

# Spatial Econometric Analysis of R&D Spillovers in Turkey

Dilek Cetin<sup>1</sup>

*Department of Economics, Kirikkale University, Kirikkale, Turkey*

Elif Kalayci

*Department of Economics, Atilim University, Ankara, Turkey*

## **Abstract**

*Research and development (R&D) activities are of great significance in the long term development of firms and R&D expenditures have been studied by economists including Romer. This paper sets out to investigate the effects of R&D spillovers at provincial level with specific reference to Turkey. To serve this purpose, data published by Turkish Statistical Institute have been employed. The paper covers the period from 2003 to 2007. The number of data points is 342 subsequent to the aggregation of data at the firm level. Of the data aggregated, it has been found out that 162 of them are zero. While running the spatial econometric estimations, inverse distance and neighboring matrices were employed as the weighting matrix. The determinants of R&D activities employed in the study are size, represented by the number of employees; qualified labor, represented by the number of R&D employees; technology transfer represented by expenses for licensing; foreign ownership, Pavitt sector dummies, location dummies by the sea, border or airport. The results of the analyses suggest that when both weighting matrices are used, spatial lag and error yielded significant results. There is R&D knowledge spillovers at provincial level in Turkey, shown by the spatial spillover effects in nearly one third of the total effects.*

Keywords: *R&D expenditures, Knowledge spillovers, Spatial econometrics, Turkey*

JEL codes. O33, C21, O18

Copyright © 2016 JAEBR

## **1. Introduction**

The emergence of technology as the motivating power behind regional and economic growth (Buswell, 1987; Malecki, 1997) has been a topic of interest starting with Schumpeter (1954). The crucial part technological development plays in economic growth has come to the fore thanks to the endogenous growth theory (Grossman and Helpman, 1994; Romer, 1994). Technological gap has been cited as one of the factors in regional economic differences (Fagerberg, 1994; Fagerberg et al., 1997). This being the case, there has been a great deal of attention by decision-makers toward how to attain economic development and to gain competitive power both in national and international markets through innovation (Malecki, 1997). A noteworthy supporter of national innovation structure is industrial innovation, which derives from two diverse sources: internal R&D activities and the spillover effects by the periphery industrial establishments (Sun, 2002). The way knowledge has its way through the industrial communication channels, which are usually implied and non-formal (Arrow, 1962), is what makes the spillover effects come to the fore.

Starting from the Marshall's (1890) concept of industrial districts, a comprehensive body of postulations has been put forward as to the kinds of spillovers. Since the major feature of spillovers is thought to be their non-market character, it is not an easy task to determine spillovers on the whole. In their daunting study to undertake the afore-mentioned task, Audretsch and Feldman (2004) hold that geographic neighborhood for spillovers is a matter of consideration when industrial activities with related nature happen to be clustered in

---

<sup>1</sup> Correspondence to Dilek Cetin, E-mail: [dilekcetin@kku.edu.tr](mailto:dilekcetin@kku.edu.tr), [dilekchetin@gmail.com](mailto:dilekchetin@gmail.com)

the peripheral geographical area. The basic idea here is the clustering of firms within a territorial unit, which facilitates knowledge spillovers among the firms under consideration (Audretsch, 2003). Spatial proximity paves the way for the transmission of knowledge (Jaffe et al., 1993).

The main objective of this paper is to examine the (non)existence of spatial spillovers at provincial level in Turkey. In the literature R&D expenditures and/or registered patents are used as the variables to measure knowledge. Since patent registration is performed at provincial level, it is viable to get the registration data; on the other hand, when it comes to R&D expenditures at provincial level, no statistical information is provided by Turkish Statistical Institute (TURKSTAT). As a developing country, property rights are a relatively new concept and hence not enforced by the book. Therefore, patents might not be an appropriate variable in reflecting the knowledge stock. This being the case, knowledge stock will be represented by R&D expenditures.

While the Gross Domestic Expenditures on R&D (GERD) is 14 billion 807 million TL (6 billion 987 million USD<sup>2</sup> and 5 billion 29 million Euro<sup>3</sup>), in 2013, the share of GERD in gross domestic product is 0.95% in Turkey. The Lisbon criteria hold that R&D expenditures should be 3% of GDP in total and to meet the criteria of Lisbon by 2023, subsidies given to R&D are on the rise in Turkey. Knowledge spillover accounts for a substantial constituent of R&D. The spillover effects of R&D have not been studied as the only variable with specific reference to spatial economic analysis, despite the fact that the constituents of R&D as a whole have been the focus of some papers in Turkey (Kalayci and Pamukcu, 2014; Taymaz and Ucdogruk, 2009). In some industrial provinces of Turkey, R&D holds an important place and, therefore, is intense in these places. This being the case, employing the spatial econometric methods, it is of great significance that the spillover effects of R&D should be analyzed in the neighboring industrial provinces.

The paper is organized as the following. The first part hosts the literature review and then comes data and variable definitions used in the paper. Subsequent to the estimation of the results, there is the discussion and finally the conclusion part. The contribution of this paper is thought to be in two ways, the first being the application of spatial econometrics data and the second one being an analysis of R&D spillovers through a perspective of a developing country, Turkey.

## 2. Literature review

R&D spillover effects are well established in the related literature with sound empirical findings for firms, industries and nations (Griliches, 1992, 1998; Nadiri, 1993). Basically, there are two types of spillover effects, which are those related to financial aspects and non-financial aspects. The financial aspects count in a supply chain as a result of the buyer and seller relation. This kind of spillover effects improves the quality of transaction in general, with an emphasis on input and output of the transaction under consideration. In this way, the exchange of goods and services in a transaction performs the function of a facilitator in this kind of spillovers. On the other hand, the second type, the one with the non-financial aspect, is the distribution of know-how among the other firms in neighboring areas, both geographically and sectorally. Considering the advancement of the current communication systems, it is nearly an impossible endeavor to keep the developments in totally isolated environment considering the fact that ideas recognize no boundaries.

<sup>2</sup> Central Bank's USD banknote selling rate is 2.1375 at 31.12.2013.

<sup>3</sup> Central Bank's EURO banknote selling rate is 2.9441 at 31.12.2013.

