capital equipment, Hulten (1992) found that the best practice technology is about 20% above the average level of efficiency in the US.

productivity (Equation 4; For all innovations and for radical innovations only) and the 2SLS equation of productivity (Equation 4; For all innovations and for radical innovations only). The results for Finland, Norway and Sweden are presented separately. The section then concludes with a comparison of the estimates for the different samples and a discussion of possible country-specific effects.

5.1 The tobit model of innovation investment

Finland: Table 7 shows estimates of innovation investment (Equation 2). For the typical manufacturing firm in Finland with 10 employees or more, innovation intensity (investment per employee) decreases with firm size, while it increases with export intensity and previous research (patent application). Unlike the pre-study expectations, a large, statistically significant and negative estimate was found for non R&D-engineers. The estimate for administrators is statistically insignificant.

None of the three control variables for recent establishment, merger or partial closing of plants appears to be of significance in the equation. Among the eight indicators for obstacles to innovation, only one shows association with the dependent variable at the 5% level of significance. However, the unexpected positive sign for lack of information for technology requires an explanation. One suggestion is that innovative firms in Finland underinvest in R&D and other innovation activities due to insufficient knowledge about technological possibilities.

Two strategy dummies are positively and highly associated with innovation investment intensity. These are extended product range and improved production flexibility. Significant positive sources of information for innovation are the major sources from within the enterprise itself, its customers and fairs and exhibitions. Domestic customers, competitors, universities and foreign suppliers operating as cooperative partners in innovation are all positively associated with the innovation investment intensity.

Norway: The size of innovation investment in Norway increases significantly with the firm size, export intensity and a history of previous R&D investments represented by a dummy for patent application. The positive relationship between size and innovation not expected. A large literature relating R&D expenditures to firm size surveyed by Cohen and Klepper (1996) shows that R&D intensity is independent of firm size. Parker (2000) discuss the importance large size firms in Norway and find that a central feature of the Norwegian strategy for industrial development has been to encourage the ‘national champions’ with the capacity to compete against foreign corporations. Other than this, the fact that we do not control for physical capital can eventually explain the sign of the significant association between size and innovation in Norway.

The next consideration is the discrete CIS-indicators aimed at capturing the hard-to-measure variables. Somewhat puzzling is that organizational rigidities are positively associated with the dependent variables, probably indicating that the causality operates the other way around; Innovative firms needs to continuously change their organizations but as Tecce (1999) reports diffusion of organizational innovations normally takes longer time than the diffusion of technological innovations.

Most of the strategy variables enter Equation (2) as statistically significant. The size of innovation input increases foremost with increasing indicators for an offensive (proactive) innovation strategy including the opening up of new markets, extending product range, and improving products. Among the sources of information for innovation, those from within the firm, customers and fairs are significantly associated with investment. Table 7 also shows a positive correlation between the size of innovation investment and cooperation in innovation with national customers and external suppliers.

Sweden: Contrary to the cases in Norway and Finland, estimates of firm size and export intensity have no significant impact on firm investment intensity in Sweden. Similarly to its both Nordic neighbors recent patent applications have a positive impact on current R&D and other innovation expenditures, which partly confirms the findings of Klette and Johansen (1998) from a panel of Norwegian firms in the high-tech industries, where they found that differences in R&D intensity are highly persistent over a number of years.[13]

Interestingly the dummy indicating recent establishment correlates negatively with innovation investments, suggesting that a typical firm lacks innovative activity when entering the market. It is plausible that some of the new firms have developed new or improved products before entering the market. Two of the dummies for various obstacles to innovation are positively associated with the dependent variable, namely lack of appropriate sources of finance, and a lack of qualified personnel. One interpretation of this finding is that an innovating firm has a pool of ideas and that financial and skills restrictions force the firm to be selective. They therefore select only those ideas with a high probability of positive net returns. Lack of information about technology seems to reduce the firms' investment efforts.

Three out of nine dummies for very important reasons for innovation enter the production function for innovation investment at the 5% level of significance, and are therefore significant. These are: improving products, extending product range, and opening up new markets. The interpretation of this is that firms with a clearly offensive (proactive) innovation strategy also finalize this in concrete actions.

The elasticity of innovation investment increases positively and significantly with the following variables: information sources within the firm and customers as very important sources of information for innovation, domestic cooperation in innovation with customers and foreign cooperation with consultants.

5.2 The 3SLS model of innovation output

Finland: Column 1 in Table 8 shows the regression coefficients obtained from the innovation output (Equation 3) using the Finnish data. Panel A in the upper part of the same table shows the estimates of all innovations, while Panel B shows results for radical innovations only. There is no significant correlation between innovation output and the intensity of innovation efforts for all innovations. Turning then to radical innovations, the same table shows a coefficient estimate of 0.29, but only significant difference from 0 at low levels of significance (10%). There is no statistically significant feedback effect from productivity to innovation.

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[13] Note the difference and contradiction between this and the findings of Hall et al. (1986) , where changes in the log of firm R&D investments are close to a geometric random walks.

Sale or closure of part of the firms' production capacities correlates significantly with innovation output in Panel A in Table 8. This finding is reinforced by the strategy indicators, which show that a defensive innovation strategy correlates to the size of innovation output. Undertaking innovation through an improved production strategy also affects innovation output.

With labor-intensive industries in the intercept, the results presented in Table 8 show large, positive and statistically significant estimates for capital-intensive industries when all innovations are considered. However, this does not hold true for radical innovations.

Firm size is insignificant in the equations in both Panels A and B in Table 8. The effect of domestic cooperation in innovation within the group as well as cooperation with universities is positive, indicating expected positive impact on the intensity of investment in Panel A.

Norway: Turning now to the Norwegian firms, the results also show a statistically insignificant relationship between predicted innovation input and innovation output (see Column 2 in Table 8). On the other hand there is a strong feedback effect from productivity to innovation output. Firm size is found to negatively affect the innovation output. It however only shows significance at a low level (10%).

Among the CIS indicators, foreign cooperation in innovation with competitors has a statistically significant and positive relationship with the size of innovation output, as well as the market being an important source of information for innovation and domestic cooperation for innovation with universities. The effect is significant at the 10% level of significance. Here the market is defined as a composite dummy for suppliers, competitors, customers and consultants. Table 8 also shows a positive association between providing reducing cost as the reason for innovation and the innovation output. This indicates that typically innovative firms are both product and process innovators. Other firms within the group, as an important source of information, has a negative impact on innovation output amongst the Norwegian firms.

Interestingly newly establishment is significant and positive associated with innovation output when radical innovations only is considered.

Sweden: Column 4 in Table 8 shows the innovation output regression results based on the Swedish data. Innovation output increases significantly with the intensity of innovation efforts for all innovations, but not for the radical innovations. The elasticity is 0.17 for all innovations differing from 0 at the 5% level of significance.

No feedback effects from productivity to innovation output were found for all innovations, while the feedback impact is fairly strong for radical innovations. Recent establishments affect innovation output positively and significantly as shown in Panel A, Table 8. This indicates that many firms in Sweden have already developed a new product at the time of their entry into the market. However this conclusion does not concern firms with radical innovations.

With labor-intensive industries in the intercept, Table 8 shows large, positive and significant estimates for knowledge as well as capital-intensive industries. This is valid only when all innovations are considered. Firm size is negative in the equation in Panel B of the same table (Radical innovations), but is statistically insignificant in Panel A (all innovations). The dummy variables for offensive (proactive) innovation strategy as well as cost-reducing activities affect innovation intensity negatively in Panel A.

The market variable, approximated by a composite dummy consisting of supplier, competitors and customers as important sources of information for innovation, has a positive impact on innovation output. The same is true when the effect of the composite dummy for ‘non-market network’, defined as universities and non-profit research institutions, and all innovations are considered. The composite dummy for more codified knowledge transfer including professional conferences, meetings, journals and computer-based searching for information, somewhat surprisingly exhibits a negative relationship with the intensity of investment. For radical innovations none of the strategy dummies are significantly different from zero.

