EXPLORING INNOVATIVE ACTIVITIES IN TURKISH MANUFACTURING INDUSTRY USING COUNT DATA ANALYSIS[1]

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ABSTRACT

The purpose of this paper is to investigate the nature of patenting activity in the context of Turkish manufacturing industry. The literature tells us that many variables can be used while investigating patenting or innovative activity. The dependent variable chosen for this study is the number of patent applications per year. Since the dependent variable is a non-negative integer, count data methodology is employed in order to capture the non-linear nature of the data. A conditional fixed effects Poisson panel regression has been estimated for Turkish manufacturing industry for the 2003-2008 period. The results indicate that the evidence from Turkish manufacturing industries support the Schumpeterian theory. Furthermore, R&D expenditures and R&D personnel intensity are important drivers of patenting activities. This study encompasses the traditional point of view towards innovative activity; however manages to take this view one step further in terms of the econometric technique used.

***JEL Classification**: O31, C23, C25, L6*

***Keywords**: Innovation, patenting activity, count data*

TÜRK İMALAT SANAYİİNDE YENİLİKÇİ ETKİNLİKLERİN SAYMA VERİ ANALİZİ KULLANILARAK ARAŞTIRILMASI

ÖZ

Bu çalışmanın amacı Türk İmalat Sanayiinde patent aktivitesinin doğasını araştırmaktır. Literatürde patentleme veya yenilikçi faaliyetler araştırılırken pek çok değişken kullanılmaktadır. Bu çalışma için seçilen bağımlı değişken her bir yıl için patent başvuru sayısıdır. Bağımlı değişken negatif olmayan bir tamsayı olduğu için ve verinin doğrusal olmayan doğasını göz önüne alabilmek için sayma sayı yöntemi kullanılmıştır. 2003-2008 yılları arasında Türk İmalat Sanayii için koşullu sabit etkiler Poisson panel regresyonu tahmin edilmiştir. Türk İmalat Sanayii için elde edilen sonuçlar, Schumpeteryan teoriyi desteklemektedir. Ayrıca, Ar-Ge harcamaları ve Ar-Ge personel

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yoğunluğu, patent aktivitesine yön veren önemli faktörlerdir. Bu çalışma, yenilikçi aktivitelerin geleneksel bakış açısını içinde barındırmakla birlikte, kullanılan ekonometrik yöntem bağlamında bu bakış açısını bir adım öteye taşımaktadır.

JEL Sınıflandırması: *O31, C23, C25, L6*

Anahtar Kelimeler: *Yenilik, patentleme faaliyeti, sayma sayı*

1. INTRODUCTION

Patenting activities are important signs for innovation which is argued to be the driving force of economic development by Schumpeter (1934; 1942) and also an important encouraging factor for competitive strategy (Stock et al., 2002). In this regard, innovation is critical for firms to develop and maintain their competitive advantage in the industry and also to obtain an opportunity to enter into new markets (Stock et al., 2002).

The aim of this study is to investigate the factors affecting the patenting activities of Turkish Manufacturing industry over the period 2003-2008 using panel count data models. This study has two main contributions to the existing literature. On the one hand, Becheikh et al. (2006), in their systematic review, stated that most of innovation related studies in the literature are conducted for the European industries, the U.S., Canada and Japan. This indicates that especially developing economies, in which innovation has a critical importance for economic development, have not attracted adequate attention. This study, therefore, makes an important contribution by focusing on a developing economy. On the other hand, although this study mainly deals with "traditional" determinants of innovation such as firm size and research and development (R&D) expenditure due to the data limitations, it differs from the studies carried out for Turkey by using panel count data models. Count data models, where the dependent variable consists of nonnegative integer values (i.e. the number of patent applications), are being increasingly used in applied econometrics over recent decades. However, there is not a comprehensive innovation study using panel count data models for Turkey. Therefore, it can be argued that this study has an important methodological contribution to the existing literature by using panel count data models.