Such features of knowledge as tacit and non-rival nature (Arrow, 1962) enable spillovers to come into effect. Still, the rate of benefit from the knowledge spillover is not the same according to some empirical studies. It is no surprise that the transmission of knowledge among the firms close to each other in location is considered a usual predictable flow (Jaffe et al., 1993). Thanks to the developments in communication field, the spread of knowledge through long distances is relatively easy. However, when it comes to rather tacit knowledge, it is not an easy thing to do and hence personal interaction plays an indispensable role (Nonaka and Takeuchi, 1985). The underlying assumption is that proximity of firms determines the level of spillover effect. In other words, there is higher chance of interaction among the firms if the firms are closer to each other, hence the spillover effect is likely to be stronger and vice versa (Audretsch and Feldman, 1996; Keller, 2002a, 2002b; Van Oort, 2004; Andersson and Gråsjö, 2009; Deltas and Karkalakos, 2013). Some amount of knowledge accumulation is a precondition for knowledge flow to occur. In the event that there is no sufficient knowledge to be spread, then there is no mention of spillover effects. On the other hand, in the case of high level of knowledge and innovation, there could be absorptive capacity problems and this is likely to hinder appropriate knowledge flow, thus disabling spillover effects (Cohen and Levinthal, 1990). Proximity is a related factor in knowledge dissemination, while such definitions on distance as organizational, social and institutional is a matter of concern in making the spillover effects easier or more difficult (Boschma, 2005).

Deltas and Karkalakos (2013) examined the elements of innovation for the periods covering 1989 and 2000 in Spain and concluded that the R&D activities are similar in the case of spillovers, while in the absence of spillovers, R&D activities are not similar. Cabrer and Serrano (2007) hold that as far as spatial spillovers in innovative activities are concerned, trade related activities are close to each other. Smith et al. (2002) in their study, which examined the relation between location and R&D activities in Denmark, found out that instead of geographical proximity, the industry-related connections shapes the R&D activities of firms under consideration. In a similar study by Liu et al. (2010), which analyzes Taiwan's manufacturing industry and spillover effects in urban areas, it is revealed that the higher the intensity of clustering of firms, the higher is the spillover effect. Glaeser et al. (1992) studied largest industries dispersed in 170 cities covering the periods 1956 and 1987 from a developmental perspective in the USA and emphasize the permanence of spillover effects observed in bigger industries solely. Their justification for their findings is due to the concentrated interaction between individuals in the cities. Interestingly, a study by Harrison et al. (1996) on the impact of firms operating in the same field on technology use, point out no spillover effects from other firms in terms of the size of the companies under consideration.

On the other hand, Bode (2004) sets out to examine the knowledge spillovers in Western Germany and concludes that no substantial spillover effects are present in the neighboring regions. Nonetheless, regions with little R&D take the advantage of knowledge spillovers. In the case of regions with higher R&D activities, the aforementioned outcome does not prove to be correct, which can be put down to the fact that regions with high R&D activities are self-supporting in innovation efforts and avoid increasing the operation expenses by means of getting in touch with regions with lower R&D activities. The opposite case applies for firms with low R&D activities. Carboni (2013) in his study uses physical and industry relatedness variables and attempts to analyze the resolutions of firms on whether to take part in R&D activities partnerships and reports that not only spatial but also industrial closeness is influential in their decisions to have partnership in R&D activities.

Laursen and Meliciani (2000) evaluate knowledge spillovers and innovation through an evolutionary economics approach and conclude that innovation should be dealt with within a sector-specific perspective. On the other hand, Pavitt (1984) in his groundbreaking study on classification framework across industries put forward four key groups; which are supplier-

dominated, scale-intensive, specialized suppliers and science-based. Supplier-dominated sectors are distinguished by their innovation efforts through machinery and equipment acquisition and possession. Specialized-suppliers are those in pursuit of cooperating with customers in capital goods and equipment acquisition. When it comes to science-based industries, electronics, chemicals, pharmaceuticals and aerospace sectors stand out and the common feature of science based industries is that they value internal R&D activities with their own means and are based on mainly scientific innovation and discoveries. On the other hand, scale-intensive industries, as the last group, concentrate on mass-production and are based upon the end-products of specialized-suppliers and science-based industries. Of the four groups mentioned, scale-intensive industries have a crucial part in the economy overall in terms of knowledge spillover effects (Pavitt, 1984; Laursen and Meliciani, 2000).

Carboni (2013) reports that the spatial proximity is of great significance as an important element in R&D expenditures. In the same vein, Eberhart et. al. (2013) underline the importance of spatial econometrics in the analysis of spillover effects on R&D expenditures. According to Carboni (2013), empirical studies on spillover effects lack spatial autocorrelation. Even if the studies employed spatial correlation, it should be paid particular attention that in the event that spatial correlation originates from the environmental influences (i.e. those from neighboring sectors in the same geographical proximity), ordinary least squares (OLS) results yield inefficient and biased estimations (Anselin, 1988). Therefore, in order to avoid the biased results, spatial econometric analysis is preferred and used in this paper.

As far as Turkey is considered, it will not be wrong to say that R&D related papers on Turkish companies are scarce. Ucdogruk (2009) examined the impact of R&D activities using a panel data covering the periods of 1998-2007 and concluded that firms in small scales are in an inclination to have more R&D activities. On the other hand, Taymaz and Ucdogruk (2009) in their study examined the effect of ownership status with establishment level data spanning 1993-2001 and reported that foreign ownership had little effect on R&D intensity and mentioned a negative correlation between R&D and size. Besides, such variables as capital intensity, age, skilled labor and exporting status did not have a statistically significant effect on R&D intensity, however, state subsidies did.

Tandogan (2011) examined the elements of R&D activities for the periods of 2003-2006 for Turkish production companies and concluded that foreign ownership has a negative effect on R&D activities. Pamukcu and Erdil (2011), in their qualitative study on R&D activities of foreign companies operating in Turkey, underline isolation of the firms under consideration from their local counterparts and hence leading to difficulty in the employment of skilled labor. On the other hand, Kalayci and Pamukcu (2014) studied foreign knowledge spillovers in Turkish firms via addressing the selection bias by employing Heckman analysis using panel data spanning 2003 and 2007. Their findings suggest that foreign knowledge spillovers have a negative impact on R&D activities and likewise firm size and export activity affect R&D activities in a negative manner.

Cetin (2016) employed spatial econometric methods in analyzing intra and inter knowledge spillovers in industrial zones and concluded that there are spillover effects in the industrial zone of Ankara, the capital city, and that more than half of the spillovers are due to the geographical factors. Karacuka and Catik (2011) examined productivity spillovers from foreign and domestic companies based in Turkey and report that spillover effects come from the neighboring companies.