The effect of domestic cooperation in innovation with customers as well as with consultants is negative for all innovations, while foreign cooperation with the group has a positive impact on the intensity of investment among radical innovations.

5.3 The 3SLS model of productivity

Table 9 shows estimation results for the determinants of productivity growth (Equation 4). Productivity is expressed as the log of sales per employee. Panel A shows the point estimates for all innovations, and Panel B shows the corresponding results for radical innovations.

Finland: Column 1 of Table 9 shows the results for the innovative firms in Finland. Notable here is the statistically insignificant relationship between predicted innovation output and productivity for all innovations as well as for radical innovations only.

Firm size is positively related to productivity when capital intensity is not controlled for. Productivity among the Finnish firms increases largely with human capital. The elasticity is 2.8 for administrators and 0.8 for non R&D-engineers when all innovations are considered. The corresponding estimates are even higher for radical innovations, being 4.5 and 1.9 respectively.

The dummy variable for process innovation is unexpectedly not significantly affecting the intensity of productivity for any of the innovation categories. Recent establishment is positively correlated with productivity in the model specification based on firm data with radical innovations.

Organizational rigidities as obstacles to innovations are somewhat puzzling, affecting productivity positively, as shown in Panels A and B of Table 9. One interpretation is that firms are typically strongly path-dependent and cannot easily or flexibly change focus to new markets or new kinds of products. Alternatively, persistently-productive firms must continuously change their organizational structure, as shown by Teece (2001) and others. In the model specification with radical innovations, lack of appropriate sources of finance and lack of qualified personnel are found to be negatively associated with productivity. Productivity increases with other sources within the group as crucial sources of information to innovation.

Norway: The elasticity of productivity, approximated by the log of sales per employee, increases with innovation output for manufacturing firms in Norway (see Column 2, Table 9). The human capital variables are significant in the productivity equation. The elasticity of non R&D-engineers is 1.3 in Panel A, and 1.5 in Panel B. The size of the estimates for administrators is 0.6 for all innovations but only significant at a low level (10%), and 2.1 for all innovations. A very high innovation cost is negatively associated with productivity in the production function for Norway.

Sweden: The most interesting result in Column 3 of Table 9, which shows 3SLS estimation results for Swedish firms, is that the elasticity of productivity, approximated by the log of sales per employee, is about 80% larger for all innovations compared to radical innovations. This is also very similar to what is found in the productivity function based on the Norwegian data set. However the Norwegian estimates are larger than the Swedish ones for both categories of innovation, 0.26 (0.15) for all innovations, and 0.17 (0.08) for radical innovations. The first pairs are significant at the 1% level of significance, while the latter at the 5% level of significance. It should be noted that the specification of the model do not for physical capital. The level of productivity increases significantly with firm size for both categories of innovations. However when physical capital is included in the productivity equation using Swedish sample, the size of firm is neutral with respect to the level of labor productivity.

Panels A and B in Table 9, which refer to all innovations and radical innovations respectively, show a negative contribution to the estimate of the dummy variable for process innovation, while both engineers and administrators contribute positively to productivity. Controlling for innovation output, human capital, and firm size, show that labor-intensive firms are more productive than knowledge-intensive and capital-intensive firms.

In the model specification with only radical innovations, it is found that a merger with another firm correlates positively and significantly with productivity. Excessively-perceived economic risk and lack of information on technology as obstacles to radical innovations have negative impacts on productivity, while excessively high innovation costs and lack of consumer responsiveness correlate positively with productivity. When the model specification with all innovations is considered, Panel A in Table 9 shows that a lack of consumer responsiveness affects the productivity of firms positively. Internal knowledge within the firm and the group of firms as crucial sources of information for radical and all innovations are positively associated with the productivity of firms.

5.4 The 2SLS model of productivity

The 2SLS model of productivity differs from the 3SLS model by excluding the feedback effects from productivity to innovation output. However in both cases the main focus is on the effects of innovation on productivity. The 2SLS model only allows one-way causality between the two variables and simplifies the estimation procedure considerably.

Finland: Table 10 shows the estimation results for the 2SLS model of productivity. The main difference with the 2SLS model results for Finland compared with those from the 3SLS model is that a modest correlation is found between innovation output and productivity with a low level of significance, when innovations are defined as radical innovations. In the 2SLS model, the impact of non R&D-engineers on productivity diminishes.

Norway: In Norway as in Finland, the 2SLS model produces a larger impact from radical innovation on productivity than the corresponding effects generated from the 3SLS model does. However, no significant difference between the two models can be found regarding the key parameters of interest.

Sweden: The results for Sweden indicate the robustness of the estimated link between innovation and productivity independent of whether or not one or two-way causality is assumed in modeling the relationship between productivity and innovation.

6. A CROSS-COUNTRY COMPARISON OF THE RESULTS

6.1 The lower employment limits

A key regression finding is that the elasticity of productivity with respect to commercially-successful innovations are within the range of the R&D elasticity, which has been found in previous studies to be typically within the interval 0.1-0.3. However, the elasticity of the innovation output, a direct measure of innovation investment, is not statistically significant at any reasonable level of significance for Finland. In the 3SLS model for all innovation, the magnitude of the estimate is just outside the 10% level of significance, and in the 2SLS model for radical innovation, it is significant just inside the 10% level. In the other two cases, the elasticities are evidently insignificant.

Table 11 shows that the sample size differs between Finland on one side and Norway and Sweden on the other. While the Finnish firms have between 10 and 9,600 employees, their counterparts in Norway and Sweden have between 20 and about 5,000. The main concentration in all cases is however at the lower limits. When the lower limit of the Swedish sample is lowered to that of the Finnish sample (as Column 4 indicates) this does not have any significant impact on the estimates, nor does increasing the minimum level of employees to 50 in the Swedish sample.

Another possible explanation for the divergence of Finnish innovation output estimates is that the mix of radical and non-radical innovations differs from its Norwegian and Swedish counterparts. Using the Swedish sample to compare the estimates for technologically-improved and technologically-new products to the firm or to the market, no significant differences between improved and new products were found. This relation holds true regardless of whether the minimum size chosen is 12 or 20 employees (see the middle part of Table 11). The tentative conclusion is therefore that the statistical insignificance seen in the Finnish estimate is due to factors other than the result of the size distributions of the firms in the sample or the mix of improved and new product innovations.

The important issue here is whether or not the regression results between the three countries are affected by data error, model specifications or unobservable country-specific effects. Starting with the data, the harmonized survey satisfies the conditions for a collection of unified endogenous and exogenous variables. However, satisfying the conditions does not necessarily guarantee a high level of confidence in the quality of the data. For instance only 24% of the Finnish firms are product innovative according to the CIS criteria, compared to 35% of the Norwegian firms and 46% of the Swedish firms. Particularly the low level of innovative firms according to the CIS-data in the highly productive Finnish economy can be questioned.

6.2 The difficulties faced in cross-country comparisons

There are a number of problems that can be identified in making cross-country comparisons in the innovative behavior of firms.

First of all, the probability for a firm to be innovative increases with the firm size, while the estimated percentage of the sale revenues associated with innovation for the innovative sample decreases with firm size but is found to be insignificant. This implies that the regression results are sensitive to the represenativeness of the total sample as well as the selected innovative sample.

In Norway however, the CIS survey was compulsory, which guaranteed that nearly all responding firms with 20 or more employees were included in the data. In Finland and Sweden only minority of all firms in the selected sample responded to the questionarie. The rate of response was biased towards large firms particularly in the case of Finland. This means that large firms are over-represented in the total sample. This problem can partly be reduced with a weighting procedure but not entirely eliminated. For technical reasons the innovative sample is unweighted. Hence, the Swedish and Finnish samples will underestimate innovative output for innovative sample. This is an conceived example for the large innovative output estimates in Norway compared to the corresponding estimates in Finland and Sweden.

