RESEARCH, INNOVATION AND LABOUR PRODUCTIVITY IN TURKEY

by

Sadettin Bacanlı

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APPROVED BY:

Esra Durceylan Kaygusuz ....

(Thesis Supervisor)

İzak Atiyas ....

Şerif Aziz Şimşir ....

DATE OF APPROVAL: ....

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Sadettin Bacanlı

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Abstract

In this thesis, I analyze the effect of innovation on labour productivity in Turkish manufacturing sector across three periods, 2002-2004, 2004-2006 and, 2006-2008, using a general framework that accounts for research activities and for process and product innovation. I apply a structural model that analyze the link between R&D expenditure, innovation output and productivity. This structural model was used first proposed by Crepon, Duguet, Mairesse(1998) and become the main model of analyzing the relationship between R&D, innovation and productivity. I use the Community Innovation Surveys(CIS) conducted in Turkey by Turkstat. I separately analyze each wave of CIS(CIS4, CIS2006, CIS2008) for Turkish manufacturing firms. My econometric results are consistent across these periods with regards to Turkish manufacturing firms; however, I find interesting differences across the waves of periods. R&D intensity effects innovation in CIS4 and CIS2008 but not in CIS2006. The effects of process innovation and product innovation on productivity is not consistent over the years.

TÜRKİYE'DE ARAŞTIRMA, YENİLİK ve İŞGÜCÜ ÜRETKENLİĞİ

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Özet

Bu tezde yeniliğin işgücü üretkenliğine etkisini 3 periyod için ayrı ayrı analizini süreç yeniliğini ve ürün yeniliğini hesaba katan genel bir çerçeve içerisinde incelemeye çalıştım. ARGE, yenilik ve işgücü üretkenliğini analiz eden bir model kullandım. Bu model ilk olarak Crepon, Duguet, Mairesse(1998)'nin çalışmasında kullanıldıktan sonra ARGE ve üretkenlik üzerine yazılan birçok makalede esas model olarak kullanılmıştır. Kullanmış olduğum data setini Türkiye için hazırlanan "Community Innovation Survey(CIS)"den aldım. Periyodlar arasında ki farkları analiz edebilmek için 3 farklı CIS datası kullandım. Bunlar CIS4, CIS2006 ve CIS2008'dir. Sonuçlarım genel olarak yıllar arasında benzerlik gösterse de bazı ilginç farklılıklar da göze çarpmaktadır. ARGE yoğunluğu üretkenliği CIS4 ve CIS2008'de olumlu olarak etkilesede CIS2006'da bu etki görünmemektedir. Ürün yeniliği ve süreç yeniliğinin üretkenliğe etkisi yılla arasında sürekli bir benzerlik göstermemektedir.

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1 Introduction

The effects of research and development on a firm's productivity and output are well known, as they have been documented in the seminal paper by Pakes and Griliches(1980). This study shows that R&D spending accumulates as the knowledge a firm's capital enters into the production function. This quantifies the marginal effect of R&D on the production function. However, there were obvious concerns about the selection and simultaneity problems. The relationship between R&D, innovation and productivity also create selectivity(i.e. non-random sample bias) and simultaneity problems as well. The selection problem arises from the fact that R&D performing firms are self-selected firms. Relatively few firms perform R&D, thus analysis is limited to only R&D performing firms and may be biased. The simultaneity problem arises from the fact that R&D investments are affected by past productivity. Because of this relationship both variables tend to move together.

First, the lack of a detailed data set was one of the main reasons that these issues have not been addressed. The introduction of community innovation surveys (hereafter referred to as CIS) opened new opportunities for new research efforts to understand the effect of R&D on productivity better. The waves of CIS are based on Oslo Manual which developed a framework for innovation survey. All countries conducting CIS use this framework. This allows researchers to do country comparisons. Second, the structural model developed by Crepon, Duguet and Mairesse(1998)(CDM from now on) solved the problems mentioned above. Also, the availability of micro-level data allowed researchers to apply the CDM Model to many questions and data sets in different countries.

The general aim of this study is to analyze the current relationship between R&D, innovation and productivity at the firm level in Turkey by using CIS data within a framework that accounts for research activities for both product and process innovation. Process innovation is when a firm has having introduced new or significantly improved production process similarly, product innovation is when a firm has introduced new or significantly improved products. Firms are asked whether they innovated or not. CIS's also allow researchers to get information about the firm's size, sources of funding, doing/reporting R&D expenditure, amount of investment intensity and sources of information.

I use the three waves of CIS that is CIS4 which covers the years 2002-2004, CIS2006 which covers the years 2004-2006 and CIS2008 which covers the 2006-2008. Using these waves of the survey, I conduct an inter-temporal comparison on the Turkish manufacturing industry. I rely on a structural model using cross-sectional data, which is similar to papers that analyze the relationship between R&D, innovation and productivity for different countries. My model is based on CDM Model but a modified version by Griffith et.al.(2006). The study estimated CDM Model for all firms, not only doing/reporting R&D firms. Because this study believes that all firms do R&D not just reporting R&D firms.

In summary, I first show that if a firm is involved in international competition, its probability of doing R&D increases if a firm receives support from national funding, its R&D intensity increases controlling size across all analyzed years. Second, by controlling size, sources of funding and selection problems, R&D intensity increases the the probability of product and process innovation. The results are significant for years 2002-2004 and 2006-2008 but they are insignificant for the 2004-2006 wave in the Turkish manufacturing sector. Finally, process innovation effects significantly labour productivity only in 2006-2008 but is insignificant for the rest of waves. In addition, product innovation only significantly effects labour productivity in 2004-2006 at 10 percent level of significant.

This paper is organized as follows: section 2 presents the literature review, section 3 explains the theoretical model and section 4 describes the data and choice of variables used in the various equations of the model. Section 4 reports the results and their explanations and lastly I conclude in a final section.

2 Literature Review

Understanding the determinants of economic growth is at the heart of economic research. One major component of economic growth is the growth of firm level productivity. To understand this, we refer back to Griliches' paper(1979) in which he analyzed productivity function based on Total Factor Productivity (TFP) as a function of past R&D expenditures. This is the theoretical paper upon which all economic growth is analyzed.