### **3. Data and Methodology**

This study exploits data collected by TURKSTAT, thorough Research and Development Survey (RDS) and Structural Business Survey (SBS), both of which are performed at firm level. RDS is based on the Frascati Manual which defines R&D as ‘creative work undertaken on a systematic basis in order to increase the stock of knowledge of man and society, and the use of this stock in order to devise new applications’ (OECD, 1993). On the other hand, SBS adopts questionnaires with the employees of all firms with more than 20 employees. RDS encompasses the R&D performers subsidized from public resources and enterprises. The data obtained from the two surveys were matched and data for R&D performers was employed, despite the fact that this might imply a sample selection bias. Following Hall and Mairesse (1995), the data is screened for outliers as per sales, employee growth and value added rates of companies. The firms with possible inorganic growth patterns, mergers and acquisitions were not covered in the study. As the next step, outliers in R&D activities were left out as suggested by Aldieri and Cincera (2009). Subsequent to these steps, 342 observations remained, 162 of them were zero<sup>4</sup>.

The sample coverage rates for the micro data of the Business Enterprise Research and Development Expenditures (BERD) is 60% spanning the periods of 2004-2006, while it is around 35% for the years 2003 to 2007 for the sample. The total sample micro data involves nearly half of the data for five consecutive years. Detailed information is provided in Appendix A. On the other hand, the provinces are provided in the order of license plate number, which follows an alphabetical pattern mostly, in Appendix B.

### 3.1. Variable Description

Table 1 reports the descriptive statistics employed in this paper. The data collected is at the micro level, i.e., firm level; however, provincial data is needed in order to compute the regional effects and to serve this purpose the data is aggregated at the provincial level. This was an essential task to move forward since TURKSTAT does not give out data at provincial level. The logarithm of the provincial average of R&D expenditures (clrd) represents the endogenous (dependent) variable for the econometric analysis<sup>5</sup>. Instead of the total sum of R&D expenses, the averages have been employed in order to prevent the size effect of the provinces under consideration. The rationale behind use of natural logarithm of the average expenditures is that it allows for information irrespective of the size of the provinces firms are located in. Such a choice serves the main objective of this study, which is to examine the effect of the R&D expenditures of neighboring provinces on R&D activities of firms.

The logarithm of the number of R&D employees (crdemp) has been used for skilled labor while in order to incorporate the effect of firm size, the logarithm of employees (clemp) has been utilized. In settings where fierce competition exists, companies find themselves in pursuit of getting external know-how by means of foreign technologies, which pushes them to have their individual R&D activities (Sasidharan and Kathuria, 2011). Hence, licensing expenditures (clrlie) such as product design, blueprints and patents have been incorporated in order to determine the effect of technology transfer.

The evidence on the impact of foreign capital on home companies is scant in the studies performed. Karray and Kriaa (2010), Harris and Trainor (2009) hold that foreign capital might yield some negative effects, while according to Lin and Yeh (2005), it could be a positive one or none. The ratio of foreign capital to the total sum capital (cfor) is used in order to integrate

<sup>4</sup> The five-year data for 81 provinces has been aggregated as per the years. There is missing data for 9 provinces. These provinces’ license plate codes are 4, 12, 13, 30, 49, 62, 73, 71, 80. Furthermore there is no data for certain provinces in some years. Annually missing data as per provincial codes are 24, 25, 66, 72 for 2003; 8 for 2004; 8, 24, 25, 69, 66, 72 for 2005; 8, 24, 29 for 2006, and 8, 29, 72, 66 for 2007.

<sup>5</sup> We also tried patent applications and patent grants as dependent variables. The estimation results are not significant. The econometric estimation results are available upon request.

the impact of foreign capital ownership on R&D expenditures. When it comes to the task of labeling the firms as foreign or domestic, 10% foreign capital share is considered as the minimum criterion.

**Table 1: Summary statistics of the variables**

Variable	Abbr.	Obs	Mean	Std. Dev.	Min	Max
R&D expenditures (level)	crd	342	38951	111508	0	1204194
Ln R&D expenditures	clrd	342	5.188	5.103	0	14.001
Number of employees	cemp	342	137.409	98.369	20	832.385
Ln of Number of employees	clemp	342	4.735	0.610	2.99	6.724
Number of R&D employees	crdemp	342	0.751	1.402	0	7.273
Ln of licensing expenditures	clrlc	342	0.676	0.923	0	9.446
Foreign share	cfor	342	0.025	0.0531	0	0.333
R&D subsidy amount	cfina	342	0.063	0.258	0	2.312
Dummy for Supplier Dominated sector	cdsd	342	0.552	0.239	0	1
Dummy for Scale Intensive sector	cdsi	342	0.330	0.232	0	1
Dummy for Specialized Supplier sector	cdss	342	0.089	0.098	0	1
Dummy for Science Based sector	cdsb	342	0.029	0.043	0	0.286
Dummy for Seaside provinces	sea	342	0.398	0.490	0	1
Dummy for provinces on border	border	342	0.149	0.357	0	1
Number of airports in province	air	342	1.044	0.205	1	2

The effect of R&D subsidy is represented by the natural logarithm of subsidy received by the firm (cfina). In qualitative study on R&D performing firms in Turkey, Kalayci (2012) finds as firms receive R&D subsidy, others may monitor their performance and follow course. Thus we use this variable to capture the effect of R&D subsidy. Kalayci (2012), in her qualitative study reports that in the event that a firm is granted R&D subsidies, others are likely to observe the firms with subsidies and may choose to pursue the same procedures. Table 1, summarized the main statistics of the variables.

55% of the firms covered in our sampling are supplier-dominated, while 33% are scale intensive and 9% are in the category of specialized suppliers. Only 3% of the firms in the sample are in the group of science based. As far as the taxonomy of Pavitt is considered, the science based firms were taken as the reference class and dummy variables were put for the other groups; namely, supplier-dominated, scale-intensive and specialized-suppliers. As a final point, dummy variables for locations by coast<sup>6</sup>, border<sup>7</sup> and air<sup>8</sup> were employed, so as to measure the impact of externalities.