The second problem originates from the difficulty relating to estimating the data in a pooled regression model. The common model specification has been determined based on the results from the Swedish data. Similar model specification has then been applied to the Finnish and Norwegian data sets. The opportunities for successively modifying the basic model with respect to the peculiarities in all three different country data sets have been limited by a number of factors, for instance the difficulty in selecting instrument variables to account for simultaneity bias, or in the specification of the probit and the tobit equations. It is reasonable to assume that the model is biased towards the Swedish data specifications. Specification of the model was based on variable selection results from the Swedish data.

Panel A in Table 8 reveals some of the consequences of the second problem mentioned above. The table provides the estimated elasticity of the log of innovation sales per employee with respect to the predicted log of innovation investment per employee. The innovation sale is the first equation out of the two equations in the 3SLS simultaneous equation system. While the size of innovation input elasticity in the Swedish case is plausible (0.17) and significant (5% level of significance), the corresponding elasticities in Finland (–0.05) and Norway (–0.01) are insignificant. These estimates can be compared with those where the predicted log of innovation sales per employee is replaced by its observed value estimated by a simple OLS using innovative samples. The elasticities followed by the significance levels of their data sets were 0.16 (1%), 0.04 (5%) and 0.10 (1%) for Finland, Norway and Sweden respectively, and are therefore statistically significant.

It is important to note that the regression results are subject to both of the problems mentioned above. In the following section some interesting similarities and differences in the point estimates will be briefly discussed. The probit equation (Table 6) shows that the probability of making innovation investment increases with firm size and previously performed R&D. Here R&D is approximated by patent applications during the period 1994-1996, in all three countries respectively. In Finland and Sweden it was

[14] Table 4, including the descriptive statistics based on weighted values shows that 46% of the Swedish firms, 35% of the Norwegian and 24% of the Finnish firms are product innovative. Unger (2000) reports that the average level of product innovativeness among EU members is 48% in the CIS-II data set.

found that the probability of undertaking R&D increases significantly with export intensity defined as a log of export revenues per employee.

6.3 Investment in innovation

The regression coefficients displayed in Table 7 provide information regarding determinants of innovation intensity. The main findings are as follows.

The effect of firm size was found to be very different in each of the sample countries. While investment intensity decreases with firm size in Finland it shows an increasing relationship in Norway. In Sweden it was found that firm size was neutral with respect to innovation intensity.

Innovation intensity was found to increase significantly with export intensity in Finland and Norway but not in Sweden. When the control variable for recent establishment is excluded, the regression also shows a positive effect for export on innovation investment in Sweden. The control variable is highly and negatively correlated with innovation investment.

The intensity of current innovation investments is strongly correlated with patent applications in all three countries, indicating that previous investment behavior is a good predictor of current behavior among the Nordic countries.

Some major dissimilarities were found among the factors hampering innovation. For example, a lack of appropriate sources of finance and lack of qualified personnel positively affects the dependent variable in the Swedish regressions, organizational rigidities in Norway, and lack of information on technology in Finland. One interpretation of this is that increasing the supply of skilled personnel would stimulate the innovation activity in Sweden, organizational innovations in Norway and more efficient diffusion of technology in Finland. If this interpretation is correct, then contrary to Finland, innovation investment in Sweden decreases with a lack of information on technology.

A close relationship was observed between all of the three dummy variables indicating an offensive (proactive) innovation strategy and the one dependent variable in Norway and Sweden, extending product range, is significant in Finland. On the other hand, providing improved production flexibility as the reason for introducing innovation, positively affects innovation investment in Finland only.

Two estimates of crucial sources of information for innovation are significant in the models for all three countries. These sources incorporate both the sources within the enterprise and the customers. For the firms in Finland and Norway, fairs and exhibitions are very important sources promoting innovation activities, and other firms within the group in Norway. Somewhat puzzling was the significant and strongly negative relationship between computer-based information networks and the dependent variables in the Swedish sample, but not in the two other country samples.

Finally, innovation cooperation with domestic customers is positively associated with the size of innovation investment in all three Nordic countries. Table 7 shows that the Finnish sample differs from the others in the fact that domestic cooperation with universities and competitors also has a positive effect on the intensity of investments. The latter correlates negatively with the dependent variable in the Swedish sample. External foreign cooperation with suppliers is positively related to innovation investment in Finland and Norway, while the effect of external consultants has a positive effect on innovation investment in Sweden.

6.4 The innovation input and output relationships

Table 8 presents regression results relating to the logarithm of innovation sales per employee. Based on the results from the original CDM model applied to data from French manufacturing firms, it would be expected that the elasticity of innovation sales with respect to innovation investment would be significant and in the range of 0.2-0.4. However, only the Swedish estimates are in the vicinity of these results. The other two country regressions showed no significant estimates.

The innovation input estimates reveal the weakness of the method used for cross-country comparisons using separate regressions and a limited number of possibilities for modifying the basic model by alternative specifications when certain variables are added or deleted from the relation.

6.5 The innovation and performance relationship

The performance of the innovation output variables displayed in Tables 9 and 10 agrees generally with the expectations. French estimates and various different versions of the original CDM model give rise to estimates in the range of 0.1-0.3, compared favorably with the regression coefficients of 0.09, 0.26 and 0.15 produced here for Finland, Norway and Sweden respectively, using on the 3SLS estimation method. The corresponding results from the 2SLS model are 0.07, 0.26 and 0.18. The Finnish estimates are statistically insignificant in both estimation methods.

Panel C in Table 3 reveals that the relatively weak rate of labor productivity in Norway compared with Finland and Sweden is not a consequence of a different underlying structure in the total manufacturing industry when aggregated data are considered. With the exception of the industry stone, clay and glass and other manufacturingthe annual productivity growth is considerably lower in Norway than in Finland and Sweden. The weak contribution from the important fabricated metal products and machinery is particularly noticeable.

The productivity equations displayed in Tables 9 and 10 have been assessed in relation to the productivity figures presented in Table 3. When controlling for firm size, human capital, industry and factor intensity, innovation output is found to be a highly-significant factor, contributing positively to the level of labor productivity, approximated by sales per employee in Norway and in Sweden. This indicates that the Norwegian productivity problem is not due to inefficiency in the innovation process at the firm level. The total R&D investment as a percentage of R&D in Norway is 1.7% compared to 2.7% in Finland and 3.7% in Sweden. However the CIS data shows that the outcome using the broader definition of innovation investments—as a percentage of total sales—is in fact larger in Norway than in Finland, with mean values of 2.5% and 1.9% respectively. At the firm level, the difference from Sweden (mean 3.3%) is not very large.

6.6 Policy Conclusions

A number of possible factors explaining the differences in innovation behavior among the sample countries have been listed. One is the effect of firm size on innovation behavior. Another factor is the type of industrial structure prevailing within the sector that a firm operates and thereby contributing to a difference in the innovation behavior independent of country of location. Industries vary in export intensity, which affects their innovation behavior and performance. A common factor is the positive association between past and current R&D behavior. The countries studied differ in the factors hampering their innovation. For example innovation is affected by a lack of appropriate sources of finance and qualified personnel in Sweden, by organizational rigidities in Norway and by lack of information on technology in Finland. It can therefore be interpreted that increasing the supply of skilled personnel in Sweden, the rate of organizational innovation in Norway and the efficiency of the diffusion of technology in Finland would stimulate their innovation activities. Finally, the countries differ in the nature of external co-operation in innovation.