Further, Griliches(1986) has analyzed approximately the largest 1000 American manufacturing firms during 1957-1977 in terms of R&D, sales and employment. He found that R&D expenditure significantly effects Total Factor Productivity.

Researchers have used the Griliches knowledge of the capital model as a benchmark in where innovation inputs are used as an explanatory variable in the production function estimation. In their survey paper, Mairesse and Sassenou (1991) document different types of estimation techniques links, R&D efforts and productivity and their model specification. In a similar study, Hall and Mairesse (1995) analyze relation between R&D and productivity in the French manufacturing sector. They found that having a longer history of R&D had improved productivity within French manufacturing firms. From this, Lotti and Santarelli (2001) tried to explain the relation among R&D expenditure, investment in new machinery and productivity within the German and Italian manufacturing sectors. They found that R&D expenditure and investment in new machinery positively effect productivity.

The relationship between R&D, innovation and productivity also create the selectivity(i.e. non-random sample bias) and simultaneity problems as well. Selection problem arises from the fact that R&D performing firms are self-selected firms. Only relatively few firms perform R&D, thus analysis is limited to only R&D performing firms that may be biased. Simultaneity problem arise from fact that R&D investments are affected by past productivity so both variables tend to move together.

In order to fix the selectivity and simultaneity problems Crepon, Duguet, Mairesse (1998) offer a system(CDM Model) that includes 4 equations based on Pakes-Griliches's findings (1980). Pakes and Griliches estimate 3 different equations with three sequential steps. Crepon, Duguet, Mairesse added "selection equation" to the model of Pakes-Griliches. They estimate 4 equations in 3 steps: (i) The firm decide whether to perform R&D or not and decide intensity of investment, (ii) Use R&D expenditure as an explanatory variable to estimate probability of innovation and (iii) They analyze relationship between innovation output and productivity. They contribute to the literature as they are the first introduce innovation output as the reason for productivity growth. They disregard the innovation input. Second, Pakes-Griliches's contribution was makes use of new the information provided by Community Innovation Survey(CIS), such as whether the firm's innovation effort is influenced by consumer demand or technological change. Finally, their method can deal with the simultaneity and selectivity problems. Since then, researchers have used the three-stage estimation procedure to take advantage of the CDM Model. Many of these studies have made cross-sectional analysis, while some of them have made panel data analysis.

Due to the increasing availability of innovation survey data at the micro level, there is a growing literature that uses the CDM Model to analyze the relationship between innovation and productivity. Van Leeuwen and Klomp (2001) bring together all demand-shifting factors, and they define productivity as the ratio of revenue(sales) to the number of employees rather than the ratio of value-added to number of employee. They apply the CDM model to 3000 Dutch firms drawn from CIS2. They found that revenue per employee as the productivity measure yields more significant and robust results than value-added per employee. From this, Lööf and Heshmati (2002) have applied the CDM Model to the Swedish manufacturing and service sector firms in the 1990s by using the Swedish business register data and CIS. They were able to estimate sensitivity by using two different data sets and several variables.

They found that the probability of innovation increases with firm size and capital intensity for both manufacturing and service firms. I addition, Benavente (2002) has tried to estimate the relation between R&D, innovation and productivity in Chile. He uses an asymptotic least square estimation method that corrects simultaneity and selectivity bias account for characteristics of available data. His results are different from other countries. He found that the effect innovative effort and the ratio of research expenditure to productivity is insignificant. This contradicting result suggest that innovation characteristics are different between developing and developed countries. Mairesse and Robin (2009) investigated the effect of R&D expenditure on product and process innovation and the effect of different types of innovation on productivity in France between 1998-2004. Their data came from French CIS3 and CIS4. Authors construct a system of 5 different equations. The first equation is selectivity equation to not fall into selection bias problem. Second equation estimate R&D intensity for firms that doing/reporting R&D. The latter two equations investigate the relation between R&D and process/product innovation. Lastly, they estimated labour productivity by estimating five equations simultaneously rather than sequentially to deal with the endogeneity problem. Their results are that product innovation is the main factor of labour productivity and that the estimation result of product innovation is robust. Masso and Vahter(2008) investigated whether there is significant relation between R&D, innovation and productivity in manufacturing sector of Estonia by using CIS3 and CIS4 which is then combined with the Estonian Business Register data. Their contribution to literature is that their paper is the first study using CDM Model to estimate link between R&D, innovation and labour productivity in Estonia. They found that if they use CIS4, only process innovation effect to productivity significantly. However, when they use CIS3, impact of process innovation to productivity is insignificant but product innovation significantly effect.

Although many studies analyze the relationship between R&D expenditure, innovation and productivity at the national firm level, the comparison of results between different countries is not common. Mairesse and Mohnen (2003) estimated the link between R&D, innovation and productivity using the micro-level data of CIS2, covering the years 1994-1996, across France, Germany, Spain and the United Kingdom. They examine manufacturing firms data for each country. Although Germany is more innovative than the average of Europe, their productivity is less than average. On the contrary, although Spanish firms less innovative than average of European firms, their productivity is above the average. As a result, Mairesse and Mohnen claim that productivity and innovativeness do not go to the same direction. Griffith, Huergo, Mairesse, Peters(2006) analyze the relation between R&D, innovation and productivity across 4 European countries, France, Germany, Spain and UK. They exploit CIS3, which is conducted in 2001, and provide information between 1998-2000 to analyze this relation. Their results are very similar across the countries although there are some differences. For instance, innovation effort does not affect productivity similarly across the country. Eventhough product innovation is significant at 1% level France, Spain and UK, the effort of product innovation does not affect productivity significantly in Germany. Further, process innovation is significant only in France.