### 3.2. Methodology

The spatial econometric estimation is the methodology which is coherent with the hypothesis of this study. The difference between the standard and spatial econometric

<sup>6</sup> Coastal provinces: 1, 7, 8, 9, 10, 16, 17, 22, 28, 31, 33, 34, 35, 37, 39, 41, 48, 52, 53, 54, 55, 57, 59, 61, 67, 74, 77, 81

<sup>7</sup> Provinces at the border: 4, 8, 22, 27, 30, 31, 36, 39, 47, 63, 65, 73, 75, 76, 79

<sup>8</sup> Provinces with an airport: 1, 2, 4, 5, 6, 7, 10, 16, 17, 20, 21, 23, 24, 25, 27, 31, 32, 43, 44, 46, 47, 48, 49, 50, 55, 56, 34, 35, 36, 38, 41, 42, 57, 58, 59, 60, 61, 63, 64, 65, 67, 72, 76. [www.dhim.gov.tr/havaalanlari.aspx](http://www.dhim.gov.tr/havaalanlari.aspx) (Accessed on 6.6.2013)

estimation is in the latter one spatial dependence between the provinces are taken into consideration. The spatial econometric estimation is especially an appropriate tool when “distance matters”.

Spatial Autoregressive Models (SAM) and Spatial Error Models (SEM) are commonly used models for spatial econometric estimation. In the former one, spatial dependence in the dependent variable is considered while in the latter one in the error terms (Anselin, 1988: Ward and Gleditsch, 2008).

The model which is to be estimated is,

$$lnrd = \alpha_0 + \alpha_i \sum_i^n X_i + \epsilon \tag{1}$$

$$i = 1, \dots, n$$

$$\epsilon \sim N(0, \sigma^2 I)$$

where  $\epsilon$  is normally distributed error term with a constant variance and  $X$  is the dependent variables matrix.

$$X = f(rdemp, lemp, lrlic, for, fina, Pavitt dummies, sea, border, air)$$

With the provincial aggregation, the equation becomes

$$clnrd = \alpha_0 + \alpha_i \sum_i^n X_{ipt} + u \tag{2}$$

$$X = f(crdemp, clemp, clrlic, cfor, cfina, Pavitt dummies, sea, border, air)$$

$$p = 1, \dots, 81 ; t = 2003, \dots, 2007$$

where c stands for provincial aggregation, p stands for province and t stands for time.

When spatial dependence is considered, different from standard econometric estimation, it is necessary to define the relationship between the spatial units. Inverse distance and binary contiguity, commonly-held weighting matrices in the literature, have been used in the tests and estimation processes<sup>9</sup>. In order to explain the structure and the strength of spatial relationship in the observation, exogenous weighting matrix,  $W$ , has been applied.  $W$  is the inverse distance matrix of provinces. Based upon binary values, another weighting matrix,  $W1$ , is used also. Two neighbor provinces in a weighting matrix are based on binary values which takes either the value of 1 when they are correlated or the value of 0 when they are not. In other words, considering the activities of R&D, there is a bilateral relationship. In the study, the distances between the points have been taken as neighboring provinces with a distance of less than 250 km. Considering the fact that the maximum values of the minimum distances between any given two provinces is 225 km in Turkey, we take 225 km as a unit measure of neighboring provinces and this implies that each province has at least one neighboring province.

SAM is;

$$clnrd = \alpha_0 + \alpha_i \sum_i^n X_{ipt} + \rho W clnrd + \epsilon \tag{3}$$

where  $W$  is row-standardized weighting matrix and  $\rho$  is spatial lag parameter.

<sup>9</sup> We use the number of patent application and grants to construct a weighting matrix which defines the technological proximity between provinces but spatial econometric estimation does not produce significant results. These results are available from the authors upon request.

SEM is;

$$clnrd = \alpha_0 + \alpha_i \sum_i^n X_{ipt} + \varepsilon \quad (4)$$

$$\varepsilon = \lambda W\delta + \epsilon$$

General form of SEM is

$$clnrd = \alpha_0 + \alpha_i \sum_i^n X_{ipt} + \lambda W\delta + \epsilon \quad (5)$$

where  $W\delta$  is the spatial lag of error term and  $\lambda$  is the spatial autoregressive coefficient or the vector of parameters that show the spatial relation of the error terms.

#### 4. Discussion of the Estimation Results

The spatial autocorrelation has to be tested in the dependent variable prior to performing spatial econometric estimation. To serve this purpose, Moran's  $I^{10}$  and Geary's  $C^{11}$  tests have been employed. Moran's  $I$  tests the correlation between the dependent variable and the spatial lag (Moran, 1948, 1950a, 1950b; Geary, 1958).

Moran's  $I$  and Geary's  $C$  tests have been employed as the main criteria in testing the autocorrelation in all variables under consideration. The results of the tests suggest that there is autocorrelation in all the variables used, with the exception of dummy variable of the Pavitt taxonomy (1984), as can be seen from Table 2. See Appendix C for further information on Pavitt taxonomy.

**Table 2: Moran's I and Geary's C test results**

Variables	Weight	Moran's I	Z-value	p-value*	Geary's C	Z-value	p-value*
crd	W	0.001	0.313	0.377	1.012	0.385	0.350
	W1	-0.004	-0.023	0.491	1.002	0.032	0.487
clrd	W	0.077	6.658	<b>0.000</b>	0.921	-6.508	<b>0.000</b>
	W1	0.091	2.773	<b>0.003</b>	0.906	-2.763	<b>0.003</b>
cemp	W	0.001	0.293	0.385	1.002	0.115	0.454
	W1	-0.062	-1.771	<b>0.038</b>	1.094	1.967	<b>0.025</b>
clemp	W	0.027	2.521	<b>0.006</b>	0.967	-2.415	<b>0.008</b>
	W1	-0.034	-0.929	0.176	1.035	0.985	0.162
crdemp	W	0.030	2.764	<b>0.003</b>	0.954	-2.800	<b>0.003</b>
	W1	0.035	1.124	0.130	0.996	-0.099	0.461
clrlc	W	0.000	0.294	0.384	0.984	-0.690	0.245
	W1	-0.021	-0.563	0.287	1.004	0.083	0.467
cfor	W	0.031	2.854	<b>0.002</b>	0.945	-2.632	<b>0.004</b>
	W1	0.034	1.119	0.132	0.929	-1.487	0.069
clfina	W	-0.001	0.190	0.425	1.002	0.085	0.466
	W1	0.001	0.115	0.454	0.954	-0.807	0.210
cdsd	W	-0.023	-1.665	<b>0.048</b>	1.030	2.258	<b>0.012</b>
	W1	-0.074	-2.092	<b>0.018</b>	1.079	2.214	<b>0.013</b>
cdsi	W	0.004	0.550	0.291	1.003	0.231	0.409
	W1	-0.016	-0.392	0.347	1.021	0.573	0.283
cdss	W	0.038	3.553	<b>0.000</b>	0.969	-1.344	0.089
	W1	0.033	1.084	0.139	1.019	0.382	0.351
cdsb	W	0.020	1.909	<b>0.028</b>	0.962	-2.307	<b>0.011</b>
	W1	0.099	3.044	<b>0.001</b>	0.896	-2.555	<b>0.005</b>