Regarding the traditional determinants of innovation, the relationship between firm size and innovation has long been investigated by a vast amount of empirical literature (e.g. Acs and Audretsch, 1987; Damanpour, 1992; Bertschek and Entorf, 1996). According to the Schumpeterian hypothesis (1942), the large firms are proportionally more innovative than small firms. One of the reasons behind this hypothesis comes from the advantage of large firms regarding economies of scale in R&D activities (Stock et al., 2002). In this respect, large firms have an ability to employ more R&D personnel which in turn leads to economies of scale in R&D activities. For example, a high number of R&D staff means that they have more colleagues to discuss or share the ideas and allows the division of labour in R&D (Kamien and Schwartz, 1982; Stock et al., 2002). Secondly, large firms have more resources to devote to innovation activities and this high level of resources gives these firms a chance to compensate unsuccessful innovations. Furthermore large firms are more likely to have more skilled human resources, which enables them to have high levels of technological knowledge (Damanpour, 1992).

Although most of studies have found an evidence supporting Schumpeterian hypothesis, (e.g. Damanpour, 1992; Cohen and Klepper, 1996; Evangelista et al., 1998), some studies have reported different findings such as better innovation performance of small or medium sized firms, same for large and small size at the same time or insignificant relationship between the two variables (e.g. Acs and Audretsch, 1987; Pavitt et al., 1987; Gravez and Langowitz, 1996; Bertschek and Entorf, 1996; Kumar and Saqib, 1996; Crepon et al., 1998; Stock et al., 2002). The diversity in the estimation results may be attributed to the empirical methods or the measures of innovativeness used in the analysis. However, other factors such as technological environment, market structure and unobserved differences between firms, which are generally difficult or impossible to measure, may also affect the firm size and innovation relationship (Blundell et al., 1995; Bertschek and Entorf, 1996; Becheikh et al. 2006).

Another important traditional determinant of innovation is the R&D strategy of the firms including R&D expenditures and R&D personnel. Higher levels of R&D expenditure tend to result in more new products and/or processes (Graves and Langowitz, 1996). Furthermore, it helps to absorb outside sources of knowledge which is also a critical component of innovation process (Cohen and Levinthal, 1990). At this point, it should be stated that the factors affecting product and process innovations are generally different especially when it comes to the effect of R&D expenditures (Raymond and St-Pierre, 2010). However, examining the determinants of product and process innovations requires more detailed data which is an important limitation of most data sets. In general, Becheikh et al. (2006) stated that more than half of the studies conducted for the period of 1993-2003 found a positive association between R&D and innovation.

As a result of increasing patent databases in all over the world allows for exploring the different dimensions of innovation performance. Therefore, in addition to the traditional determinants, there is a range of variables used in the innovation studies as the determinants of innovation performance. However, most of these variables require quite detailed firm-level data sets. These include, for example, organizational factors (François et al., 2002), management related variables (Souitaris, 2002; Baldwin and Johnson, 1996) and innovation strategies (Peeters and de la Potterie 2006). Among these studies, Peeters and de la Potterie (2006) has a particular importance in terms of its emphasis on the effect of innovation strategy. They stated that even if all traditional factors such as size, age, ownership type, market power and technological opportunities are the same for all firms, the innovation performance of the firms will differ on the basis of their strategic choices regarding innovation.

The structure of the remainder of the paper is as follows. The next section presents the data and methodology used for the empirical analysis. Possible effects of explanatory variables on the patenting behaviour of the industries are also discussed in this section. Section 3 reports the estimation results and Section 4 discusses the main findings and concludes the paper.

2. DATA AND METHODOLOGY

The empirical analysis is based on data drawn from three different sources regarding 2-digit industry level information on Turkish manufacturing industries from 2003 to 2008. These three sources of data are from the Turkish Statistical Institute (TurkStat), the Turkish Patent Institute and OECD Statistics. Data regarding the number of patent applications is obtained from the Turkish Patent Institute, data regarding R&D expenditure and R&D personnel are drawn from OECD Statistics and, finally, data regarding gross entry, exit and investment, exports, imports, number of firms, number of workers and total value of sales are obtained from the Turkish Statistical Institute. The combined data set is a panel of 6 years and a total of 37 industries.