As I mentioned previously, estimation of CDM Model with panel data is rare within the literature. Some of them is the followings: Jefferson, Huamao, Xiaojing, Xiaoyun(2002) used three-stage estimation model to estimate the relation R&D, innovation, productivity in China between 1995-1999. Authors have taken advantageous of the large Chinese panel of innovation within survey data. Jefferson, Huamao, Xiaojing, Xiaoyun add the new profitability equation to the original CDM model. They could not find any relation between R&D intensity and firm size unlike the other papers that used the CDM Model. One explanation for this is that they included lagged R&D intensity which reduces the explanatory power of other variables. Parisi, Schiantarelli, Sembenelli (2002) exploited the rich Italian innovation data set which was surveyed in 1995 and 1997. Each data set includes 5000 manufacturing firms in Italy. Parisi, Schiantarelli, Sembenelli use the three-stage estimation model by combining two data sets to make panel data estimation. Their results are very interesting. They claim that if a firm makes only process innovation, its productivity will increase more than in the case of making just product innovation. This implies that if a firm make R&D expenditure, its productivity growth increase by simplifying the absorption new technology. Chudnovsky, Lopez, Pupato(2006) used Argentine manufacturing firms data during a 10-year period, 1992-2001. They found that the bigger the firm is in terms of number of employees, the more innovative it is. However, foreign ownership does not effect innovation activities. Also, their results indicate that if R&D expenditure increases, probability of product and process innovation is increasing. Heshmati and Kim (2011) investigated the relation between R&D investment and productivity using Korea's firm level panel data between 1986-2002. Their estimation techniques are only slightly different than the original CDM Model. The selection equation and R&D intensity equation estimated using the Heckman procedure. However, they also analyze the effect of R&D growth on productivity growth and the productivity growth effect on R&D growth with a system of equation estimated simultaneously by using 3SLS method. Heshmati and Kim found a positive feedback effect from the productivity growth to R&D growth. After the Asian financial crises in 1997 R&D expenditure decreased dramatically. This led to decreasing productivity growth Korea. Huergo and Moreno(2006) studied the 1072 Spanish manufacturing firms between 1990-2005 to analyze the link between R&D expenditure, innovation and productivity by taking into account persistence of a firm's behavior. They adapted the CDM Model to analyze the link for a panel of 1072 Spanish manufacturing firms. Their results show that if a firm wants to increase its productivity, it should increase process innovation rather than product innovation. Also, authors remark that size of a firm is an advantage to be more innovative but not to be more productive. In other words, larger firms in terms of number of employees have many difficulties improving their productivity. Goya, Vaya, Surinach(2013) analyze the impact of innovation expenditures and externalities on the productivity of 9042 Spanish firms for the period of 2004-2010 by using the CDM Model. Their aim is that control for unobserved firm heterogeneity and control time lag between firm R&D expenditure decision and productivity. They found that external knowledge would encourage the firm to conduct R&D activities. In other words, if the higher number of firms carry out R&D activities in the same sector, the probability of a firm engaging in R&D activities in this sector increases.

To the best of my knowledge, this paper is the first to analyze the link between R&D expenditure, innovation and productivity in the Turkish manufacturing firms. Some of the Turkish studies that are similar to my research are as follows. In 2007 Ozcelik and Taymaz tried to understand the effect of public R&D support on industrial R&D expenditures by using the data of 10565 Turkish manufacturing firms. They found that first of all, public R&D support did not crowd out private R&D support in the Turkish manufacturing sector. Secondly, they found that firm size has a great impact on R&D expenditure. Lastly, they found that technology transferred from abroad has a positive effect on R&D expenditure. They conclude that a R&D grant or loan could be more effective than an R&D tax in Turkey to incentivite firms to do R&D. Dayar and Pamukcu(2011) analyzed the relation between R&D expenditures and productivity for 5393 Turkish manufacturing firms between 2003-2007 by using Structural Business Statistics and R&D survey both collected by Turkstat. They run cross-sectional probit estimation for each year from 2003-2007. In their analysis, they separated their data as high, medium and low technology firms according to the NACE codes. They found that high and medium technology firms have a better chance than lower technology firms in terms of engage in R&D and observing the effects on productivity. Further, physical capital stock has had significantly positive effect on productivity. Another main result is that foreign ownership firms' R&D efforts have bigger effects than local ownership firms' R&D efforts on labor productivity.

3 Model

In this section, I model the innovation process. I assume that variables that constitute firm characteristics, market structure and technological condition shape R&D expenditure, product or process innovation and labour productivity.

Griliches(1979) is the seminal paper that explains the link between R&D and productivity to explain that link. Griliches model can be described as the following:

Let $Y = F(X, H, u)$ be the Cobb-Douglas production function connecting output Y to the inputs X, stands for index of conventional inputs such as labor and capital, H,a measure of technical knowledge and u, other unmeasured determinants of output and productivity. Let us assume that there exist a relationship between technical knowledge and $R\&D_{t-i}$, index of current and past R&D levels. Thus,

$$H = G(R\&D_{t-i}, v) \tag{1}$$

where v is another measurement error and

$$R\&D_{t-i} = (R\&D_t, R\&D_{t-1}, R\&D_{t-2}, ...) \tag{2}$$

However, when we estimate link between R&D expenditure and productivity, two problem would arise, selection bias and simultaneity. First, since only R&D performing/reporting firms are observed, they are self-selected. Second, lagged productivity affects the amount of R&D. At the same time, lagged R&D expenditure affects productivity. Thus, simultaneity problem arise. Crepon, Duguet and Mairesse (1998) developed an empirical model(CDM hereafter) to correct for selectivity bias and simultaneity bias. So they presented a new equation system that combines innovation selection function, knowledge function and productivity function. Theoretical framework contains two parts. In the first part, R&D intensity is explained Tobit Model and in the second part I explain the link between R&D expenditure, innovation and productivity. The structural model has the following timing of events: First, firms decide the amount of effort to put in innovation; Then knowledge is produced as a result of this effort; Finally, produced knowledge is internilized as a change in productivity. The CDM Model is visualized in figure 1:

3.1 First Stage: The Research Equations

The first two equations of the model are concerned with firms' research activities. I follow the generalized Tobit model (Heckman 1976, 1979) to estimate the decision to do R&D and the amount invested in R&D expenditure. However, we don't observe R&D expenditure if the firm doesn't choose to perform R&D. So the first equation is the selection equation that

Figure 1 CDM Model

Decision to Innovate

↓

Innovation Intensity

↓

Innovative Output

↓

Firm Performance

indicates whether the firm is doing R&D or not.Different studies have chosen different types of CDM Model and explanatory variable. Griffith, Huergo, Mairesse (2006) estimated CDM Model for all firms not only doing or reporting R&D. Because they believe that all firms make R&D not just reporting R&D. For instance, maybe R&D department of the firm make some R&D but amount of R&D can be below a reporting threshold so the firm wouldn't report that action. Here I mostly follow Griffith et al.(2006).