\*1-tail test

<sup>10</sup> There is no spatial autocorrelation is the null hypothesis of Moran's  $I$ . Besides, whether there is a positive or negative correlation is determined by the sign of Moran's  $I$  test. Moran's  $I$  takes values between -1 and 1. The closer the value is to 1, the higher the positive autocorrelation. The closer the value is to -1, the higher the negative autocorrelation. If the value is equal to 0, there is no autocorrelation.

<sup>11</sup> Geary's  $c$  takes values between 0 and 2. The closer it is to 0, the higher the positive autocorrelation. The closer it is to 2, the higher the negative autocorrelation. If the value is equal to 1, then there is no autocorrelation.

The natural logarithm of R&D expenditures is taken as the dependent variable, with spatial autocorrelation for both weighting matrices. There is no spatial auto correlation when R&D expenditures are taken for both statistics and both weighting matrices. Since there is spatial autocorrelation in the case of the natural logarithm of R&D expenditures, the next step is to perform spatial econometric estimation. Some of the independent variables have spatial autocorrelation for binary contiguity weighting matrices, whereas others have inverse distance matrix.

The natural logarithm of the number of employees, R&D employees, foreign share and specialized supplier dummy are the variables with spatial autocorrelation in the event that inverse distance matrix is employed. Considering binary contiguity and the inverse distance matrices, the dummies for the science-based and scale intensive Pavitt sectors have been computed to have spatial autocorrelation.

Table 3 and Table 4 report the estimation results, where inverse matrix and binary contiguity matrix have been used as weighting matrix, respectively. The results of the OLS estimations are provided in the first columns of Table 3 and Table 4. As for the panel data estimations for fixed and random effects with no spatial effects are given in the second and the third columns of the Table 3 and 4. On the other hand, spatial error and lag estimation for panel data are shown in the fourth and the fifth columns of both tables. For all the estimations, signs prove to be consistent. In view of some variables, estimations for panel data do not yield significant results, while as for OLS and spatial estimates do.

Firm size has a positive effect on R&D level. There are some studies supporting this point that the bigger the firm is in size the higher the effect of size (Czarnitzki and Toole, 2007; Lin and Yeh 2005), while some studies suggest that as far as Turkey is considered, the size effect is negative (Ucdogruk, 2009; Ucdogruk and Taymaz, 2009; Kalayci and Pamukcu, 2014). As is expected, the skilled labor variable has a positive impact on R&D activities. On the other hand, the foreign share affects R&D negatively, while technology transfer has a positive impact on R&D level. Considering the negative effect of foreign share, it makes sense that foreign firms are in an inclination to have R&D activities in their home countries. Excluding the spatial effects, it is seen that foreign capital share along with technology transfer reveals no significance; however, when spatial models are implemented, they both have significant effects on R&D. owing to the comparatively lower wages offered in Turkey, companies choose to operate in Turkey, which is plausible. However, when it comes to R&D activities, home countries take precedence (Un and Cazorra 2008, Kumar 1987).

The signs of other sectors have been found out to be negative compared to the science-based sector. Significantly different than the science-based sector are the supplier-dominated and scale-intensive ones. It has been found out that being located by the sea exerts positive effects, while by-border location does not. Forefront R&D companies are based in Istanbul, Izmir and Kocaeli, all of which are located by the sea. When it comes to by-border firms located near the borders, due to the small-scale with little R&D nature, the spatial effect on R&D is negative, which does not reveal an unanticipated result. The airport factor has no significant effect on R&D level.

**Table 3: Estimation Result with inverse distance matrix as the weighting matrix**

VARIABLES	(1) clrd OLS, W	(2) clrd Panel, Fixed, W	(3) clrd Panel, Random, W	(4) clrd Spatial, W	(5) clrd Error, Spatial, Lag, W
crdemp	<b>1.711***</b> (0.152)	<b>1.356***</b> (0.158)	<b>1.502***</b> (0.146)	<b>1.706***</b> (0.150)	<b>1.700***</b> (0.148)
clemp	<b>1.010***</b> (0.344)	<b>1.980***</b> (0.695)	<b>1.581***</b> (0.450)	<b>0.926***</b> (0.337)	<b>0.923***</b> (0.334)
clrlie	<b>0.553**</b> (0.218)	0.118 (0.170)	0.218 (0.168)	<b>0.522**</b> (0.213)	<b>0.524**</b> (0.211)
cfor	<b>-7.022*</b> (3.809)	-11.65 (9.379)	-6.415 (5.415)	<b>-6.924*</b> (3.736)	<b>-7.602**</b> (3.693)
clfina	<b>3.119***</b> (0.729)	<b>0.953*</b> (0.532)	<b>1.407***</b> (0.531)	<b>2.914***</b> (0.714)	<b>2.920***</b> (0.709)
cdsd	<b>-13.05***</b> (4.789)	-5.475 (6.913)	<b>-11.43**</b> (5.540)	<b>-14.32***</b> (4.762)	<b>-14.46***</b> (4.660)
cdsi	<b>-15.70***</b> (4.837)	-9.994 (7.082)	<b>-14.59***</b> (5.638)	<b>-16.72***</b> (4.800)	<b>-16.85***</b> (4.698)
cdss	-6.120 (5.327)	-4.354 (7.846)	-8.525 (6.061)	-8.236 (5.338)	-8.359 (5.211)
sea	<b>1.402***</b> (0.409)		<b>1.569**</b> (0.691)	<b>1.499***</b> (0.407)	<b>1.546***</b> (0.399)
border	<b>-1.129**</b> (0.555)		<b>-1.802**</b> (0.906)	<b>-0.959*</b> (0.554)	<b>-0.930*</b> (0.542)
air	0.403 (0.960)		0.283 (1.643)	-0.239 (0.996)	-0.311 (0.959)
Constant	<b>10.85**</b> (4.986)	1.658 (7.735)	7.658 (6.177)	<b>13.11***</b> (5.066)	<b>11.66**</b> (4.835)
lambda				<b>0.356**</b> (0.170)	
rho					<b>0.323***</b> (0.107)
sigma				3.312*** (0.127)	3.288*** (0.126)
Observations	342	342	342	342	342
R-squared	0.571	0.304			
Number of il_kodu		72	72		