The dependent variable used in this study is the number of patent applications in an industry within a year. As the dependent variable is a discrete count variable, the preferred estimation methodology should be able to accompany the non-linear nature of data. Therefore, count data models are employed. The estimation methodology employed in this study is panel Poisson model with fixed effects on industries.

The basic framework of count data models starts with Poisson distribution. The specification of such modelling is as follows[2]:

$$Prob(Y_i = y_i | x_i) = \frac{e^{-\lambda_i} {\lambda_i}^{y_i}}{y_i!} \quad (1)$$

where, $y_i = 0,1,2,...$

The most common formulation for λ_i is the log linear model:

$$ln\lambda_i = \boldsymbol{x}_i^{'}\beta \quad (2)$$

The expected number of events per period is given by:

$$E[y_i \mid x_i] = var[y_i \mid x_i] = \lambda_i = e^{x_i^{'}\beta} \quad (3)$$

Hence;

[2](Greene, 2002) (Wooldridge, 2002) (Cameron & Trivedi, 1998).

$$\frac{E[y_i \mid x_i]}{\partial x_i} = \lambda_i \beta \tag{4}$$

The Poisson model is simply a nonlinear regression; however it is easier to estimate the parameters of the model with maximum likelihood techniques. The log-likelihood function in such case is:

$$lnL = \sum_{i=1}^{n} [-\lambda_i + \boldsymbol{y_i x_i'} \beta - ln y_i!] \tag{5}$$

Poisson distribution assumes equidispersion, *i.e.* it assumes that the count dependent variable's mean is equal to its variance. However, overdispersion is a highly observed phenomenon in count data models. In this context, the Negative Binomial model is proposed to overcome overdispersion. The Negative Binomial model is also a non-linear model, which is a good fit for count data model estimations. Furthermore, the Negative Binomial estimator relaxes the equidispersion assumption and, hence, a better fit for the cases where the variance exceeds the mean (Cameron and Trivedi, 1998).