More precisely, rd_i^* is the latent variable for firm i given by the following equation:

$$rd_i = \begin{Bmatrix} 1 \text{ if } rd_i^* = \ C \ + \ \beta_i X_{1i} \ + u_i > 0 \\ 0 \text{ if } rd_i^* = \ C \ + \ \beta_i X_i \ + u_i \leq 0 \end{Bmatrix} \tag{3}$$

where $i = 1, ..., N$ is index for firms and rd_i is the observed binary variable equals to 1 for firms performing R&D and 0 otherwise. rd_i^* represent decision criteria like the expected utility associated with R&D expenditure. Firms decide to do in R&D if rd_i^* is bigger than the threshold level 0 in the equation (3) X is the variable that explains the R&D decisions, β is a vector of parameters and u is an error term. This equation is a probit model to find out firms' decision which is about whether a firm make investment to innovation.

The second equation of the model estimates intensity of R&D conditional on firm i doing or reporting R&D:

$$ird_i = \begin{Bmatrix} ird_i^* = \ C \ + \ \gamma_i X_{2i} \ + \varepsilon_i \text{ if } rd_i = 1 \\ 0 \qquad\qquad\qquad\qquad\qquad \text{ if } rd_i = 0 \end{Bmatrix} \tag{4}$$

ird_i is defined as R&D expenses / number of employee of firm i, we can measure firm's innovative effort ird_i^* which is unobserved latent variable accounting for firm's innovative effort. ε_i is random error terms with mean zero and variance is constant. γ_i is a vector of parameters. Note that the error terms u_i and ε_i are assumed to have joint normal distribution, with zero mean:

$$\begin{pmatrix} u_i \\ \varepsilon_i \end{pmatrix} \underrightarrow{iid} \quad N\left(\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} \sigma_0^2 & \rho\sigma_0\sigma_1 \\ \rho\sigma_0\sigma_1 & \sigma_1^2 \end{pmatrix}\right) \tag{5}$$

where σ_0 and σ_1 are standard errors of u_i and ε_i respectively and ρ is their correlation coefficient. Standard estimation σ_0 is normalized to 1 for estimate the model.

Equation (3) and (4) are jointly estimated by Generalized Tobit Model by maximum likelihood which is called Heckman correction model[1]. The main advantages of Heckman correction model is that R&D intensity is not estimated for only firms doing/reporting R&D expenditures but for all firms. By using this method I can correct for selection biases.

3.2 Second Stage: The innovation Equation

The second stage links R&D activities(innovation input) and innovation(knowledge) output. The following equation is knowledge or innovation equation:

$$innov_i = C + \delta_i X_i + \alpha_i ird^* + \omega_i \tag{6}$$

In the equation (6) $innov_i$ is product or process innovation output indicators. $innov_i$ takes the value 1 if a firm introduces a process(or product) innovation over three years. Process or product equations are estimated with Probit Model. ird^*-predicted from equation (3) equation (4)- enters into equation (6) as an explanatory variable, X_i is a vector of firms' characteristics, δ_i and α_i vector of parameters and ω_i is an error term. I estimate knowledge equation as separate two probit equation one for process innovation and one for product innovation. In equation (6) R&D intensity (ird_i) is the predicted value of R&D intensity so I can estimate knowledge equations for all firms not only for R&D reporting firms. By

[1]Heckman was Nobel Prize awarded for developing tools for handling sample selection. Sample selection bias occurs when the availability of data are influenced by a selection process related to the value of dependent variable. For example, suppose you want to estimate relation between earnings and some regressor using a random sample from the population. If you estimate the regression using subsample of employed workers, the OLS estimate could be subject to selection bias. Heckman's solution was to specify a preliminary equation with a binary dependent variable indicating whether the worker is in or out of the labor force and to treat this equation and the earnings equation as a system of simultaneous equations.(Source:Stock and Watson Introduction to Econometrics, second edition (2007))

taking predicted value of R&D intensity I can measure some unobservable characteristics of firms which can increase its innovativeness Crepon, Duguet, Mairesse(1998) used number of patents as the knowledge output variable. Later, researchers used process and product innovation as knowledge output as well. The reason why I haven't used patents equation is that patents reflects only small measure of firm innovation activities.

3.3 Third Stage: The Productivity Equation

Last equation in the model is the productivity equation which is assumed Coub-Douglas technology. Knowledge outputs are also included in addition to labor and capital. Crepon et. al. (1998) assert that knowledge output(technical innovation) has more effect on productivity rather than knowledge input(R&D expenditure).

$$lp_i = \lambda_i k_i + \pi_i innov_i^* + \psi_i \tag{7}$$

where lp_i is productivity defined as the log of output(sales) per worker, k_i is the physical investment per worker, $innov_i$ is knowledge proxied by equation (6). To take care of endogeneity of $innov_i$ I used predicted value from the equations of process and product, and ψ_i is the error term. The fourth equation is a Cobb-Douglas production function where the inputs are labour, capital, knowledge.

After all, my model consists of 4 equation, I estimated in three steps. In the first step I estimated Generalized Tobit model (equation (3) and (4)) by using Heckman correction. Second, I estimated process and product innovations as two probit equations using predicted value of innovative effort (equation (6)). Finally, I estimated productivity by using predicted value of innovation from second step. To correct selection bias problem I simultaneously estimate equation (3) and (4) by using Heckman Method. In order to correct for simultaneity problem equation (6) and (7) are estimated by a simultaneous system(2SLS).

I estimated the equations of the CDM Model sequentially rather than simultaneously. Advantageous of estimating sequentially is robustness although result of sequential estimation is less efficient than simultaneous estimation. The reason is that simultaneous estimation needs stronger exogeneity assumptions. It means that the regressors need to be uncorrelated with error terms in all equations.

