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Scale and scope of university technology transfer: A flexible multiproduct approach

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Economies of scale and scope of university research and technology transfer: a flexible multi-product approach

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Abstract

This paper empirically analyzes the economies of scale and economies of scope in the production of research and technology transfer outputs in the Spanish public university system. We employ the flexible fixed quadratic cost (FFQC) function which relates the total university R&D expenditure with different outputs of research and technology transfer, from where we compute the ray economies of scale, the specific economies of scale and the economies of scope. From a survey of Technology Transfer Offices (TTO) network in Spain, data from the Institute of Documentary Studies on Science and Technology (IDSST) and from the Rector's Conference of Spanish Universities, we constructed a dataset for the period 2004 – 2008 and for 45 public universities. The results support the presence of ray economies of scale and product specific economies of scale. Our results also show that the cost subadditivity is positive constraint, meaning that there are economies of scope.

Key word: Multi-product cost function; Economies of Scale and Scope; Research and Technology transfer.

JEL classification: I21 and I23

1. Introduction

Traditionally, Higher Education Institutions (hereafter HEIs) have been focused on the production of teaching and research outputs, but in the past two decades, especially in industrialized countries, both universities and governments have increased their interest in the investment in innovation and research commercialization, and in encouraging more effective links between universities, government and enterprises (Etzkowitz and Leydesdorff, 1997 and 2000; Etzkowitz, 1998). This investment has been driven by a perceived need to smooth the progress of Technology Transfer (TT) from university inventions and discoveries to bear the economic and social development (Geiger, 2004; Mowery, 2007). On the other hand, HEIs have increased their motivation to commercialize research outputs for many reasons, mainly, the generation of new sources of income and strengthening cooperation links with firms.

Since the early 80's, research on the economics of higher education has recognized the possible economies of scale in the production of universities' outputs (Brinkmand and Leslie, 1986). A large number of studies (James, 1978; Jimenez, 1986; Cohn *et al*, 1989; Cohn and Geske, 1990; de Groot *et al*, 1991; Lloyd *et al.*, 1993; Koshal and Koshal, 1995 and 1999; Hashimoto and Cohn, 1997; Johnes, 1997; Longlong *et al.*, 2009; among others) have analyzed the economies of scale and scope for the HEIs, basically studying the relationship between the total university expenditure and the production of teaching and research outputs.

Cohn *et al.*, (1989) is one of the first studies that analyzed the HEIs system in the United States using multi-product cost function approach. They studied the economies of scale and scope for a large sample of 1,887 HEIs, practically covering all four-year institutions. This study was extended by de Groot *et al.*, (1991). Firstly, they focused on a subsample of 147 doctorate-granting universities, from which they draw specific conclusions about the economies of scale and scope for universities with a large research emphasis. Secondly, those authors carried out some sensitive analysis of the cost function estimates to different output measures for the research output, and finally, they test the impact of the estate regulation of personnel and financial administrative practices on production efficiency in HEIs.

In a subsequent study, Koshal and Koshal (1995) presented the relationship between cost and quality, pointing that previous studies have ignored this aspect in explaining the cost variations among HEIs. It is therefore important to assume that the average university cost varies depending on the quantity and the quality of the outputs. Moreover, in a more recent paper (Koshal and Koshal, 1999) these authors noted the importance of differentiating HEIs according to their specific goals, because it is not appropriated to perform the same analysis for small colleges with specific interest in teaching along with large universities where research plays a major role.

The main conclusion of the studies mentioned above is the existence of ray economies of scale, product specific economies of scale and economies of scope in the production of teaching and research outputs, nonetheless, the marginal cost coefficients associated to the outputs of teaching and research vary significantly across the different studies.

Until now, the discussion about the complementarity or substitutability between research and teaching outputs has been stressed out in different ways concluding that HEIs behave as multi-product firms, demonstrating the presence of economies of scale and scope. However, it is well known that in recent years, the goals of universities have gone beyond research and teaching, and gradually, the TT has gained more importance for universities, governments and the private sector. Little has been said about the presence of economies of scale and scope in the production of knowledge in universities, approached by the research and the TT outputs, what is the main objective of this paper.

This paper empirically analyzes the economies of scale and economies of scope in the production of research and TT outputs in the Spanish public university system. We employ the flexible fixed quadratic cost (FFQC) function which relates the total university R&D expenditure with different outputs of research and TT, from where we calculate the Ray Economies of Scale, the Specific Economies of Scale and the Economies of Scope, based on the Baumol, Panzar and Willing (BPW) model (Baumol *et al.*, 1982).