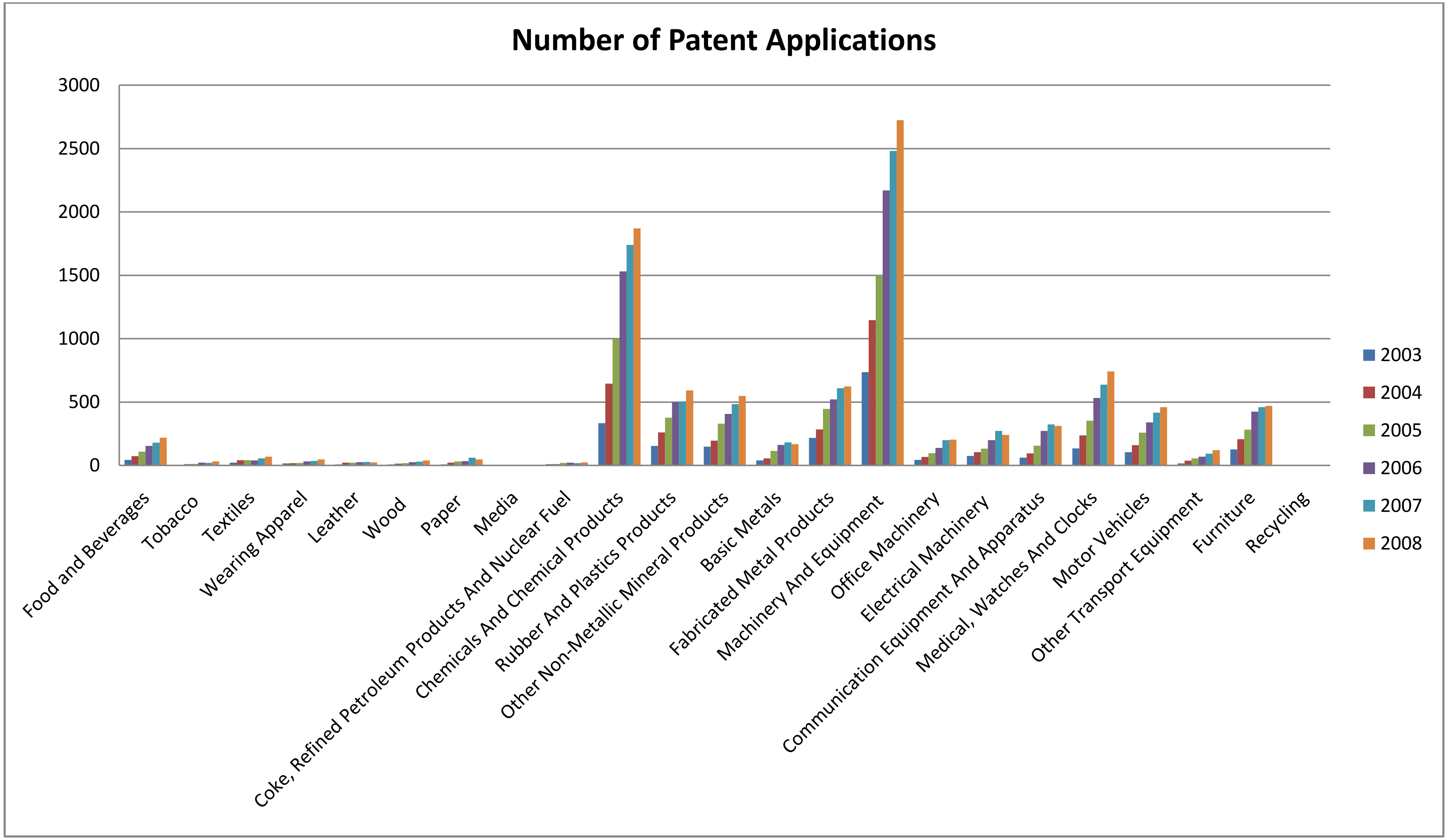
In count data models, the high number of zero counts is also widely observed. In such cases zero inflated Poisson and Negative Binomial models are used to take into account the high number of zeros that are observed in the dependent variable. Poisson and Negative Binomial models can also be applied to panel data. Hausman, Hall and Griliches (1984) were the first to use a panel count data model to estimate the relationship between patent applications of firms and R&D activities. They developed random and fixed effects Poisson regression models. The fixed effects Poisson regression specification is as follows:

$$ln\lambda_{it} = \boldsymbol{x_{it}'} \beta + \alpha_i \tag{6}$$

The fixed effects setting generates a particular advantage in terms of dealing with the unobserved heterogeneity, since error terms need not to be uncorrelated with the explanatory variables (Greene, 2002). However, the fixed effects setting has an important disadvantage. With the fixed effects methodology, the time invariant parameters of the specified models are bound to be wiped out. In equation (6), when fixed effects are preferred, α_i would be completely vanished. Such issue becomes a problem if the researcher is interested in the marginal effects, since marginal effects cannot be calculated without the constant terms (Wooldridge, 2002).

In this study, the existence and magnitude of overdispersion indicate Poisson model as the preferred specification. Moreover, the dependent variable, *i.e.* number of patent applications in an industry, does not have a high number of zero counts. In fact, among 138 observations only 12 of them are zero. Hence, it can be argued that there is no need to use a zero inflated estimation methodology. Finally, fixed effects are encountered specifically on industry groups in order to take into account the unobserved heterogeneity causing from industry specific characteristics. As stated by Blundell et al. (1995), the differences in the innovation performance of the firms cannot be solely attributed to observable differences but rather unobserved heterogeneity may cause these differences and, therefore, should be included in the empirical analysis of innovation.

Graph 1. The number of patent applications, 2003-2008



Graph 1 shows the number of patent applications in each industry for the time period considered in the analysis. As seen from the graph, there is an increasing trend in the number of patent applications for each industry, even for the low-tech sectors such as textile, from 2003 to 2008. The two industries that have the highest number patent applications are machinery and equipment and chemical and chemical products.

The variables used in the estimation, their definitions and the expected signs are given in Table 1.