4 Data and Variables

4.1 Data

The OECD, Eurostat, Turkstat and other national and international organizations have developed a standard framework to collect comparable information from all participating countries.The Community Innovation (CIS) is designed for that purpose. The CIS is based on Oslo Manual which set framework for the innovation survey. The manual proposes guidelines for the collection and interpretation of technological innovation data**.** The Oslo Manual is mostly concentrated new or significantly improved products and processes. OECD/Eurostat, Oslo Manual, Proposed Guidelines for Collecting and Interpreting Technological Innovation Data, 1997 Last edition of Oslo Manual is released in 2005. The CIS is carried out by the methods of face to face, web-based survey and via E-mail with two years' frequency.

I used firm-level data from CIS4, CIS2006 and CIS2008 of the Turkish component of the CIS.CIS4 provides information for period 2002-2004, CIS2006 for 2004-2006 and CIS 2008 for 2006-2008. All waves of the survey provide information about R&D expenditure, innovation activities (product and process information), funding, sources of information, size employment level**.** Number of firms which is asked questions in all years is just 117. This is not enough to make panel data estimation**.** This is one reason why I do cross-section estimation. I will analyze relationship between R&D activities, innovation, and productivity in Turkish manufacturing industry from years 2002-2004 to years 2006-2008.

Initially, I have 2852 firms in CIS4, 2170 firms in the CIS2006 and 5863 firms data in the CIS2008**.** In this paper I estimate the structural model for only manufacturing firms with 2-digit NACE (Nomenclature des Activités Économiques dans la Communauté Européenne) codes between 15 and 37 [2] [3]. Using manufacturing firms in this study allows me to link in innovation, R&D and productivity[4]. This restriction put down the sample size for all years. Number of firms decreases to 1828, 892, 3126 respectively. Detailed information about the distribution of firms over industries is given in Table 1. After eliminating missing data, I have 1011 data of firms in CIS4, 376 data of firms in CIS2006 and1319 data of firms in CIS2008. CIS2006 is not propertied in terms of data. When I compared CIS2006 and other waves , number of firms is dramatically decreased in CIS2006. As you'll see results part this can be the one reason of insignificant results.

[2]NACE is the classification system in Europe for classifying business activities.

[3]NACE rev 1.1 was used in CIS4, CIS2006, CIS2008.

[4]Defining productivity for service sector is problematic. Furthermore, the paper by Griffith et. al. (2006) used only manufacturing firms. This allows me to compare their results with the results in this paper.

		CIS4	CIS2006	CIS2008
Industry	NACE	Number of Firms		
Food,Beverages	15-16	84	51	101
Textile	17-19	109	88	185
Wood,Paper	20-22	75	20	136
Chemicals	23-24	82	25	117
Plastic,Rubber	25	55	18	144
Non-metallic	26	65	21	100
BasicMetals	27-28	125	45	159
Machinery	29	161	38	130
Electrical	30-33	130	21	76
Vehicles	34-35	78	29	100
Misc.	36-37	47	20	71

Table 1: Distribution of firms over industries

4.2 Choice of explanatory variables

First equation in the CDM Model is ”selection equation”. First equation includes proxy variables for explaining take advantage from innovation (Appropriability Conditions), for market conditions and for Schumpeterian determinants. Appropriability Conditions are shown by two dummy variable in Crepon et al.(1998) and Griffith et al.(2006). First one stand for protection of innovation is formal protection. Formal protection equals to one if firms used patents, copyrights etc. to zero otherwise. The second variable is strategic protection equals to one if firms confide in secrecy or lead-time advantage and zero otherwise. However, only CIS2006 includes formal protection in Turkstat's database. CIS4 and CIS2008 doesn't include data of formal protection in Turkish CIS . Also data of strategic protection doesn't occur in any of CIS data set in Turkstat. I couldn't analyze how appropriability conditions effect selection equations because Turkstat didn't collect data of Appropriability Conditions in CIS4, CIS2006 and CIS2008. International competition represent market conditions in selection equations. This equals to one if enterprise's most significant market is international. For the selection model I used some unobservable for non-R&D doing/reporting firms but significant to characterize the R&D process. These are public support such as local funding, national funding, European Union (EU). Local funding stands for funding from local or regional funding for innovative projects, National funding characterize funding from national government, EU funding indicates funding from the EU. Schumpeterian determinant of innovation in selection model is size of the firms. Size is measured by number of employees. According to the number of employees in 2004, 2006, 2008 set size dummy is categorized in 5 dummies which are 20-49, 50-99, 100-249, 250-999 and >1000 employees. The second equation of CDM Model is R&D intensity equation. R&D intensity is dependent variable in Equation 2. Dependent variable measured R&D expenditure per employee in logs. Not to fall identification parameter problem, I exclude size of firms in equation 2. Explanatory variables in R&D intensity equation includes same variables as selection equation. It includes cooperation in innovative activities which is only reported by doing/reported R&D expenditure. Cooperation is a dummy variable which takes the value 1 if the firms has some cooperative arrangements on innovation activities and zero otherwise.

As mentioned before, I analyze innovation in two separate parts product and process innovations. This is the most important contribution of the paper to Turkish literature. Each innovation represented by a dummy variable. If a firm introduced product or process innovation, related variable take value one and zero otherwise. In the product innovation equation includes 2 exogenous variables and one endogenous variable. Endogenous variable is predicted value of log of R&D intensity. Predicted value of log of R&D intensity appears here as a explanatory variable. If size of firms increase, I expect probability of achievement in innovation increase as well. So size in product innovation equation as explanatory variable. Also, I expect firms to be more innovative, if they use customers or competitors as a sources of information[5](Esther Goya et al.(2013)). Process innovation equation includes investment per employee in tangible goods as an explanatory variable. The reason for including this variable is that process innovation is about in the product line which consequence of adoption of new machinery and/or equipment (Jacques Mairesse, Stephane Robin(2009)). If firms use their competitors and suppliers as a sources of information, their probability of success increase. In the equation of innovation process, size, investment, competitors and suppliers as sources of information stand for explanatory variable. Also similar to product innovation equation predict log R&D intensity from equation 2 and size appear as an explanatory variable in process innovation equation.