Standard errors in parentheses

\*\*\* p&lt;0.01, \*\* p&lt;0.05, \* p&lt;0.1

**Table 4: Estimation Result with binary contiguity matrix is used as weighting matrix.**

VARIABLES	(1) clrd	(2) clrd	(3) clrd	(4) clrd	(5) clrd
	OLS, W1	Panel, Fixed, W1	Panel, Random, W1	Spatial, Error, W1	Spatial, Lag, W1
crdemp	<b>1.711***</b> (0.152)	<b>1.356***</b> (0.158)	<b>1.502***</b> (0.146)	<b>1.704***</b> (0.151)	<b>1.708***</b> (0.149)
clemp	<b>1.010***</b> (0.344)	<b>1.980***</b> (0.695)	<b>1.581***</b> (0.450)	<b>1.001***</b> (0.337)	<b>1.010***</b> (0.336)
clrlc	<b>0.553**</b> (0.218)	0.118 (0.170)	0.218 (0.168)	<b>0.553***</b> (0.214)	<b>0.527**</b> (0.214)
cfor	<b>-7.022*</b> (3.809)	-11.65 (9.379)	-6.415 (5.415)	<b>-6.810*</b> (3.758)	<b>-7.237*</b> (3.722)
clfina	<b>3.119***</b> (0.729)	<b>0.953*</b> (0.532)	<b>1.407***</b> (0.531)	<b>3.114***</b> (0.716)	<b>3.077***</b> (0.712)
cdsd	<b>-13.05***</b> (4.789)	-5.475 (6.913)	<b>-11.43**</b> (5.540)	<b>-13.36***</b> (4.754)	<b>-13.36***</b> (4.680)
cdsi	<b>-15.70***</b> (4.837)	-9.994 (7.082)	<b>-14.59***</b> (5.638)	<b>-15.90***</b> (4.785)	<b>-15.85***</b> (4.724)
cdss	-6.120 (5.327)	-4.354 (7.846)	-8.525 (6.061)	-6.573 (5.309)	-6.785 (5.216)
sea	<b>1.402***</b> (0.409)	0 (0)	<b>1.569**</b> (0.691)	<b>1.436***</b> (0.408)	<b>1.467***</b> (0.402)
border	<b>-1.129**</b> (0.555)	0 (0)	<b>-1.802**</b> (0.906)	<b>-1.060*</b> (0.558)	<b>-1.006*</b> (0.547)
air	0.403 (0.960)	0 (0)	0.283 (1.643)	0.256 (0.977)	0.167 (0.947)
Constant	<b>10.85**</b> (4.986)	1.658 (7.735)	7.658 (6.177)	<b>11.30**</b> (4.981)	<b>10.79**</b> (4.869)
lambda				0.0544 (0.0930)	
rho					<b>0.110*</b> (0.0612)
sigma				3.333*** (0.127)	3.317*** (0.127)
Observations	342	342	342	342	342
R-squared	0.571	0.304			
Number of il_kodu		72	72		

Standard errors in parentheses

\*\*\* p&lt;0.01, \*\* p&lt;0.05, \* p&lt;0.1

The coefficient of spatial error (lambda) has been calculated 0.0544 when inverse matrix is employed and reveals statistically insignificant result. Similarly, in the use of spatial lag coefficient (rho), which is 0.110, the result has been found out to be statistically significant, as well. The spatial error coefficient (lambda) is an insignificant 0.0544 and spatial lag coefficient (rho) is 0.110 and significant (p<0.10), as far as the binary contiguity weighting matrix is used. Firstly, the result obtained implies the fact that distance is a matter to be considered. It can be concluded from the result found with the use of inverse distance matrix, there is spatial autocorrelation. Nonetheless, this is not valid when the neighboring matrix is

used. Secondly, spatial effects account for the one third of the aggregate effects, which results from the spatial lag model. OLS estimation can point to the significance of the coefficient of the spatial error. OLS estimation has the explanatory power of 57% of the variation, which may imply a possibility of an omitted variable problem in the model.

## 5. Conclusion

The main objective of this study was to examine the presence or absence of knowledge spillovers in Turkey. Since TURKSTAT publishes no statistics on R&D expenditures at the province level, firm level data from the R&D and the Structural Business Surveys covering the years 2003 to 2007 were aggregated at the province level. In order to perform econometric estimation, panel spatial econometrics method was employed with two weighting matrices, inverse distance matrix between the provinces and binary contiguity matrix for neighboring provinces.

The dependent variable is the natural logarithm of R&D expenditure, in which there is spatial autocorrelation, shown by Moran's I and Geary's C tests. Most of the findings such as the signs and the significance of some variables are in tandem with the findings in the related literature. The significance obtained varies by the model employed, that is, with panel data estimation, technology transfer and foreign capital share, the results are insignificant but with spatial models they are significant. "Distance matters" in R&D spillovers for Turkey. Inverse distance matrix reveals spatial autocorrelation, while neighboring matrix does not. Another point to mention is that spatial effect accounts for one third of the total effects, which is revealed as a result of the spatial lag model.

Nearly all firms with R&D departments are subsidized by public agencies. Thus, in econometric estimation analysis, the issue of endogeneity should be dealt with particular focus. The future research is expected to overcome this issue. Besides, time lag between R&D activities and the resulting spillover effects should be incorporated in the models, since dissemination of knowledge takes time to be realized. Considering the short time span of the data, nevertheless, time lag is not included in the model. Thus, in a similar manner, time lag in the spatial model is another limitation of this paper, which requires improvement in future research. Another drawback of the study is selection bias that arises due to the employment of R&D performing firms only. Despite all the drawbacks in this study, it is still a contribution to the literature as it reveals the spatial effects of R&D spillovers.