Table 1. Variable Definitions and Expected Signs

Variable	Definition	Expected Sign
Patent (dependent variable)	The number of patent applications per year	-
R&D expenditure	Log of total R&D expenditures in an industry	Positive
R&D personnel	R&D personnel intensity: Ratio of R&D personnel to the total number of workers in an industry	Positive
Entry Rate	Ratio of the number of gross entry to the total number of firms in the industry	Positive
Exit Rate	Ratio of the number of gross exit to the total number of firms in the industry	Positive
Investment	Ratio of total gross investment to total value of sales	Positive
Export	Export Penetration: Ratio of value of exports in the total value of sales	Positive
Import	Import Penetration: Ratio of value of imports in the total value of sales	Ambiguous
Firm Size	Ratio of number of workers in an industry to the number of firms	Ambiguous

The expected signs of all variables are positive with two exceptions; import penetration and firm size. These two variables can take either positive or negative signs depending on the market structure. Import penetration is used as the ratio of imports to the total value of sales. This variable can increase in two different ways; first it increases if the value of imports in total sales increases. In such case, competition in the industry will increase and we would expect a positive effect on the number of patent applications per year. However, if the increase in the variable is resulting from the decrease of total value of sales while import is constant, we would expect a negative effect on the number of patent applications. Secondly, firm size can also take negative or positive signs depending on the market structure. The Schumpeterian hypothesis states that there is a positive relationship between firm size and innovation (Schumpeter, 1934; 1942). In this manner, there are some advantages of large firms for innovation. First, they take the advantage of economies of scale and scope. Second, they can benefit from having more departments through complementarities and spillovers between these departments. Third, their risky innovation projects generally find financing options in the capital markets (Cohen and Levin, 1989). Therefore, a positive relationship between firm size and the number of patent applications per year can be expected. However, such expectation would not imply that the number of patent applications is a perfect proxy for innovation, which is discussed in detail below. On the other hand, there have been many studies which test the Schumpeterian hypothesis and found results that both support and contradict the Schumpeterian hypothesis[3]. The studies that found empirical evidence contradicting the Schumpeterian hypothesis argue that smaller firms have more advantages for innovation as compared to large firms such as greater flexibility, less bureaucracy, better communication (Stock et al., 2002).

In addition to R&D expenditure, R&D personnel intensity is used in the analysis. This variable is one of the most important variables and it represents more qualified labour force. It is expected that more R&D personnel will lead to an increase in the number of patent application per year since it allows firms to create new technologies and it means that R&D departments play an important role in the firm structure.

Table 2 presents the descriptive statistics of the data.

Table 2. Descriptive statistics

Variable	Mean	Std. Dev.	Min	Max
Patent	270.9783	465.4461	0	2723
R&D expenditure	.0037426	.0071851	0	.0509623
R&D personnel	.6452021	1.077711	.0004424	4.462116
Entry Rate	.0816388	.2698431	.0024361	2.555556
Exit Rate	.0272923	.0726885	.0006534	.4545455
Investment	.0873295	.0720144	.0041991	.4609266
Export	.0002127	.0001395	.0000172	.0006714
Import	7.82e-07	1.96e-06	3.01e-08	.0000157
Firm size	128.2728	521.2939	.0036928	3022.667

3. RESULTS

Table 3 presents the results of the conditional fixed effects Poisson regression. All variables used in the estimation are statistically significant at 1% level and have the expected signs. As mentioned above, this study takes a traditional point of view to innovation. In this context, R&D

[3] See Kamien and Schwartz, 1975 and Becheikh et al. 2006 for two excellent surveys.

expenditures and number or intensity of R&D personnel are two important variables. As in line with previous studies, a positive relationship is observed between R&D expenditures, R&D personnel intensity and the number of patent applications in Turkish manufacturing industries.

