A Multi-Country Study of Complex Interactions of Factors Affecting Product Innovation and Process Innovation in Small and Medium Enterprises (SMEs) in the Manufacturing Sector

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Extended Abstract

Manufacturing is the most important source of economic development and growth and, undoubtedly, small and medium enterprises (SMEs) make a significant contribution to economic growth. The aim of this exploratory study is to examine the complex interactions among variables that affect the innovation dimensions (product and process innovation) of European manufacturing SMEs by using two hierarchical log linear models. The focus of this paper is twofold. First, we unveil the complex interactions among seven different variables on Product Innovation (ProDI) and Process Innovation (ProCI). Second, we depict all the complex interactions visually. The empirical evidence is based on an official survey conducted by European Commission's "Sectoral e-Business Watch" in 2009. This survey consists of 627 telephone interviews in 6 selected EU countries. The seven variables used in our study concern outsourcing ICT services, employment of ICT practitioners, impact on economic crisis on ICT investments, internationalization activities, implementation of advanced sustainable manufacturing technologies (i.e. technologies to increase manufacturing efficiency in the use of energy and materials and drastically reduce emissions), energy cost advantages, and company size. First, all seven variables were found to be associated with the two outcome variables ProDI and ProCI in a chi-square test analysis. Second, the hierarchical log linear analysis among ProDI and the chosen variables revealed thirteen out of an original twenty-eight possible two-way interrelationships. Along the same line the second analysis between ProCI and the chosen variables revealed fourteen two-way interrelationships. It is hoped that this exploratory research has laid the foundation for further examination of innovation activity in the SME context. Future studies should be able to replicate the process in other industries and on a larger scale. Results of this research may have implications for both policy makers and the industries themselves. The findings of this study extend the innovation literatures and help build a foundation for further understanding of the links between the different dimensions of Innovation. This paper constitutes a continuation of authors' works on the concept of Innovation.

Keywords
Product Innovation, Process Innovation, Small Enterprises, Manufacturing Sector

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Introduction

The manufacturing industry plays a significant and also a vital key role not only to GPD, on which a 20 percent target has been set by the European Commission, but also its role becomes noteworthy in the EU reaching 7.000€ billion in turnover, accounting for 80 percent of the total EU exports, but also 80 percent of the private R&D expenditure. Another contribution of the industry is that it creates job opportunities frequently employing more than 30 million employees in several companies of either small or medium-size (Eurostat, 2013). Nevertheless, due to the global recession, the manufacturing industry is suffering severely as over 3.8 million people have been left unemployed in Europe since day one, following a constant downward tendency. The latter leads to a reduction in industrial production and a further dramatic drop in value added in 2008 that is not likely to regress in its prior state of the recession (European Commission, 2014). It is inevitable to assume that this situation could be reversible, should there be more innovations developed, exquisite qualifications, added resource efficiency, as for instance sustainable technologies.

Should the above be followed, the newly developed but also the older enterprises could profit from the development and the introduction of innovative products and procedures for further development and expansion. (Frenken and Boschma, 2007, Tourigny and Le 2004; Storey 2000). It is also highly likely that the smaller sized enterprises will benefit greatly in terms of productivity and possibilities for future development, should they encompass and embrace innovative techniques (Madrid-Guijarro et al., 2009, Cefis and Marsili 2006). On the other hand, companies that will not embrace change, are more liable to becoming less competitive and uncreative in terms of building products and procedures that are state of the art. (Cotec 2006). McAdam and McConvery (2004) are strongly inclined to believe that those companies that will be innovative and pioneering are likely to exceed in authenticity those that are not.

Numerous statistical methods have been utilized to generate predictive models that identify factors affecting innovation of SMEs (Papastathopoulos, & Beneki, 2011; Lin et al., 2010; Dibrell et al., 2008). While these models provide an accurate statistical description between these variables and outcome, they do not readily lend themselves to presenting the complex interactions visually. This study contributes toward this direction and hopes to inspire those who want to investigate systematically all orders of interactions of factors affecting the ProDI and ProCI of European manufacturing firms. Additionally, the analysis stresses that companies taking into account different factors can improve the chances of achieving better levels of innovation-improvements.