7. SUMMARY AND CONCLUSIONS

This paper investigates the relationship between innovation and productivity in manufacturing industries at the firm level in Finland, Norway and Sweden. The study has two main objectives. The first is to investigate the existence of differences in aggregated productivity growth between the three countries, though they enjoy a high degree of political, social and cultural similarity. The study attempted to answer whether or not these differences could be explained by information contained in the internationally-harmonized firm-level innovation survey, known in Europe as Community Innovation Survey (CIS) data. The second objective was to investigate whether or not a recently introduced econometric model had general characteristics appropriate for handling CIS data collected in different countries.

When aggregated labor productivity growth in manufacturing is considered, Finland and Sweden show the highest growth rates amongst the OECD countries over recent years, while Norway has shown a very low growth rate. At the same time Finland and Sweden are highly ranked internationally as R&D investors and have a high ratio of residential patent applications per head of population, while Norway's ranking is very low in both cases. This suggests that the R&D and innovation performances might be key factors causing the differences in productivity growth between the countries.

Analyzing firm-level data reveals however that the proportion of innovative firms, the amount of innovation investment or innovation output is not low in Norway. Looking then at the relationship between innovation and productivity, it can be seen that the estimated elasticity of productivity with respect to innovation output is higher in Norway than in its two neighbors in this study. Surprisingly no significant relationship was found between innovation and productivity for the average manufacturing firm in Finland, a country with a highly-productive economy.

Concrete conclusions cannot be drawn about whether or not the regression results between the three countries are affected by data errors, model specifications or unobserved country-specific effects. A number of factors might individually or jointly contribute to explaining some of the observed productivity patterns.

One explanation for the observed differences might be that the study is analyzing the level of productivity while the weak Norwegian productivity reflects the rate of growth of productivity. From the firm perspective however, it is generally necessary to be competitive in both the level and the rate of growth. Therefore highly- productive firms productive firms today are also likely to be highly-productive firms tomorrow as well. This has been well documented in the literature.

Another set of possible causes for the somewhat unexpected results might be found in the quality of the CIS data, the appropriateness of the econometric model used, and by the method of estimation. Here a single model specification is estimated at an individual country level without pooling the data. When the data is estimated in separate regressions, the specifications should ideally be country specific. In the absence of confidentiality problems, the use of firm-level CIS data in a pooled country regression of the relationship between productivity growth and innovation could be a preferable research method. Of course this is meaningful only for complementary information on firm-specific and country-specific effects. Given that problems discussed above do not cause disturbances in the regression results, the tentative conclusion from this study suggest that origins of the strong productivity performance in Finland and the weak performance in Norway can be found more in the national innovation systems in these countries, rather than in relationship between innovation and productivity. In Sweden however, there seems to be some correspondence between micro and aggregated figures.

This research has demonstrated that the CIS data is an important complement for gaining a deeper understanding of the complicated process of transforming commercial knowledge in terms of innovations, into productivity at different levels of aggregation. The study has also shown that the CDM model is very useful in this respect. The authors encourage continued development of the model to achieve a better fit with the real data and to the relationships being studied.

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Table 1: Productivity, R&D and innovativeness in 12 OECD countries.

	Annual output per employed person in manufacturing 1988-1998	Annual output per hour worked in manufacturing 1988-1998	R&D/GDP	Innovativeness coefficient (residential patent applications/10 000 population)
Finland	5.5	5.8	2.7	4.6
Sweden	5.2	4.1	3.7	4.7
France	3.5	3.5	2.2	2.2
Belgium	3.0	3.0	1.6	0.9
Netherlands	3.0	2.8	2.0	1.6
USA	2.9	2.7	2.7	4.5
Germany (West)	2.7	3.3	2.3	5.5
Japan	2.4	3.6	2.9	27.7
UK	2.2	2.4	1.8	3.1
Canada	2.1	2.2	1.6	1.1
Italy	2.1	2.5	1.0	1.2
Norway	1.3	1.2	1.7	2.7
Total	*2.9*	*2.9*	*2.2*	*5.0*

Sources: US Department of Labor, Statistics Finland and OECD.

Table 2: World competitiveness executive opinion survey 1995-1998.

	Finland	Norway	Sweden	France	Japan	USA
Personal taxes	1.5	3.7	2.4	2.9	3.5	<u>5.5</u>
Government policy	5.8	6.2	3.7	4	3.1	<u>6.3</u>
Political system	5.8	<u>6.3</u>	3.8	3.9	2.1	6.1
Bureaucracy	<u>6.2</u>	5.5	5.6	3.1	2.4	4
Corporate creditability	<u>7.4</u>	7	7	5.7	6.6	6.5
Industrial relations	7.2	<u>8.1</u>	<u>8.1</u>	5.3	7.8	6.8
Workers motivation	6.3	6.8	6.6	5.2	<u>7.3</u>	6
Work organizations	6.9	6.6	7.4	6.4	<u>8.4</u>	7
Consumer orientation	6.5	6.2	7.1	5.7	<u>7.6</u>	7.2
Entrepreneurship	6.7	5.8	6.5	5.7	4.3	<u>6.9</u>
Technology cooperation	<u>6.4</u>	5.6	5.9	5.4	6.1	5.7
Research cooperation	6.4	5.1	5.6	4.6	5	<u>6.1</u>
Financial resources	6.7	6.6	<u>6.9</u>	5.4	6.1	6.7
Skilled labor	7	6.1	5.8	6.7	<u>6.9</u>	5.9
Qualified engineers	6.9	6.2	3.7	<u>7.8</u>	6.7	6
Basic research	<u>6.9</u>	5.5	6	6.4	6.3	6.7
Science and education	6	4.9	4.5	<u>7</u>	6.2	4.2
Educational system	<u>6.9</u>	5.3	4.2	4.7	4.7	4.4
Economic literacy	6.6	5.9	6	4.5	<u>7.4</u>	5
Within firm training	7	6.2	6.7	6	<u>7.7</u>	5.6
Average	*6.4*	*6.0*	*5.7*	*5.3*	*5.8*	*5.9*

Notes: Arbitrarily selected variables from four annual reports from World Economic Forum. The underscore indicates highest values among the six countries. The scale in the survey is 0-10 where higher numbers indicates a more competitive economy.

Table 3: Selected economic variables.

	Finland		Norway		Sweden	
Panel A. Annual macroeconomic variables						
Population in millions, 1996	5.1		4.4		8.9	
GDP per person employed as % of US 1996[1]	74		92		73	
Manufacturing/GDP	33.2		29.7		27.5	
Services/GDP	62.2		56.7		62.7	
Export/GDP	43.2		40.0		41.5	
Import/GDP	34.2		33.0		34.3	
Export/Import ratio aerospace industry	0.21		0.41		1.39	
Export/Import ratio electronics industry	1.97		0.46		1.93	
Export/import ratio office machinery and computer industry	0.75		0.26		0.30	
Export/import ratio drug industry	0.30		0.21		2.59	
Total taxes and fees as proportion of GDP (1999)	46.5		41.8		52.1	
Personal income taxes, highest marginal tax rate						
Employers' social security contribution, % of the payroll	26		13		33	
Corporate tax, %	28		28		28	
Capital tax, %	28		.		30	
Proportion of population (25–64) with higher tertiary education, % [2]	13		24		13	
Proportion of population (25–64) with lower tertiary education, % [3]	29		26		28	
Panel B: R&D						
GERD[4] per capita population (current PPP $)	556		443		774	
R&D personnel per thousand labor force	16.4		10.9		15.4	
GERD financed by industry	62.9		49.4		67.7	
GERD financed by government	30.9		42.9		25.2	
GERD performed by the business sector	66.0		56.9		74.8	
GERD performed by the higher education sector	20.0		26.6		21.5	
GERD performed by the government sector	13.6		16.4		3.5	
National patent applications	83944		30165		88537	
External patent applications	76213		65555		161223	
Panel C: Manufacturing: Value added and productivity						
% of value added 1994 (A). Annual growth in labor productivity 1990-1997 (B).	A	B	A	B	A	B
Food, drink and tobacco	12	4.3	16	1.1	8	4.4
Textiles, apparel & leather	7	7.3	3	2.4	3	5.0
Wood, cork and furniture	7	8.2	7	1.8	8	3.4
Paper & printing	22	6.2	14	0.0	16	2.9
Chemical products	11	3.3	11	0.0	11	5.7
Stone, clay and glass	4	6.2	4	3.2	3	-0.1
Basic metal industries	4	7.3	13	0.7	6	6.8
Fabricated metal products and machinery	32	9.3	32	1.7	46	6.4
Other manufacturing	1	0.0	1	0.0	0	0.0
Total manufacturing	100	6.1	100	1.1	100	5.2