Another important traditional determinant is firm size and, as mentioned above, empirical studies provide controversial results regarding the Schumpeterian hypothesis. In this manner, firm size is an important tool to validate or reject the Schumpeterian hypothesis. Studies supporting or contradicting the Schumpeterian hypothesis are both common. Therefore, we believe that firm size is an important variable in order to grasp the nature of Turkish manufacturing industries better. The positive sign of firm size indicates that Turkish manufacturing industry's structure is in line with the Schumpeterian hypothesis and as firms grow in terms of size, the overall number of patent applications in that industry increases.

The total value of investment is another traditional and straightforward variable that can be used in innovation studies. High levels of investment are expected to yield higher numbers of patent applications and the expectations are realized for Turkish manufacturing industries.

Table 3. Estimation Results of the Conditional Fixed Effects Poisson Regression Model

Dependent Variable: The number of patent applications per year	
R&D Expenditures	0.1216*** (.0254)
R&D Personnel	0.2434*** (.0287)
Entry Rate	1.5565*** (.5158)
Exit Rate	6.7802*** (1.2287)
Investment	2.5810*** (.236)
Export	3830.414*** (394.407)
Import	-10972*** (76055.65)
Firm Size	0.0009*** (0.0002)
Number of obs.	138
Number of groups	17
Prob>chi^2	0.0000

Notes: 1) *** 0.01>p, ** 0.05>p, * 0.1>p.
2) Numbers in parentheses are standard errors.

Entry and exit, on the other hand, are not commonly used variables in the studies investigating various aspects of patent applications. Although the aim of this study is to investigate the determinants of patenting activities in the traditional determinants context, it is believed that these two variables may provide useful information since they can be viewed as proxies for another traditional determinant, industrial concentration. Entry and exit rates have found to positively affect the number of patent applications in Turkish manufacturing industries. High entry exit rates indicate low degrees of concentration. In this respect, empirical studies on concentration suggest that concentration and patent applications are negatively related (e.g. Acs and Audretsch, 1987; Negassi and Shiri, 2012). In a similar vein, a positive relationship between entry exit rates and the number of patent applications support such findings. Furthermore, Acs and Audretsch (1987) suggest that entry barriers, concentration and firm size are vital in terms of investigation of the innovative activity.

Similarly, export and import opportunities are not among the commonly used variables especially in firm level studies. However, to be able to use export and import penetration in this study is among the rare advantages of using an industry level data set. Export opportunities in an industry mean larger market shares for firms operating in that industry. Firms with larger market share opportunities are expected to be more innovative. Montobbio and Sterzi (2013) suggest that export is an important tool in transferring technological knowledge between countries. Furthermore, Acs and Audretsch (1987) suggest that export rate is important in terms of signalling global activity. Therefore export rates can be seen as an important proxy for knowledge spillovers. Negassi and Shiri (2012) found positive effects from export to the number of patent applications. Landry et al. (2002) also found a positive relationship between exports and innovative activity.

Montobbio and Sterzi (2013) also suggest that import rates are important in terms of diffusion of technology and once again of knowledge spillovers. Following Coe et al. (1997), it can also be argued that a positive relationship between imports and innovative activity is expected especially for developing countries. However, Coe et al. (1997) emphasize that this can be the case if and when the developing country concentrates its imports on intermediate products and capital equipment which can influence knowledge spillovers. Therefore, the negative sign of import penetration in Turkish manufacturing industry possibly originates from the structure of Turkish manufacturing industries. Turkish manufacturing industries mainly consist of low-technology based firms and, hence, the chances of imports being technological or capital equipment are quite low. The negative sign of import penetration indicates that either; firms in Turkish manufacturing industries are not competitive enough or such negative relationship is caused from the decrease in total sales rather than the increase in imports as mentioned above.

4. CONCLUSION

The main purpose of this paper is to investigate the traditional patterns of innovation in Turkish manufacturing industry using 2-digit, industry level data. Industry level studies have some disadvantages over firm level studies. Mainly, industry level data is aggregated and, hence, less informative when compared to firm level data. However, aggregation of the data creates a specific advantage in our case. Since we are working at the industry level, it is possible to avoid the selection bias. An industry consists of both innovating and non-innovating firms. When firm level data is used with the number of patent applications, only innovating firms are considered and this may cause a selection bias. In this regard, although less detailed, industry level data yield unbiased results.