Concepts and Literature

Product innovation means there is a change to the end product or service (Camison-Zomoza, et al., 2004) as to improve the quality and variety of goods, develop opportunities, through production of larger quantities and better prices (Vaona, A. & Pianta, M. (2008) in the forms of upgrades, modifications, and extensions of existing products (Dibrell et al., 2008). Moreover, it is worth pointing out that more and more SMEs have been facing international competition in recent years, thus entering international markets making "internationalization" a key concept (Beneki, at al. 2011; Analoui and Karami, 2003) affecting European and other global businesses, export-oriented or active in their domestic market (European Commission, 2003). As far as firm size is concerned, I would like to illustrate the fact that some researchers have suggested a positive relation, stressing that company size can best indicate innovation (Papastathopoulos, & Beneki, 2011; César Camisón-Zornoza et al., 2004). However, others find no relation at all (Aiken et al. 1980). Other studies have suggested that these contradictory results could have come about because important variables were measured incorrectly. Let us turn to the issue of ICT, which is most productive when integrated with investments in working practices, human resources, and company restructuring (Brynjolfsson and Hitt, 2000). However, in a survey of over 700 European firms in seven countries, market research firm IDC found that one third of these companies reported delays in projects by suppliers lacking necessary skills and that nearly half of the companies faced problems in hiring personnel with IT skills in 2008 (IDC, 2008). It is worth mentioning that despite the fact that ICT facilitates the implementation of strategic plans (e.g., Aral and Weill, 2007; Oh and Pinsonneault, 2007) and the capacity to link innovations with existing businesses (Bhaskaran 2006), the economic crisis has brought major changes since 2008, as over 40 percent of the Glass, Ceramic and Cement companies stated that their ICT investments would be hit by the crisis. Over 20 percent reported that they were already downsizing or cancelling current projects, and 20 percent announced budget cutbacks. This is the most serious decrease in ICT budgets, in any business sector, since e-Business Watch began this survey in 2002.

At this point, we should refer to "energy management systems" (EMS), systems used by energy consumers in industry for monitoring, analyzing and improving their energy consumption patterns, ranging from a relatively simple time clock controlling a single circuit to sophisticated direct digital controls (DDC) that manage all of the energy intensive systems in a building (European Commission, 2009d). A market study in the USA by BCC Research estimates that the market for energy management information systems increased from approximately 10.4$ billion in 2003 to 17.6 billion in 2006 and that revenues will reach nearly 23$ billion by 2011, representing an average annual growth rate (AAGR) of 5.4 percent from 2006 to 2011 (BCC Research, 2006). Another aspect of IS/IT management is outsourcing leading to the development of certain assets for the company even for smaller companies, since there is going to be a huge internet availability also regarding broadband (SMEs) According to an e-Business Watch study on the chemical industry (2008) outsourcing has gained ground in ICT and e-business fields, since it has also incorporated the "SaaS", the "Software as a Service", distribution model, that 20 percent of the companies have incorporated. It is noteworthy that the main aim of outsourcing would be the accomplishment of the development concerning productivity; the latter can be achieved by triggering companies to concentrate mainly on their core business. As for the specialized service provider, they ought to be quite targeted in establishing procedures having to do with outsourcing. Nevertheless, there are certain hazards lurking with outsourcing and those concern not only the loss of control of competences but also a miscalculation of the transaction costs as well as of coordination efforts (European Commission, 2009a). Another aspect of ICT concerns sustainability as it can help reduce the emissions intensity, but the potential differs between industries. An e-Business Watch study finds that in three of the five most energy-intensive sectors in the EU, greater ICT capital intensity has been associated with increased efficiency and lower emissions intensity. This trend bodes well for a future reduction in emissions intensity due to ICT (European Commission (2009b).Sustainable development is a new area that has started to be incorporated into mainstream operations management, logistics and information systems. Research related to sustainability is still at an early stage but is increasing rapidly (Linton *et al.*, 2007). Sustainability, according to the definition of the European Commission, includes not only economic, but also social and environmental aspects (European Commission, 2007), so these issues need to be reflected when decisions on IT/IS investments are being made.