Notes: (1) PPP adjusted by the so called EKS method, (2) Three years or more, (3) Shorter than three years (4) Gross expenditures on R&D. Sources: The OECD Stan database for industrial analysis (1995), OECD Economic Surveys, Sweden (1998), Main Science and Technology Indicators (2000). Human capital: OECD, Education at a Glance. Export & value added: OECD. Nace and ISIC are based on the same classification of firms but the code numbering differs.

Table 4: Summary statistics by degree of innovativeness.

	Finland	Norway	Sweden
Panel A: Total sample	*n = 1062*	*n = 1315*	*n = 746*
Sales in 1000s and in local currency			
Mean	91 726	154 000	243 979
Median	15000	47 300	61 573
Min	700	2000	6 000
Max	1.19e+07	8.71e+06	2.19e+07
Employment			
Mean	95	105	148
Median	27	44	50
Min	10	20	20
Max	9602	4 912	5000
Sample composition			
Labor-intensive firms, %[a]	0.636	0.678	0.565
Knowledge-intensive firms, %[a]	0.303	0.258	0.314
Capital-intensive firms, %[a]	0.053	0.063	0.073
Innovativeness			
Product innovation, %[a]	0.240	0.348	0.459
Process innovation, %[a]	0.203	0.402	0.361
Patent, %[a]	0.117	0.076	0.193
Innovation input, %[b]	0.019	0.025	0.033
Innovation output, %[b]	0.080	0.114	0.151
Human capital			
Engineers, %[c]	0.053	0.050	0.083
Administrators, %[c]	0.029	0.044	0.020
Panel B: Innovation sample	*n = 323*	*n = 485*	*n = 407*
Sales in 1000s and in local currency, mean			
Mean	259 267	292 000	350 710
Median		80 900	90 000
Min	2200	3 200	12 000
Max	1.19e+07	8.71e+06	2.19e+07
Employment			
Mean	233	184	209
Median		70	65
Min	10	20	20
Max	9602	4 912	5000
Sample composition			
Labor-intensive firms, %[a]	0.447	0.506	0.457
Knowledge-intensive firms, %[a]	0.450	0.422	0.451
Capital-intensive firms, %[a]	0.094	0.071	0.084
Innovativeness			
Product innovation, %[a]	1.000	1.000	1.000
Process innovation, %[a]	0.607	0.756	0.652
Patent, %[a]	0.433	0.354	0.385
Innovation input, %[b]	0.071	0.076	0.061
Innovation output, %[b]	0.336	0.357	0.330
Human capital			
Engineers, %[c]	0.065	0.102	0.110
Administrators, %[c]	0.038	0.048	0.021

Notes: (a) percentage of the firms, (b) percentage of sales, (c) percentage of employees. All values are weighted.

Table 5: Descriptive statistics of the CIS indicators by innovativeness divided into total sample (T), innovative sample (I), domestic (D) and foreign (F);. expressed in percentage of the firms.

	Finland		Norway		Sweden	
Panel A: Obstacles to innovation (T) and (I)						
Sample	(T) *n=1062*	(I) *n=323*	(T) *N=1315*	(I) *n=485*	(T) *n=746*	(I) *n=407*
Excessively perceived risk	0.14	0.27	0.09	0.22	0.20	0.32
Innovation cost too high	0.15	0.25	0.07	0.18	0.16	0.26
Lack of appropriate sources of finance	0.09	0.16	0.05	0.11	0.10	0.18
Organizational rigidities	0.06	0.15	0.14	0.31	0.17	0.29
Lack of qualified personnel	0.09	0.21	0.12	0.29	0.20	0.37
Lack of information on technology	0.10	0.25	0.06	0.15	0.09	0.13
Lack of information on markets	0.06	0.17	0.05	0.13	0.09	0.16
Problem fulfilling regulations or standards	0.04	0.08	0.02	0.04	0.06	0.10
Lack of consumer responsiveness	0.08	0.14	0.04	0.09	0.10	0.17
Panel B: Strategy on innovation (I)	*n = 323*		*n = 485*		*n = 407*	
Factors of crucial importance						
Improving product quality	0.31		0.69		0.59	
Opening up new markets / increasing market share	0.34		0.68		0.56	
Extending product range	0.28		0.52		0.35	
Reducing labor costs	0.2		0.47		0.37	
Improving production flexibility	0.23		0.33		0.24	
Reducing materials consumption	0.17		0.3		0.32	
Replacing products being phased out	0.27		0.23		0.43	
Fulfilling regulations, standards	0.13		0.23		0.31	
Reducing environmental damage	0.08		0.18		0.27	
Reducing energy consumption	0.07		0.14		0.19	
Panel C: Sources of information for innovation (I)	*n = 323*		*n = 485*		*n = 407*	
Factors of crucial importance						
Clients or customers	0.44		0.60		0.69	
Sources within the firms	0.39		0.58		0.57	
Suppliers of equipment, materials, components or software	0.08		0.23		0.12	
Competitors	0.09		0.21		0.17	
Fairs, exhibitions	0.13		0.19		0.16	
Other firms within the group	0.09		0.18		0.11	
Professional conferences, meetings, journals	0.05		0.09		0.04	
Universities or higher education institutions	0.09		0.06		0.04	
Consultant enterprises	0.04		0.05		0.02	
Computer-based information networks	0.02		0.05		0.02	
Patent disclosures	0.02		0.01		0.02	
Panel D: Cooperation in innovation (I)	*n = 323*		*n = 485*		*n = 407*	
	(D)	(F)	(D)	(F)	(D)	(F)
Customers	0.41	0.31	0.29	0.19	0.35	0.25
Government/private non-profit research inst.	0.36	0.09	0.27	0.04	0.14	0.06
Suppliers of equipment, materials, or software	0.36	0.28	0.25	0.23	0.27	0.17
Universities or higher education institutions	0.46	0.12	0.22	0.05	0.26	0.09
Other enterprises within the enterprise group	0.17	0.16	0.17	0.15	0.17	0.19
Consultant enterprises	0.23	0.08	0.17	0.06	0.23	0.07
Competitors	0.11	0.11	0.06	0.05	0.03	0.05

Table 6: Probit model of innovation decision (Equation 1). Results are based on total samples.

	Finland	Norway	Sweden
Sample size	1 062	1 315	746
Firm size	0.171 [a] (0.043)	0.223 a (0.061)	0.141[a] (0.045)
Export intensity	0.104 [a] (0.021)	0.006 (0.007)	0.070 [a] (0.023)
Patent applications 1994-1996	1.572[a] (0.142)	0.555 a (0.211)	1.455[a] (0.165)
Non R&D-engineers	-1.432[b] (0.622)	0.107 (0.869)	0.820 (0.892)
Administrators	0.310 (0.971)	2.405 b (0.996)	-0.354 (1.626)
During the period 1994-1996 the production was changed with at lest 10% due to			
- The firm was established	0.010 (0.226)	0.107 (0.280)	-0.716 [c] (0.372)
- Merger with another firm or part of it	0.267 (0.168)	-0.100 (0.194)	0.117 (0.175)
- Sale or closure of part of the firm	- 0.028 (0.205)	0.306 (0.282)	-0.031 (0.237)

Notes. Significant at the 1% (a), 5% (b) and 10% (c) levels of significance, t-values in parentheses.