The last equation of CDM Model is "labor productivity equation". Dependent variable is labour productivity which is measured sales per employee. Productivity equation includes two endogenous variables two exogenous variables. Exogenous variables are size and investment intensity. They are measured the same way with the previous equations. Two endogenous variables which are predict value of product and process innovation equation

[5]According to the literature, I select this variable as an exclusion restriction to provide more robust estimations.

stands for as an explanatory variables.

4.3 Descriptive Statistics

In this section, I present the results of the estimation of the model which is presented section 2. As equations (3), (4), (6), (7) indicate, I estimate those equations recursively. Before move on to the estimation results, I want to give descriptive statistics for the variables in the across the years. I restrict my analysis to firms with at least 20 employees. Table 2 shows the results:

	CIS4	CIS2006	CIS2008
R&D intensity(for firms doing R&D)	6.864	7.02	7.04
Process innovation	0.724	0.742	0.697
Product innovation	0.704	0.763	0.749
Productivity	11.492	11.672	11.777
Investment intensity	2526.639	4072.749	17978.34
Local funding	0.049	0.106	0.012
National funding	0.348	0.265	0.288
EU funding	0.011	0.0265	0.018
Internal Sources within the group	0.644	0.779	0.802
Universities as source of information	0.416	0.385	0.374
Government as source of information	0.360	0.327	0.308
Suppliers as source of information	0.749	0.773	0.808
Competitors as source of information	0.636	0.696	0.648
Cooperation	0.340	0.257	0.219
International competition	0.677	0.609	0.658
Size:20-49	0.386	0.468	0.338
Size:50-99	0.157	0.079	0.125
Size:100-249	0.147	0.077	0.206
Size:250-999	0.237	0.119	0.252
Size:>1000	0.071	0.255	0.076
Observations	1011	376	1319

Table 2: Means of variable

First, it can be seen that the proportion of firms that reporting/doing R&D increasing year by year i.e. firms do so more intensively R&D throughout the years. Although R&D intensity increases throughout the years, innovation outcome peaks in wave 2004-2006, but then declines for wave CIS2008. This shows clearly the uncertanity associated with R&D activity. Roughly I can say that R&D expenses don't imply innovation activity on the other hand, average labor productivity in manufacturing firms is increasing over the years. Investment in tangible goods per employee dramatically increases as well. Last notable statistics is the following: firms are in cahoots with other firms decreasing throughout the years. Firms prefer doing less cooperative arrangements on innovation activities with other firms in 2002-2008.

	CIS4	CIS2006	CIS2008
National Funding	34.8%	28.9%	26.5%
Local Funding	0.49%	1.28%	1.06%
EU Funding	1.18%	1.81%	2.65%
Non	63.53%	68%	69.7%

Table 3: Distribution of Funding Resources by surveys

Table 3 gives information about distribution of funding resources. 34.8 percent of all manufacturing firms was taken funding from national resources. It decreases year by year and reach 26.5% at the last CIS survey CIS2008. However, distribution of funding from European Union increases from 1.18% to 2.65%. Lastly, Local funding undulated year by year.

5 RESULTS

5.1 First Stage: Research Equations

Table 4 and Table 5 present the results for equation of engage in R&D and R&D intensity equation by using Heckman two-step estimation. Table 4 show the estimates of the determinants of whether a firm engages in R&D activities using probit model for three different survey (CIS4, CIS2006, CIS2008). Table 5 then shows R&D investment intensity conditional on a firm doing/reporting R&D. The numbers are presented for Table 4 and Table 5 are marginal effects evaluated at the sample means. All of the explanatory variables in Table 4 and Table 5 are dummy variables- if they are important for firms, variables take the value 1 (for precise definition look at Appendix). So, coefficients of variables show the effect of changing variables from 0 to 1.

First of all, consider the coefficient of firm size. According to the literature, firm size has significantly positive effect on R&D activities i.e. the larger firms, the more likely to engage in R&D activities (Chudnovsky(2006), Griffith et. al.(2006)). This could be explained because the larger firms has more reserve to invest in R&D. As far as international competition is concerned, I find that firms which operate mostly in international markets are more likely to engage in R&D nevertheless, coefficient of international competition on R&D intensity equation is insignificant. This findings is consistent with literature which work on United Kingdom(UK) and Germany(Griffith et. al.(2006)). International competition effects significantly engage in R&D but not R&D intensity in UK and Germany(Griffith et. al.(2006)). As expected, receiving national funding increases the probability to engage in R&D, we can see easily that there is pattern throughout the years. Effect of national funding is increasing year by year. For instance, Turkish manufacturing firms that receive funding from national sources are 28 percent more likely to engaging in R&D than firms that receive no funding from national sources in 2002-2004 and 30 percent more likely to engaging in R&D than firms that receive no funding from national sources in 2006-2008. However, we couldn't estimate the impact of local funding and European union funding in CIS4 because surveyor didn't ask those questions in that wave. I can observe the impact of those in CIS2006 and CIS2008. EU funding significantly impacts engagement R&D in just CIS2006, firms that receive funding from EU sources are 42.2 percent more likely to engage in R&D than firms that receive no funding from EU sources in 2004-2006.

When we look at the estimation results for R&D intensity, in Table 5, estimation results are very similar to equation of engage in R&D in terms of significance. Firms' that receive no funding from national sources, R&D intensity increase 67.5 percent if those firms start receiving funding from national sources in 2002-2004, 52.3 percent if those firms start receiving funding from national sources in 2004-2006, 86.7 percent if those firms start receiving funding from national sources in 2006-2008. Interestingly, if firms start receiving funding from EU, their R&D intensity decreasing by 11.4 percent. The result is striking. However, similar conclusion can be made for German manufacturing firms(Griffith et. al.(2006)). This can be a monitoring problem due to the scale. Moreover, international competition affects R&D intensity, however its effect on R&D intensity is insignificant.