Research Design Methodology

Research Design

The raw data were drawn from an official survey conducted by the European Commission's "*Sectoral e-Business Watch"* in 2009. The Sectoral e-Business Watch has been collecting data related to the use of ICT and e-business in European enterprises by means of representative surveys since 2002. This survey took place among SMEs from the "Glass, Ceramic and Cement" industries and consists of 627 telephone interviews with ICT decision-makers in six selected EU countries (UK, France, Germany, Spain, Italy and Poland). Interviews were carried out with ICT decision-makers in the company in March 2009, using computer-aided telephone interview (CATI) technology.

Population and Sampling Frame

The survey population was defined as companies that had at least 10 employees, used computers, were active within the national territory of one of the six countries covered, and had their primary business activity in one of the sectors covered.

The sample drawn was a stratified random sample of companies from the population in each of the six countries. Samples were drawn locally by fieldwork organizations based on official statistical records and widely recognized business directories. Dun & Bradstreet was used in France, Italy, Spain and the UK, Heins Partner Business Pool in Germany, and Hoppenstedt Bonnier in Poland. Fieldwork was coordinated and conducted by the German branch of Ipsos GmbH in cooperation with the aforementioned institutions on behalf of the Sectoral e-Business Watch. Pilot interviews prior to the regular fieldwork were conducted with about 25 companies in Germany in February 2009, in order to test the questionnaire (structure, comprehensibility of questions, average interview length).

The final allocation of our sample (n = 627 SMEs) according to firm size, industry and country is illustrated Exhibit 1.

Measure Development and Statistical Method

In order to examine the complex two-way interactions among variables that affect the product and process innovation of European manufacturing SMEs, a hierarchical log linear analysis was applied. The major emphasis of log-linear analysis is to obtain a log-linear model that is linear in logarithms of the expected frequencies of a contingency table and that adequately describes or fits the associations and interactions that exist in the contingency table as closely as possible (Wrigley, 1985). The principal reason for utilizing log-linear procedures in this study lies in the fact that interactions and interrelationships underlying categorical survey data can be analytically highlighted. A backwards elimination was used to remove non-significant two-way interactions between variables using a statistical significance cut-off of 0.05. Associations for each predictor against dichotomized outcome variables were tested using chi-squared test analyses.

Exhibit 2 details the research variables used in this study, including concept, operational measure and sampling source. In log linear models, all variables that are used for classification are independent or predictor variables and the dependent variable is the log of the number of cases in a cell of the multiway cross-tabulation (Norusis, 2008). The outcome variable *product innovation* is empirically measured in terms of launching any new or improving products or services and the outcome variable *process innovation* is empirically measured in terms of introducing any new or significantly improving internal processes. The raw data were coded and analyzed using the PASW Statistics 18.

Statistical Results

Analysis of Associations

In order to test the complex interactions among variables that stimulate the Product Innovation and Process Innovation of European manufacturing SMEs, a Pearson's Chi-Square test was used in order to examine whether there is an association between response categorical variables and outcome categorical variables).

All the related p-values were less than the traditional threshold of .05. Thus, it can be verified that these values are highly significant, which indicates that the employment of ICT Practitioners, the impact of economic crisis on ICT-investments, the implementation of advanced sustainable manufacturing technologies, the outsourcing of any ICT services, the

export activities of SMEs, the energy cost advantages and company size had a significant effect on whether a SME achieves product innovations and process innovations.

Loglinear Analysis Results

The results reveal thirteen and fourteen out of an original twenty-eight possible two-way interactions between the chosen variables and outcome variables ProDI and ProCI respectively. Two-way interactions were investigated only because trying to make sense of three-way and higher-way interactions is notoriously difficult, so the reason for limiting to two-way was pragmatic, based on the need to keep any interpretations as simple as could be. Making the interactions any more complex does not help and may actually hinder interpretation of what the multivariate data are saying.