Table 7: Tobit model of innovation investment (equation 2). Results are based on total samples.

	Finland	Norway	Sweden
Sample size	1 062	1 315	746
Firm size	-0.483 [a] (0.099)	0.951 [a] (0.323)	0.108 (0.106)
Export intensity	0.181 [a] (0.042)	0.081 [b] (0.038)	0.055 (0.045)
Knowledge-intensive industry	-1.849 (1.878)	-1.822 [c] (0.985)	1.376[c] (0.776)
Capital-intensive industry	-0.115 (1.101)	-1.747 [c] (0.946)	2.490 [c] (1.40)
Patents	1.630 [a] (0.267)	2.678 [a] (0.943)	0.727[a] (0.274)
Non R&D-engineers	-3.179 [a] (1.173)	-0.450 (4.112)	0.640 (1.508)
Administrators	0.573 (2.107)	13.775 [b] (5.506)	2.227 (2.623)
During the period 1994-1996 the production was changed with at lest 10% due to			
- The firm was established	-0.478 (0.444)	1.578 (1.410)	-2.597 [a] (0.966)
- Merger with another firm or part of it	0.323 (0.328)	0.227 (1.084)	-0.139 (0.302)
- Sale or closure of part of the firm	0.530 (0.429)	0.199 (1.417)	-0.398 (0.437)
Obstacles to innovation			
Excessively perceived economic risk	0.522 (0.343)	1.335 (0.950)	-0.207 (0.333)
Innovation costs too high	0.207 (0.341)	0.577 (1.006)	0.399 (0.320)
Lack of appropriate sources of finance	0.175 (0.322)	-0.983 (0.173)	1.003 [a] (0.338)
Organizational rigidities	0.386 (0.351)	2.171 [a] (0.817)	-0.217 (0.279)
Lack of qualified personnel	0.535 [c] (0.312)	-0.411 (0.877)	0.686 [b] (0.283)
Lack of information on technology	0.726 [b] (0.309)	1.311 (1.010)	-0.776 [b] (0.341)
Fulfilling regulations or standards	-0.456 (0.374)	-0.447 (1.122)	0.066 (0.360)
Lack of consumer responsiveness	-0.219 (0.362)	-1.986 (1.236)	0.541 [c] (0.322)
Strategy on innovation (very important factors)			
Improving products	0.179 (0.258)	3.798 [a] (0.682)	1.294 [a] (0.231)
Opening up new markets	-0.042 (0.259)	3.212 [a] (0.700)	0.566 [b] (0.243)
Extending product range	1.005 [a] (0.284)	4.013 [a] (0.670)	0.619 [b] (0.261)
Fulfilling regulations or standards	0.086 (0.338)	0.228 (0.777)	0.412 (0.258)
Replacing products being phased out	0.005 (0.281)	1.481 [c] (0.779)	0.405 [c] (0.235)
Reducing labor costs	-0.342 (0.338)	1.597 [b] (0.738)	0.190 (0.269)
Reducing material consumption	0.282 (0.410)	-0.891 (0.836)	-0.234 (0.301)
Improving production flexibility	0.940 [a] (0.291)	0.111 (0.740)	-0.164 (0.275)
Reducing environmental damage	1.165 [b] (0.499)	-2.612 [a] (0.993)	0.306 (0.348)
Crucial sources of information for innovation			
Sources within the enterprise	0.983 [a] (0.248)	3.041 [a] (0.641)	0.979 [a] (0.244)
Clients or customers	0.596 [b] (0.240)	2.758 [a] (0.689)	1.471 [a] (0.254)
Other firms within the group	0.331 (0.463)	2.193 [b] (0.907)	-0.677[c] (0.381)
Competitors	-0.388 (0.438)	-0.423 (0.810)	-0.155 (0.311)
Consultancies	0.195 (0.632)	-1.259 (1.400)	0.554 (0.723)
Suppl.of equip, materials, comp. software	-0.654 (0.419)	-0.809 (0.778)	0.511 (0.360)
Universities or higher education instit.	-0.143 (0.466)	1.897 (1.499)	-0.417 (0.562)
Patent disclosures	0.493 (0.896)	3.060 (3.993)	0.207 (0.636)
Professional conf. meetings, journals	0.156 (0.535)	-1.902 (1.203)	0.035 (0.671)
Computer-based information networks	-0.784 (0.832)	0.811 (1.700)	-2.434 [a] (0.761)
Fairs, exhibitions	0.742 [b] (0.366)	2.939 [a] (0.861)	0.186 (0.339)
Domestic cooperation in innovation			
Customers	0.986 [a] (0.281)	3.327 [a] (0.875)	0.660 [b] (0.278)
Suppliers	0.148 (0.291)	0.719 (0.874)	0.496 (0.326)
Competitors	0.864[b] (0.412)	1.716 (1.450)	-1.577 [b] (0.660)
Other firms within the group	0.128 (0.363)	-0.830 (0.958)	0.254 (0.357)
Consultancies	-0.224 (0.329)	-0.067 (0.992)	0.263 (0.328)
Universities	1.185 [a] (0.310)	0.850 (1.003)	0.149 (0.328)
Government	0.418 (0.290)	1.159 (0.897)	0.180 (0.373)
Foreign cooperation in innovation			
Customers	0.055 (0.331)	-0.835 (1.102)	0.403 (0.325)
Suppliers	0.964 [a] (0.327)	2.816 [a] (0.970)	-0.352 (0.352)
Universities	0.418 (0.464)	-3.423 [c] (1.883)	-0.716 (0.509)
Consultancies	-0.164 (0.493)	0.315 (1.548)	1.121 [b] (0.527)

Notes. Significant at the 1% (a), 5% (b) and 10% (c) levels of significance, t-values in parentheses.

Table 8: 3SLS model of innovation output (knowledge capital, Equation 3). Results are based on innovative sample.