Dependent Variable	CIS4	CIS2006	CIS2008
International Competition	0.105^{***} (0.038)	0.157^{***} (0.046)	0.144^{***} (0.034)
Local Funding		-0.111 (0.126)	-0.129 (0.155)
National Funding	0.282^{***} (0.027)	0.285^{***} (0.060)	0.297^{***} (0.031)
EU Funding		0.422^{***} (0.071)	-0.029 (0.089)
Size			
50-99	0.044 (0.041)	-0.009 (0.103)	0.036 (0.074)
100-250	0.133^{***} (0.035)	0.196^{***} (0.089)	0.091^{**} (0.043)
250-999	0.099^{***} (0.036)	0.188^{**} (0.089)	0.187^{***} (0.041)
>1000	0.098^{**} (0.051)	0.255^{***} (0.070)	0.366^{***} (0.046)

Table 4: Engage in RD (0/1) in CIS4, CIS2006, CIS2008

Dependent Variable	CIS4	CIS2006	CIS2008
International Competition	0.235 (0.133)	-0.225 (0.118)	-0.278 (0.064)
Cooperation	0.216 (0.118)	0.318 (0.096)	0.325^{*} (0.055)
Local Funding		-0.027^{**} (0.155)	0.350 (0.134)
National Funding	0.675^{***} (0.145)	0.523^{**} (0.109)	0.867^{***} (0.056)
EU Funding		-0.114^{**} (0.072)	0.360 (0.107)

Table 5: RD intensity in CIS4, CIS2006, CIS2008

5.2 Second Stage:Innovation Equation

The second stage of estimation system is about estimating knowledge production function generated from firm's technological effort. I consider the estimation of process and product innovation equations, introducing the predicted value of R&D intensity as an explanatory variable, in the second stage of estimation system. As a result of R&D effort of a firm, we observe process and product innovations as outcome. Table 6 summarizes the results of process innovation and Table 7 for product innovation. The numbers reported in tables are marginal effects evaluated at sample means. All the explanatory variables are dummy variables except R&D intensity and investment intensity. Dummy variables are take the value 1 if the factor is important for the firm. If it is not important for the firms, it takes the value 0. Thus, the coefficients show the impact of changing the dummy from 0 to 1.

As expected, predicted R&D intensity has positive and significant effect on probability of a firm's doing process and product innovation in CIS4 and CIS2008. The insignificant effect of R&D intensity on product or process innovations is common in the literature. Benavente(2007) found similar results for Chile. Benavente explained this result by the dynamic nature of the innovation process where it is difficult to expect instant success related to R&D activities.[6] Also, Mairesse and Robin(2009) found R&D intensity effect innovation activities insignificantly in France 1998-2004. A unit increase in the R&D intensity results in an increase 24 percent probability of doing a process innovation in 2002-2004 and an increase 10 percent probability of doing process innovation in 2006-2008. For product innovation, a unit increase in R&D intensity results in an increase 36.1 percent probability of doing product innovation in 2002-2004 and increase 10.3 percent probability of doing product innovation in 2006-2008. Therefore, all variables that impact R&D also indirectly impact process and product innovation output. Furthermore, Griffith et.al.(2006) use investment intensity per employee in the equation of process innovation. Because they argue that there is complementaries between process innovation and investment in capital. To be more precise, process innovation generally implies buying of new equipments or machines. The marginal effect of investment intensity on tangible goods is significant and positive on process innovation over the years. However, effect of investment intensity on process innovation is fractional when compared to other explanatory variables. Griffith et.al.(2006) was also found frictional effect of investment intensity on process innovation for France, Germany, Spain and UK.

The impact of information source on knowledge production functions is an important issue in literature. While suppliers as a source of information are an important sources of information for process innovation, customers as sources of information are an important sources of information for product innovation. So, when I try to estimate process innovation, I don't use customers as a source of information also, when I try to estimate product innovation, I don't use suppliers as a source of information. Although, suppliers are important source of information for process innovation for Turkish manufacturing firms in CIS4, CIS2006 and CIS2008, information gathering from competitors doesn't effect probability of

[6] See Benavente(2007)

process innovation. The results are similar with Germany and UK in the study of Griffith et. al.(2006). The impact of information source from suppliers is significant at the 1% level in CIS4, CIS2006, CIS2008. But information from competitors doesn't effect the process innovation even at 10% level. Furthermore, as expected, customers are an important source of information for product innovation for over all years while competitors are not such an important source of information as customers(magnitude or in significant).

There is huge amount of study in literature for analyzing the relation between firm size and innovation activities. Analyzing firm size and innovation activities was started by Joseph Schumpeter who claimed that large firms have an advantage of innovation. Our results indicate that larger firms are more likely to be process innovator especially in 2004-2006 and 2006-2008. Also, larger firms also appear more likely to be product innovators especially in 2004-2006 and 2006-2008. In the Turkish case, bigger firms tend to have more success in process and product innovation compared with their smaller counterparts.

Dependent varible	Process Innovation(0/1)		
	CIS4	CIS2006	CIS2008
R&D intensity	0.248^{***} (0.046)	0.034 (0.042)	0.101^{***} (0.028)
Investment intensity	0.003^{*} (0.003)	0.001 (0.005)	0.002^{*} (0.005)
Sources			
Suppliers	0.191^{***} (0.043)	0.195^{***} (0.069)	0.213^{***} (0.039)
Competitors	0.011 (0.035)	0.032 (0.055)	0.007 (0.031)
Size			
50-99	0.137^{***} (0.035)	0.024 (0.073)	-0.051 (0.043)
100-250	0.250^{***} (0.024)	0.057 (0.071)	0.074^{**} (0.033)
250-999	0.240^{***} (0.030)	0.101^{*} (0.049)	0.123^{***} (0.032)
>1000	0.224^{***} (0.027)	0.124^{**} (0.053)	0.176^{***} (0.039)

Table 6: Process Innovation

Dependent Variable	Product Innovation(0/1)		
	CIS4	CIS2006	CIS2008
R&D intensity	0.361^{***} (0.058)	0.009 (0.043)	0.103^{***} (0.026)
Sources			
Competitors	0.128^{***} (0.048)	0.020 (0.057)	0.0635^{**} (0.030)
Customers	0.178^{*} (0.063)	0.168^{**} (0.070)	0.154^{***} (0.038)
Size			
50-99	-0.09^{*} (0.049)	0.012 (0.079)	0.049 (0.36)
100-250	0.067^{*} (0.066)	-0.127 (0.098)	-0.025 (0.034)
250-999	0.003 (0.052)	0.043 (0.068)	0.022 (0.33)
>1000	0.039 (0.090)	0.155^{***} (0.049)	0.151^{***} (0.035)

Table 7: Product Innovation

5.3 Third Stage:Productivity Equation

Finally, I discuss the estimation results of productivity equation in Table 8. The CIS data doesn't give information on value added only give information on sales. So, logarithm of sales per employee is used as dependent variable in equation of labor productivity.