## References

- Aldieri L, Cincera M. 2009. Geographic and technological R&D spillovers within the triad: micro evidence from US patents. *The Journal of Technology Transfer* 34:2, 196-211.
- Anselin L. 1988. *Spatial Econometrics: Methods and Models*. Boston, MA: Kluwer Academic.
- Arrow K. 1962. The economic implications of learning by doing. *Review of Economic Studies* 29:3, 155-173.
- Andersson M, Gråsjö U. 2009. Spatial dependence and the representation of space in empirical models. *The Annals of Regional Science* 43:1, 159-180.
- Audretsch DB. 2003. Innovation and spatial externalities. *International Regional Science Review* 26:2, 167-174.

- Audretsch DB, Feldman M. 1996. R&D spillovers and the geography of innovation and production. *American Economic Review* 86:3, 630–640.
- Audretsch DB, Feldman M. 2004. Knowledge spillovers and the geography of innovation, in: Henderson, J.V., Thisse, J.F. (Eds), *Handbook of Regional and Urban Economics*, Vol. 4, pp. 2713-2739.
- Boschma RA. 2005. Proximity and innovation: a critical assessment. *Regional Studies* 39:1, 61–74.
- Bode R. 2004. The spatial pattern of localized R&D spillovers: an empirical investigation for germany. *Journal of Economic Geography* vol. 4, 43-64.
- Buswell RJ. 1987. Research and development and regional development: a review. in: Gillespie, A. (Eds.), *Technological Change and Regional Development*. Pion, London, 9–22.
- Cabrer-Borras B, Serrano-Domingo G. 2007. Innovation and R&D spillover effects in spanish regions: a spatial approach, *Research Policy*, 36, 1357–1371.
- Carboni OA. 2013. Spatial and industry proximity in collaborative research: evidence from italian manufacturing firms. *Journal of Technology Transfer* 38, 896–910.
- Cetin D. 2016. *Knowledge Spillovers and Clusters: A Spatial Econometric Analysis on Ankara and Istanbul OIZs*, LAP Lambert Academic Publishing: Germany.
- Cohen W, Levinthal DA. 1990. Absorptive capacity: a new perspective on learning and innovation. *Administrative Science Quarterly* 35:1, 128-52.
- Czarnitzki D, Tool AA. 2007. Business R&D and the interplay of R&D subsidies and product market uncertainty. *Review of Industrial Organization* 31, 169–181.
- Deltas G, Karkalakos S. 2013. Similarity of R&D activities, physical proximity and R&D spillovers. *Regional Science and Urban Economics* 43, 124-131.
- Eberhart M, Helmers C, Strauss H. 2013. Do spillovers matter when estimating spillovers for R&D? *The Review of Economics and Statistics* 95:2, 436–448.
- Fagerberg J. 1994. Technology and international differences in growth rates. *Journal of Economic Literature* 32, 1147–1175.
- Fagerberg J, Verspagen B, Caniels M. 1997. Technology, growth and unemployment across European regions. *Regional Studies* 31, 457–466.
- Geary RC. 1958. A Note on the Comparison of Exchange Rates and Purchasing Power Between Countries. *Journal of the Royal Statistical Society. Series A (General)* 121, 97-99.
- Glaeser LE, Kallal HD, Scheinkman JA, Shleifer A. 1992. Growth in cities. *Journal of Political Economy* 100:6, 1126-1152.
- Griliches Z. 1992. The search for R&D spillovers. *Scandinavian Journal of Economics* 94 (Suppl.), 29–47.

Griliches, Z. 1998. *R&D and Productivity: The Econometric Evidence*. Chicago, IL: University of Chicago Press.

Grossman GM, Helpman E. 1994. Endogenous innovation in the theory of growth. *Journal of Economic Perspectives* 8, 23–44.

Hall BH, Mairesse J. 1995. Exploring the relationship between R&D and productivity in french manufacturing firms. *Journal of Econometrics* 65, 265-293.

Harris R, Trainor M. 2009. Why do some firms undertake R&D whereas others do not? *Spatial Economics Research Center Discussion Paper 20*, Retrieved from: <http://www.spataleconomics.ac.uk/textonly/serc/publications/download/sercdp0020.pdf> , last accessed at August 2012.

Harrison B, Kelley MR, Gant J. 1996. Innovative firm behavior and local milieu: Exploring the intersection of agglomeration, firm effects, and technological change. *Economic Geography* 72:3, 233-258.

Jaffe AB, Trajtenberg M, Henderson R. 1993. Geographic localization of knowledge flows as evidenced by patent citations. *Quarterly Journal of Economics* CVIII: 577–598.

Kalayci E. 2012. *Analyzing the Determinants of R&D, Its impact on Productivity and Efficiency of Firms in the Turkish Manufacturing Industry*, Unpublished PhD Thesis, Middle East Technical University, Ankara.

Kalayci E, Pamukcu MT. 2014. Assessing the drivers of R&D activities of firms in developing countries: evidence from turkey, *European Journal of Development Economics* 26:5, 853-869.

Karacuka M, Catik AN. 2011. A spatial approach to measure productivity spillovers of foreign affiliated firms in Turkish manufacturing industries. *DICE discussion paper 21* <http://hdl.handle.net/10419/45793>, accessed on June 30<sup>th</sup>, 2015.

Karray Z, Kriaa M. 2009. Innovation and RD investment of tunisian firms: a two regime model with selectivity correction. *Economic Research Forum Working Paper* 484.

Keller W. 2002a. Trade and the transmission of technology. *Journal of Economic Growth* 7:1, 5–24.

Keller W. 2002b. Geographic localization of international technology diffusion. *American Economic Review* 92:1, 120–42.

Laursen K, Meliciani V. 2000. The importance of technology-based intersectoral linkages for market share dynamics. *Review of World Economics (Weltwirtschaftliches Archiv)*, Springer, 136:4, 702-723.

Kumar N. 1987. Technology imports and local research and development in indian manufacturing. *The Developing Economies* 25:3, 220-233.

Lin H, Yeh RS. 2005. The interdependence between FDI and R&D: an application of an endogenous switching model to taiwan's electronics industry. *Applied Economics* 37, 1789-1799.