	Finland	Norway	Sweden
Panel A: All innovations	*n = 353*	*n = 485*	*n = 407*
Innovation input	-0.050 (0.088)	-0.013 (0.172)	0.166 [b] (0.073)
Productivity	0.390 (0.219)	1.333 a (0.329)	0.095 (0.443)
Firm size	-0.074 (0.063)	-0.098 c (0.527)	-0.050 (0.058)
Knowledge-intensive industries	0.478 (1.037)	0.720 (1.388)	2.642 [a] (0.803)
Capital-intensive industries	1.401 [b] (0.696)	0.301 (1.332)	2.068 [b] (1.028)
During the period 1994-1996 the production was changed with at lest 10% due to			
- The firms was established	0.274 (0.258)	0.322 (0.262)	1.251 [b] (0.548)
- Merger with another firm or part of it	0.076 (0.178)	0.216 (0.188)	-0.185 (0.168)
- Sale or closure of part of the firm	0.615 [b] (0.276)	0.243 (0.248)	0.191 (0.254)
Strategy on innovation			
- Offensive (proactive)	0.326 (0.547)	0.377 (0.958)	-1.103 [b] (0.431)
- Defensive	0.844 [a] (0.181)	0.096 (0.074)	0.144 (0.132)
- Reduce cost	0.168 (0.137)	0.305 a (0.113)	-0.398 [b] (0.175)
- Improve production flexibility	0.327 [b] (0.133)	-0.102 (0.094)	0.212 (0.140
Important(moderate) sources of information for innovation			
- Other firms within the group	-0.239 (0.171)	-0.305 [b] (0.146)	0.158 (0.166)
- The market	0.015 (0.142)	0.247 [b] (0.126)	0.404 [b] (0.179)
- Non-market network	-0.198 (0.130)	0.173 (0.165)	0.277 [b] (0.125)
- Prof. Conf., meetings, journals, IT	0.005 (0.126)	0.021 (0.119)	-0.341[a] (0.124)
Domestic innovation cooperation			
- Customers	-0.094 (0.137)	0.101 (0.099)	-0.318 [b] (0.142)
- Consultancies	0.138 (0.151)	0.023 (0.104)	-0.396 [b] (0.163)
- Universities	0.020 (0.158)	0.182 [c] (0.109)	0.172 (0.161)
Foreign innovation cooperation			
- Within the group	0.416 [b] (0.190)	0.221 [c] (0.121)	0.277 (0.187)
- Suppliers	0.030 (0.150)	0.129 (0.101)	0.532 [a] (0.188)
- Competitors	-0.221 (0.206)	0.438 [b] (0.208)	-0.036 (0.264)
- Universities	0.338 [c] (0.202)	-0.153 (0.205)	0.285 (0.243)
Panel B Radical innovations	*n = 173*	*n = 208*	*n = 212*
Innovation input	0.294[c] (0.160)	0.018 (0.040)	0.028 (0.106)
Productivity	0.249 (0.306)	1.203 [a] (0.346)	1.098 [b] (0.507)
Firm size	-0.115 (0.107)	-0.192 [b] (0.085)	-0.196 [b] (0.082)
Knowledge-intensive industries	0.828 (1.275)	-0.307 (0.547)	1.059 (1.543)
Capital-intensive industries	0.498 (0.829)	-1.571 [c] (0.948)	1.648 (1.682)
During the period 1994-1996 the production was changed with at lest 10% due to			
- The firm was established	0.718 [c] (0.400)	1.627 [a] (0.390)	-1.051 (0.674)
- Merger with another firm or part of it	0.286 (0.265)	0.243 (0.287)	-0.193 (0.233)
- Sale or closure of part of the firm	0.483 (0.536)	-0.673 [c] (0.356)	0.907 [b] (0.379)
Strategy for innovation			
- Defensive	0.942 [a] (0.288)	0.037 (0.141)	0.098 (0.202)
- Reduce cost	0.027 (0.233)	0.359 [c] (0.195)	-0.478 [c] (0.249)
Important (moderate) sources of information for innovation			
- Other firms within the group	0.039 (0.395)	0.023 (0.241)	-0.413 [c] (0.230)
- The market	0.111 (0.214)	0.409 [b] (0.207)	-0.088 (0.220)
- Non-market network	0.172 (0.325)	0.182 (0.265)	-0.358 [c] (0.194)
Domestic innovation cooperation			
- Suppliers	0.139 (0.220)	0.088 (0.178)	0.400 [c] (0.234)
- Customers	0.267 (0.312)	0.244 (0.186)	-0.378 [c] (0.223)
Foreign innovation cooperation			
- Within the group	0.251 (0.294)	-0.200 (0.218)	0.698 [a] (0.242)

Notes: Significant at the 1% (a), 5% (b) and 10% (c) levels of significance, t-values in parentheses.

Table 9: 3SLS model of productivity (Equation 4). Results are based on innovative sample.

	Finland	Norway	Sweden
Panel A: All innovations	*323*	*485*	*407*
Innovation output	0.090 (0.058)	0.257 [a] (0.062)	0.148 [a] (0.044)
Firm size	0.062 [a] (0.021)	0.031 (0.021)	0.067 [a] (0.016)
Non R&D–engineers	0.851 [a] (0.164)	1.269 [a] (0.317)	0.638 [b] (0.304)
Administrators	2.758 [a] (0.719)	0.617 [c] (0.358)	3.392 [a] (0.597)
Process innovation	-0.029 (0.060)	0.008 (0.044)	-0.148 [a] (0.043)
Knowledge-intensive industries	-0.546 (0.516)	-0.424 (0.604)	-1.132 [a] (0.245)
Capital-intensive industries	0.110 (0.356)	-0.285 (0.578)	-1.360 [a] (0.304)
During the period 1994-1996 the production was changed with at lest 10% due to:			
The firms was established	0.184 (0.131)	-0.106 (0.114)	-0.382 c (0.200)
Merger with another firm or part of it	-0.078 (0.084)	0.010 (0.083)	0.070 (0.056)
Sale or closure of part of the firm	-0.296 (0.139)	-0.078 (0.109)	- 0.135 [c] (0.081)
Obstacles to innovation			
Excessively perceived economic risk	0.033 (0.089)	-0.038 (0.047)	-0.032 (0.056)
Innovation costs too high	-0.125 (0.090)	-0.076 (0.047)	-0.007 (0.056)
Lack of appropriate sources of finance	-0.113 (0.088)	-0.031 (0.053)	-0.051 (0.053)
Organizational rigidities	0.240 [a] (0.087)	-0.030 (0.040)	-0.076 [c] (0.046)
Lack of qualified personnel	-0.035 (0.079)	0.024 (0.042)	-0.021 (0.045)
Lack of information on technology	0.073 (0.077)	0.054 (0.048)	-0.034 (0.058)
Lack of information on the market	-0.111 (0.087)	0.000 (0.051)	-0.086 (0.058)
Lack of consumer responsiveness	0.166 [c] (0.089)	0.082 (0.059)	0.150 [a] (0.056)
Crucial sources of information for innovation			
Within the firm	0.072 (0.058)	-0.055 (0.045)	0.007 (0.043)
Other firms within the group	0.233 [b] (0.096)	0.101 c (0.056)	0.151 [b] (0.058)
The market	-0.002 (0.058)	-0.025 (0.052)	-0.015 (0.042)
Non-market network	-0.071 (0.087)	-0.058 (0.070)	0.029 (0.074)
Prof. Conferences, meetings, journals	-0.224 (0.074)	-0.004 (0.051)	0.012 (0.047)
Panel B Radical innovations	*n = 173*	*n = 208*	*n = 222*
Innovation output	0.082 (0.080)	0.169 [b] (0.085)	0.081 [b] (0.037)
Firm size	0.062 [c] (0.032)	0.050 (0.038)	0.062 [a] (0.019)
Non R&D-engineers	1.902 [a] (0.421)	1.481 [a] (0.491)	0.688 [b] (0.726)
Administrators	4.540 [a] (1.058)	2.116 [a] (0.716)	2.331 [a] (0.715)
Process innovation	-0.027 (0.080)	0.005 (0.076)	-0.174 [a] (0.050)
Knowledge-intensive industries	-0.699 (0.539)	*1.084 [a] (0.134)*	-1.037 [b] (0.415)
Capital-intensive industries	0.074 (0.395)	*1.113 [a] (0.128)*	-1.064 [b] (0.466)
During the period 1994-1996 the production was changed with at lest 10% due to:			
- The firm was established	0.316 [b] (0.159)	-0.027 (0.237)	-0.263 (0.201)
- Merger with another firm or part of it	0.158 (0.108)	0.022 (0.126)	0.111 [b] (0.064)
- Sale or closure of part of the firm	-0.140 (0.230)	0.096 (0.171)	-0.017 (0.109)
Obstacles to innovation			
Excessively perceived economic risk	0.014 (0.230)	-0.118 (0.086)	-0.151 [b] (0.069)
Innovation costs too high	-0.028 (0.117)	-0.210 [b] (0.085)	0.128 [b] (0.068)
Lack of appropriate sources of finance	-0.245 [b] (0.113)	-0.117 (0.098)	0.007 (0.066)
Lack of qualified personnel	-0.185 [c] (0.101)	0.062 (0.086)	0.008 (0.055)
Lack of information on technology	-0.020 (0.095)	0.125 (0.099)	-0.191 [a] (0.067)
Lack of consumer responsiveness	0.242 [b] (0.122)	0.129 (0.118)	0.144 [b] (0.061)
Crucial sources of information for innovation			
- Within the firm	-0.082 (0.083)	-0.034 (0.081)	0.108 [b] (0.051)
- Other firms within the group	-0.133 (0.130)	-0.021 (0.097)	0.162 [b] (0.068)
- The market	0.013 (0.075)	0.054 (0.094)	0.005 (0.053)
- Non-market network	-0.114 (0.106)	-0.042 (0.113)	-0.116 (0.106)
- Prof. Conferences, meetings, journals	-0.199 [c] (0.108)	0.045 (0.086)	-0.159 [a] (0.056)

Notes: Significant at the 1% (a), 5% (b) and 10% (c) levels of significance, t-values in parentheses.