As expected, investment intensity in tangible goods is found to be a positive and significant contributor to labor productivity at the 10% significance level for over the years. This means that if a firm want to be more productive, investment in tangible goods is a way to increase labor productivity. The process and product innovation impact coefficients are quite mixed across the years. The estimated coefficient of process innovation in CIS2008 is the only statistically significant one. Process innovation is on average associated with a 6.9 percent increase in productivity. Estimated coefficients of product innovation are significant only in CIS2006. Product innovation accounts for a 46 percent increase in productivity in 2004-2006. As could be expected, firm size and labor productivity show systematic relationship. Bigger firms is more productive in all over the years. Generally, firms size at each level for all years effect productivity significantly except in CIS2006. Only firms, employ over 1000 employee, reap the benefit of working more employee in terms of productivity.

Dependent Variable	Labor Productivity		
	CIS4	CIS2006	CIS2008
Investment Intensity	0.016^{*} (0.006)	0.042^{*} (0.004)	0.033^{*} (0.007)
Process Innovation	0.076 (0.065)	0.078 (0.043)	0.069^{***} (0.036)
Product Innovation	0.029 (0.093)	0.046^{*} (0.040)	0.028 (0.098)
Size			
50-99	0.278 (0.022)	0.148 (0.032)	0.258^{***} (0.045)
100-250	0.377^{**} (0.055)	-0.363 (0.063)	0.386^{***} (0.069)
250-999	0.536^{***} (0.061)	0.342 (0.046)	0.537^{***} (0.048)
>1000	0.595^{***} (0.066)	0.655^{***} (0.028)	0.611^{***} (0.036)

Table 8: Product Innovation

6 Conclusion

In this paper, I examined the drivers of process and product innovation and how they effect productivity at the firm level for Turkish manufacturing sector by using CIS4, CIS2006 and CIS2008. As a major drawbacks of CIS, I couldn't observe many of the same firms repeatedly over time. So, I have to do cross-section analysis instead of panel data estimation.To do estimation, I used a structural 4-equation model that describes the link between R&D expenditure, process(product) innovation and labor productivity. Selectivity problem and simultaneity problem arise if a single equation model is used to estimate relation between R&D, innovation and productivity. For this reason, I used 4-equation CDM Model like recent related literature. Importantly, my estimation system allows for the fact that all firms exert some innovation effort, but not all reports their innovation effort.

Mostly, I found consistent results across periods for Turkish manufacturing sector. First of all, if a firm get involved in international competition, it's probability of doing R&D increases consistently all over the years. Also, receiving funding from central government for innovation projects impact positively on probability of doing R&D all over the years. Public funding is a determinant not only in research effort but also in the firm's decision whether to engage in R&D activities or not. Secondly, using suppliers as source of information effect positively probability of doing process innovation consistently all over the waves. Furthermore, firms with information from customers are also more likely to be product innovators. Finally, investment on tangible goods effect labour productivity positively for all over the years at 10 percent level of significance.

However, in contrast to the coincidence found for all over the years, some results are quite mixed across the years. Firstly, while funding from European Union effect significantly probability of engaging R&D in 2004-2006, it's effect on probability of R&D insignificantly in 2006-2008. In other words, EU funding for innovation projects doesn't always effect significantly probability of engaging R&D. Secondly, R&D expenditure per employee effect positively process innovation and product innovation during 2002-2004 and 2006-2008 but not effect significantly for product innovation and process innovation during 2004-2006. At last, product innovation is associated with higher productivity only during 2004-2006 but not other years.

A Appendix

A.1 Variable Definitions

Knowledge/Innovation

R&D engagement: Dummy variable which takes the value 1 if the firm reports engagement R&D activities during the period 2002-2004, 2004-2006, 2006-2008.

R&D intensity: R&D expenditure per employee in 2004, 2006, 2008.

Process innovation: Dummy variable which takes the value 1 if the firm reports having introduced new or significantly improved production process during the period 2002-2004, 2004-2006, 2006-2008.

Product innovation: Dummy variable which takes the value 1 if the firm reports having introduced new or significantly improved products during the period 2002-2004, 2004-2006, 2006-2008.

Labour productivity: Sales per employee in 2002, 2004, 2006.

Investment intensity: All investment expenditure in tangible goods in 2002, 2004, 2006.

Public Support

Local funding: Dummy variable which takes the value 1 if the firm received local or regional funding for innovation projects during the period 2002-2004, 2004-2006, 2006-2008.

National funding: Dummy variable which takes the value 1 if the firm received central government funding for innovation projects during the period 2002-2004, 2004-2006, 2006-2008.

European Union funding: Dummy variable which takes the value 1 if the firm received EU funding for innovation projects during the period 2002-2004, 2004-2006, 2006-2008.

Sources of information

Suppliers as source of information: Dummy variable which takes the value 1 if information from suppliers was of high importance during the period 2002-2004, 2004-2006, 2006-2008.

Competitors as source of information: Dummy variable which takes the value 1 if information from competitors and other firms from the same industry was of high importance during the period 2002-2004, 2004-2006, 2006-2008.

Customers as source of information: Dummy variable which takes the value 1 if information from customers or clients was of high importance during the period 2002-2004, 2004-2006, 2006-2008.

Other

International competition: Dummy variable which takes the value 1 if firms's most significant market is international.

Size: Set of size dummy variables according to the firm's number of employees in 2004, 2006, 2008. Categories are 20-49, 50-99, 100-249, 250-999, $>$1000 employees.

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