- Liu HL, Lin H, Peng, S. 2010. The spillover effects of R&D on manufacturing industry in taiwan's metropolitan areas. *Annals of Regional Science* 45, 519–546.
- Marshall A. 1890. *Principles of Economics*, Macmillan: London.
- Malecki EJ. 1997. Technology and economic development: the dynamics of local, regional, and national change. *University of Illinois at Urbana-Champaign's Academy for Entrepreneurial Leadership Historical Research Reference in Entrepreneurship*. Available at ssrn: <http://ssrn.com/abstract=1496226>.
- Moran P. 1948. The interpretation of statistical maps. *Biometrika* 35, 255-260.
- Moran P. 1950a. Notes on continuous stochastic phenomena. *Biometrika* 37, 17-23.
- Moran P. 1950b. A test for the serial dependence of residuals, *Biometrika* 37, 178-181.
- Nadiri IM. 1993. Innovations and technological spillovers. *NBER Working Paper* 4423.
- OECD. 1993. *Frascati Manual*, Paris: OECD.
- Pamukcu MT, Erdil E. 2011. R&D activities of multinational companies in emerging economies: analyzing the turkish case, *Paper presented at the ECON ANADOLU conference held in Eskisehir* June 15-17.
- Pavitt K. 1984. Sectoral patterns of technical change: towards a taxonomy and a theory, *Research Policy* 13:6, 343-373.
- Romer PM. 1994. The Origins of endogenous growth. *Journal of Economic Perspectives* 8:1, 3-22.
- Sasidharan S, Kathuria V. 2011. Foreign direct investment and R&D: substitutes or complements—A case of Indian manufacturing after 1991 reforms. *World Development* 39:7, 1226–1239.
- Schumpeter J. 1954. *Capitalism, Socialism and Democracy*. Harper and Row Publishing: New York.
- Smith V, Broberg AL, Overgaard J. 2002. Does location matter for firms' R&D behaviour? empirical evidence for danish firms, *Regional Studies* 36: 8, 825-832.
- Sun Y. 2002. Sources of innovation in china's manufacturing sector: imported or developed in-house? *Environment and Planning* 34, 1059–1072.
- Tandogan VS. 2011. *Impact Analysis of Industrial Research and Development Subsidy Programs in Turkey: An Appraisal of Quantitative Approaches*, Unpublished PhD dissertation, Middle East Technical University, Ankara.
- Taymaz E, Ucdogruk Y. 2009. Overcoming the double hurdles to investing in technology, R&D activities of small firms in developing countries. *Small Business Economics* 33, 109-128.

Un CA, Cuervo-Cazurra A. 2008. Do subsidiaries of foreign MNEs invest more in R&D than domestic firms? *Research Policy* 37, 1812–1828

Ucdogruk Y. 2009. R&D investment decision and internationalization: evidence form ISE listed firms, *Paper presented at EconAnadolu 2009: Anadolu International Conference on Economics*, June 17-19, 2009, Eskisehir.

VAN OORT FG. 2004. *Urban Growth and Innovation. Spatially Bounded Externalities in the Netherlands*. Gower Publishing: Ashgate, Aldershot.

Ward MD, Gleditsch K. 2008. *Spatial Regression Models*. London: Sage.

## Appendix

### A : Data coverage

Year	BERD*	Sample (Firm level)	Percent (%)
2003	510,351,896	171,000,000	33.51
2004	700,595,752	457,000,000	65.23
2005	1,297,591,429	792,000,000	61.04
2006	1,629,087,642	1,010,000,000	62.00
2007	2,513,487,115	869,000,000	34.57
Total	6,651,113,834	3,299,000,000	49.60

\* [www.tuik.gov.tr/PreIstatistikTablo.do?istab\\_id=1](http://www.tuik.gov.tr/PreIstatistikTablo.do?istab_id=1)

**B: List of Provinces with their license plate codes**

Code	Name	Code	Name	Code	Name
01	ADANA	28	GIRESUN	55	SAMSUN
02	ADIYAMAN	29	GUMUSHANE	56	SIIRT
03	AFYON	30	HAKKARI	57	SINOP
04	AGRI	31	HATAY	58	SIVAS
05	AMASYA	32	ISPARTA	59	TEKIRDAG
06	ANKARA	33	ICEL	60	TOKAT
07	ANTALYA	34	ISTANBUL	61	TRABZON
08	ARTVIN	35	IZMIR	62	TUNCELI
09	AYDIN	36	KARS	63	SANLIURFA
10	BALIKESIR	37	KASTAMONU	64	USAK
11	BILECIK	38	KAYSERI	65	VAN
12	BINGOL	39	KIRKLARELI	66	YOZGAT
13	BITLIS	40	KIRSEHIR	67	ZONGULDAK
14	BOLU	41	KOCAELI (IZMIT)	68	AKSARAY
15	BURDUR	42	KONYA	69	BAYBURT
16	BURSA	43	KUTAHYA	70	KARAMAN
17	CANAKKALE	44	MALATYA	71	KIRIKKALE
18	CANKIRI	45	MANISA	72	BATMAN
19	CORUM	46	KAHRAMANMARAS	73	SIRNAK
20	DENIZLI	47	MARDIN	74	BARTIN
21	DIYARBAKIR	48	MUGLA	75	ARDAHAN
22	EDIRNE	49	MUS	76	IGDIR
23	ELAZIG	50	NEVSEHIR	77	YALOVA
24	ERZINCAN	51	NIGDE	78	KARABUK
25	ERZURUM	52	ORDU	79	KILIS
26	ESKISEHIR	53	RIZE	80	OSMANIYE
27	GAZIANTEP	54	SAKARYA (ADAPAZARI)	81	DUZCE

**C: Classification of Manufacturing Industries as per Pavitt Taxonomy**

<b><u>Supplier Dominated</u></b>	<b>NACE 1.1</b>
Food products, beverages and tobacco	15-16
Textiles, wearing apparel, tanning, dressing and dyeing of fur, tanning, dressing and dyeing of leather, luggage, handbags, saddler, harness and footwear	17-19
Wood and products of wood and cork, except furniture, articles of straw and plaiting materials	20
Fabricated metal products except machinery and equipment	28
Furniture, Recycling	36-37
<b><u>Scale Intensive</u></b>	
Paper, pulp and paper products	21
Coke, refined petroleum products and nuclear fuel	23
Rubber and plastics products	25
Other non-metallic mineral products	26
Basic metals	27
Motor vehicles and trailers and semi-trailers	34
<b><u>Specialized Supplier</u></b>	
Publishing, printing and reproduction of recorded media	22
Machinery and equipment	29
Electrical machinery and apparatus	31
Other transport equipment	35
<b><u>Science Based</u></b>	
Chemicals and chemical products excluding pharmaceuticals	24
Office, accounting and computing machinery	30
Radio, TV and communication equipment and apparatus	32
Medical, precision and optical instruments, watches and clocks	33

Source: (Cetin, 2016)