An important limitation regarding the measurement of innovation should be acknowledged at this point. The number of patent applications for a year is used as a proxy for innovation in this study. However, this choice is criticised as being related to inventive activity rather than innovation although it is among the traditional innovation indicators. In this regard, the patent application does not necessarily mean that this idea will be turned into a new product or process (Stock et al., 2002). Furthermore, some industries or firms may choose alternative methods rather than patents to protect their innovations and, in this case, using patent applications as a measurement of innovation may lead to underestimation of the innovation performance of the firms (Becheikh et al., 2006)[4]. Despite these limitations, patents are commonly used as a proxy for innovation in most innovation studies in the existing literature (see, for example, Griliches, 1990; Crepon et al., 1998; Peeters and de la Potterie 2006).

The findings of this study help to shed some light on the innovation structure of Turkish manufacturing industry. The estimation results indicate that traditional variables such as R&D expenditure, intensity of R&D personnel, firm size and total investment are important factors that shape the innovation patterns in Turkish manufacturing industry. In this context, the findings of this study regarding firm size support the Schumpeterian hypothesis since firm size is found to be positively associated with innovation. However, it should be noted that the relationship between firm size and innovation is sensitive for the innovation proxy chosen (Baldwin et al., 2002). On the other hand, market power[5] and technological opportunities (i.e., high technology or low technology based firms) are also among the traditional determinants of innovation but they cannot be controlled for in the analysis due to the data limitations. However, entry and exit rates used in the analysis may serve as a measure for industrial concentration and market power.

[4] Other proxy measures for innovation have also both advantages and disadvantages. For details, see Kleinknecht et al., 2002.

[5] This variable is one of two fundamental factors that Schumpeter (1942) emphasises. The hypothesis states that firms having more market power are more innovative than firms having less market power. It should also be mentioned that the way of the relationship can also be from innovation to market power as successful innovations may result in an increase in a firm's market power (Blundell et al., 1995).

In this regard, in addition to the traditional variables, the effects of the unconventional variables such as entry, exit, export and import are proven to be valuable assets in this study. Increasing entry and exit rates have positive effects on the number of patent applications. Such relationship indicates that competition within the industry motivates firms to patent. However, the negative relationship between imports and the number of patent applications indicates that international competition is not a motivation for innovation for Turkish manufacturing sector. In light of these results, it can be stated that competition within the country and industry is necessary for innovation while international competition has a negative impact for the current increasing innovative trend. Such findings, brings up the debates regarding constraints over importation. However, this issue needs to be further investigated to be able to state a solid policy implication.

Blundell et al. (1995) suggest that the innovation process is dynamic and non-linear in nature. As in many areas of economics, time is an important factor when it comes to innovation. R&D activities and hence innovation can be thought as cumulative processes. Weerawardena and Mavondo (2011) also suggest that in order to capture “market dynamism”, the innovation research has to transform to a dynamic structure form a static one. Therefore a nonlinear and dynamic analysis seems to be an intriguing subject to investigate while trying to understand the nature of innovation. Therefore a dynamic analysis of the number of patent applications is considered as a further study issue.

This study has explored the factors affecting the patenting activities of Turkish manufacturing industry over the period 2003-2008 using conditional fixed effects Poisson model. The most commonly used variables in the existing literature such as firm size, R&D expenditure and total investment are all found to be the important determinants of innovation. Moreover, entry rate, exit rate and export penetration are found to have positive impacts on the number of patent applications per year whereas import has a negative impact. This finding highlights that competition within the country and industry is especially important for firms’ innovation performance. Although this study differs from most of other studies by focusing on a developing economy and by using panel count data models, it does not take into account the dynamic nature of innovation. As stated by Blundell et al. (1995), and mentioned above technological development is a dynamic, interactive and nonlinear process and this dynamic feature of innovation should be accounted for in the analysis in order to obtain unbiased estimation results. In this context, a dynamic analysis of innovation in Turkish manufacturing industry can be considered as a future study issue.

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