Table 10: 2SLS model of productivity (Equation 4). Results are based on innovative sample.

	Finland	Norway	Sweden
Panel A: All innovations	*n=323*	*n=485*	*n=407*
Innovation output	0.072 (0.066)	0.255 [a] (0.060)	0.180 [a] (0.054)
Firm size	0.063 [b] (0.029)	0.034 (0.023)	0.067 [a] (0.018)
Non R&D-engineers	0.854 [c] (0.438)	1.189 [a] (0.334)	0.510 (0.370)
Administrators	2.785 [b] (1.224)	0.462 (0.646)	3.520 [a] (0.790
Process innovation	-0.025 (0.067)	-0.082 (0.071)	-0.162 [a] (0.056)
Knowledge-intensive industries	-0.553 (0.511	-0.469 [b] (0.200)	-1.221 [a] (0.409)
Capital-intensive industries	0.128 (0.253)	-0.340 [b] (0.161)	-1.455 [a] (0.437)
During the period 1994-1996 the production was changed with at lest 10% due to:			
- The firm was established	0.196 (0.143)	-0.093 (0.120)	-0.415 (0.281)
- Merger with another firm or part of it	-0.076 (0.131)	0.012 (0.074)	0.070 (0.086)
- Sale or closure of part of the firm	-0.284 [c] (0.153)	-0.055 (0.104)	-0.140 (0.091)
Obstacles to innovation			
c-Lack of appropriate sources of finance	-0.117 (0.108)	-0.074 (0.077)	-0.052 (0.064)
d- Organizational rigidities	0.244 [b] (0.119)	-0.015 (0.074)	-0.073 (0.048)
e- Lack of qualified personnel	-0.040 (0.098)	0.052 (0.069)	0.030 (0.055)
f- Lack of information on technology	0.077 (0.099)	0.039 (0.064)	-0.047 (0.056)
g- lack of information on the markets	-0.109 (0.109)	0.030 (0.090)	-0.084 (0.077)
i- Lack of consumer responsiveness	0.167 (0.109)	0.077 (0.082)	0.171 [b] (0.078)
Crucial sources of information for innovation			
- Within the firm	0.075 (0.066)	-0.055 (0.052)	-0.007 (0.060)
- Other firms within the group	0.234 (0.177)	0.098 (0.060)	0.151 [b] (0.070)
- The market	0.002 (0.070)	-0.025 (0.066)	-0.013 (0.051)
- Non-market network	-0.070 (0.093)	-0.051 (0.088)	0.036 (0.099)
- Prof. Conferences, meetings, journals	-0.222 [b] (0.087)	0.066 (0.052)	0.009 (0.066)
Panel B Radical innovations	*n = 173*	*n = 208*	*n = 222*
Innovation output	0.104 [c] (0.060)	0.211 [a] (0.065)	0.094 [a] (0.033)
Firm size	0.062 [c] (0.036)	0.054 (0.039)	0.065 [a] (0.021)
Non R&D-engineers	1.898 [b] (0.959)	0.966 [b] (0.455)	0.489 (0.356)
Administrators	4.336 [a] (1.584)	1.986 [c] (1.127)	2.250 [a] (0.916)
Process innovation	-0.034 (0.097)	0.023 (0.106)	-0.195 [a] (0.059)
Knowledge-intensive industries	-0.743 (0.445)	-	-1.091 [a] (0.129)
Capital-intensive industries	0.028 (0.228)	-	-1.052 [a] (0.279)
During the period 1994-1996 the production was changed with at lest 10% due to:			
- The firms was established	0.298 [bc] (0.151)	-0.123 (0.239)	-0.213 (0.262)
- Merger with another firm or part of it	0.148 (0.124)	0.028 (0.127)	0.114 (0.097)
- Sale or closure of part of the firm	-0.143 (0.286)	0.160 (0.172)	-0.044 (0.105)
Obstacles to innovation			
Excessively perceived economic risk	-0.013 (0.125)	-0.170 (0.108)	-0.144 [c] (0.083)
Innovation costs too high	-0.035 (0.129)	-0.224 [c] (0.124)	0.084 (0.074)
Lack of appropriate sources of finance	-0.259 [b] (0.130)	-0.079 (0.126)	0.014 (0.097)
Organizational rigidities	0.177 (0.150)	-0.167 (0.101)	-0.063 (0.063)
Lack of qualified personnel	-0.198 [c] (0.103)	0.097 (0.105)	0.001 (0.062)
Lack of information on technology	-0.013 (0.120)	0.141 (0.099)	-0.182 [a] (0.068)
Lack of information on the market	-0.063 (0.131)	0.076 (0.144)	0.055 (0.087)
Lack of consumer responsiveness	0.250 [c] (0.138)	0.092 (0.125)	0.144 [c] (0.078)
Crucial sources of information for innovation			
- Within the firm	-0.020 (0.093)	-0.036 (0.081)	0.096 (0.641)
- Other firms within the group	-0.146 (0.158)	-0.003 (0.111)	0.163 [b] (0.079)
- The market	0.009 (0.083)	0.026 (0.104)	0.009 (0.054)
- Non-market network	-0.115 (0.104)	-0.043 (0.149)	-0.103 (0.095)
- Prof. Conferences, meetings, journals	-0.189 [c] (0.109)	0.038 (0.089)	-0.161 [b] (0.064)

Notes: Significant at the 1% (a), 5% (b) and 10% (c) levels of significance, t-values in parentheses.

Table 11. Summary of the elasticity of productivity with respect to innovation output. Productivity is defined as the log of sales per employee and innovation output as the log of innovation sales per employee.

	Finland	Norway	Sweden	Sweden B	Sweden C
Employment:					
Minimum	10	20	12	20	50
Maximum	9602	4912	9646	5000	9646
All innovations:					
3SLS model	0.090 (0.058)	0.257[a] (0.062)	0.140[a] (0.040)	0.148[a] (0.044)	0.158[a] (0.038)
2SLS model	0.072 (0.660)	0.255[b] (0.060)	0.163[a] (0.047)	0.180[a] (0.054)	0.155[a] (0.039)
Improved for the firm or market:					
3SLS model	-	-	0.154[a] (0.048)	0.137[a] (0.047)	0.146[a] (0.040)
2SLS model	-	-	0.169[a] (0.045)	0.144[a] (0.045)	0.137[a] (0.041)
New to the firm or to the market:					
3SLS model	-	-	0.176 [a] (0.043)	0.150 [a] (0.043)	0.277[a] (0.058)
2SLS model	-	-	0.163[a] (0.047)	0.154 [a] (0.046)	0.208 [a] (0.043)
New to market:					
3SLS model	0.082 (0.080)	0.169[b] (0.085)	0.104[a] (0.038)	0.081[b] (0.037)	0.039 (0.059)
2SLS model	0.104[c] (0.060)	0.211[a] (0.065)	0.086[b] (0.033)	0.094[a] (0.033)	0.132[a] (0.044)

Notes: The variable specification of the 2SLS model differs slightly from the variable specification of the 3SLS model. Process innovation is not included in the innovation output equation of the 2SLS model. The definition of radical innovations is technologically new to both the firm and the market, while technologically new is defined as technologically new either to the firm or to the market.