The log linear analysis revealed thirteen (model 1) and fourteen (model 2) appreciable complex interactions among variables affecting directly or indirectly the product and process innovation activities of European manufacturing SMEs.

Exhibits

Exhibit 1 Industry and country distribution of the sample & sampling sources

			Firm Size 10 - 49			Firm Size 50 - 249			
			Survey Sectors			Survey Sectors			
			Ceramic	**Cement**	**Glass**	**Ceramic**	**Cement**	**Glass**	**Total**
Countries	**Germany**	Count	29	68	23	11	24	16	**171**
		% within sector	17,0%	39,8%	13,5%	6,4%	14,0%	9,4%	**100%**
	Spain	Count	12	57	13	16	20	4	**122**
		% within sector	9,8%	46,7%	10,7%	13,1%	16,4%	3,3%	**100%**
	France	Count	16	39	15	6	3	5	**84**
		% within sector	19,0%	46,4%	17,9%	7,1%	3,6%	6,0%	**100%**
	Italy	Count	10	29	19	6	22	8	**94**
		% within sector	10,6%	30,9%	20,2%	6,4%	23,4%	8,5%	**100%**
	United Kingdom	Count	12	18	21	4	3	3	**61**
		% within sector	19,7%	29,5%	34,4%	6,6%	4,9%	4,9%	**100%**
	Poland	Count	8	27	7	9	33	11	**95**
		% within sector	8,4%	28,4%	7,4%	9,5%	34,7%	11,6%	**100%**
Total		Count	87	238	98	52	105	47	***627***
		% within sector	13,9%	38,0%	15,6%	8,3%	16,7%	7,5%	***100%***

In this survey, a cut-off was introduced with regard to company size: only companies with at least 10 employees were interviewed. The highest level of the population (at least 10 employees) was the set for all computer-using enterprises which were active within the national territory of one of the six countries covered, and which had their primary business activity in one of the three industry sectors specified on the basis of NACE Rev. 2.

Exhibit 2: Summary of Research Variables

Predictor Variables	**Abbreviations of Variables**	**Description – Operational Measure**	**Source**
Product Innovation (outcome 1)	ProDI	Respondents were asked whether they had launched any new or substantially improved products or services (0 = yes and 1 = no).	European Commission 'SeBWSurvey 2009'
Process Innovation (outcome 2)	ProCI	Respondents were asked whether they had introduced any new or significantly improved internal processes (0 = yes and 1 = no).	European Commission 'SeBWSurvey 2009'
ICT Practitioners	ICTP	Respondents were asked whether their firm had employed personnel with ICT qualification (0 = employment and 1 = non- employment).	European Commission 'SeBWSurvey 2009'
Impact of Economic Crisis on ICT Investments	EC	Respondents were asked whether the economic crisis had an impact on their ICT Investment plans or on ICT Projects (0 = yes and 1 = no).	European Commission 'SeBWSurvey 2009'
Outsourcing ICT services	OutS	Respondents were asked whether their firm had outsourced any ICT services to external service providers which were previously conducted in-house (0 = yes and 1 = no).	European Commission 'SeBWSurvey 2009'
Internationalization Activities	IA	Respondents were asked to indicate which sales market is the most significant (0 = Regional-Country Market and 1 = International Market).	European Commission 'SeBWSurvey 2009'
Implementation Advanced Sustainable Manufacturing Technologies	SMT	Respondents were asked whether their firm had implemented an ICT-enabled system to systematically monitor greenhouse gas emissions (0 = yes and 1 = no).	European Commission 'SeBWSurvey 2009'
Energy Cost Advantages	ECA	Respondents were asked whether the energy savings had been a relevant objective in any of their ICT investments (0 = yes and 1 = no).	European Commission 'SeBWSurvey 2009'
Company Size	CS	Respondents were asked to indicate their size group (0 = 10-49, 1 = 50-249)	European Commission 'SeBWSurvey 2009'

This table lists the variables that were incorporated into the hierarchical log linear models, their abbreviations, the operational measures, as well as the sampling source.

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