For this analysis we use a survey of 45 public universities in Spain for the period 2004 - 2008. The dataset was constructed from three different sources: (i) the survey of

Technology Transfer Offices (TTO), from which we get the information about the university TT outputs; (ii) the Institute of Documentary Studies on Science and Technology (IDSST), from where we get the university research outputs; and (iii) the Rector's Conference of Spanish Universities, from where we get the basic university' characteristics. We estimate a GLS cross-sectional time series controlling for heteroscedasticity.

The paper is structured as follows: In section II we analyze the HEIs research and TT cost function, describing the total cost of the production of research and the transfer of technology. Section III formulates the methodology used in this study. Section IV describes the data employed, the estimation results and the calculation of the ray economies of scale and economies of scope, and section VI concludes.

2. The HEIs research and technology transfer cost function.

The objective of this paper is to estimate a multi-output cost function for HEIs, and to calculate the degree of scale and scope economies, in the production of research and in the transfer of technology. Therefore, we need to identify the total university cost of the production of knowledge, followed by the different outputs of this production function.

Total cost of research and technology transfer

The total university cost of the production of research and transfer of technology is approximated by the university expenditure on R&D activities. This expenditure consists of two components: (i) the salary component, which represents salaries, remunerations and complementary expenditures on R&D personnel. (ii) Other current expenditure, such as, the purchase of materials, supplies and support equipments, etc. For more information about the measurement of the R&D expenditure see the Frascati manual and the National Institute of Statistics of Spain (INE).

We consider that the university expenditure on R&D is a good measure to approximate the total cost of the production of research and the transfer of technology, since it represents, only the budget share devoted to the activities analyzed in this study,

allowing us to avoid the analysis of teaching outputs, what is not the objective of this paper.

Research and technology transfer outputs

HEIs are extremely complex organizations and seek to achieve multiple goals simultaneously (Cohn *et al.* 1989), therefore, the identification of inputs and outputs is a complex task. The university outputs must have two basic characteristics. Firstly, they must be clearly separable between distinct objectives of the university, and secondly, they should be homogeneous and comparable across different HEIs. It is relevant to point out the absence of consensus on appropriated outputs of research and TT.

The Research Outputs

The research output, ideally, should include different measures, such as publications, patents, research reports, etc. However, the outputs mentioned above not always are homogeneous among HEIs, and for that reason, they are not necessarily comparable. In the analysis of the economies of scale and scope for the HEIs, the research outputs have been approximated by different ways, for example, Cohn *et al.* (1989) used as research output the amount of grants for research received by an HEI. Other studies like Koshal & Koshal (1999) and Longlong *et al.* (2009), the authors used the level of research expenditure of each HEI. From other hand, de Groot *et al.* (1991) used the total number of publications as research output.

We have selected a more specific variable to measure the research output – the total number of scientific articles published in journals belonging to the Journal Citation Report (JCR). This measure approximate better the research output, than the grants and the level of research expenditure of an HEI, because grants and research expenditure, in some instances, are used for different proposes than research. Moreover, by taking only JCR scientific articles we not only control for the heterogeneity in the scientific production, but also we introduce some quality consideration, as JCR is the standard in scientific research. This variable allow us to have a perfect comparable research output among HEIs

The Technology Transfer outputs

In the literature have been used a large number of variables to approximate the transfer of technology from universities to the private and public sector. All those variables could be classified into four groups: The first refers to the intellectual property, this group includes indicators such as communications of inventions, patent applications and non-disclosure agreements that protect the know-how of the university. The second group is composed by the licenses and options, such as firm licenses to use and exploit technologies developed by universities. The third group consists of R&D contracts and collaboration between businesses and universities. Finally, the fourth group refers to the creation of firms inside the universities, whether based on the knowledge generated by universities (spin-off) or entrepreneurial companies formed by university students or teachers, although these are not based on specific knowledge created by universities (Start-ups).

The most common indicators of technology transfer are the number of patents or its royalties (Siegel *et al.*, 2008; Spyros *et al.*, 2008; Thursby and Thursby, 2007, among others) and the number and value of the R&D contracts (Link *et al.*, 2007; Link and Siegel, 2005; Spyros *et al.*, 2008 and Brouwer, 2005, among others). For this paper we have selected the total value of R&D contracts generated by an HEI. This measure truly approximates transfer of technology generated in HEIs to the society, and at the same time, gives us an idea of the quality of the technology transferred, since the total value is not only a proxy of the capacity to transfer technology, but also the quality of the technology transferred.

Faculty Salary

The literature about the Economies of Scale and Scope in the HEIs has discussed the advantages or disadvantages of the introduction of input prices in the multi-product cost function. On one hand, according to Cohn *et al.* (1989) and Koshal and Koshal (1999), the HEIs are labor intensive firms. Consequently the faculty is the most important input price and it could alter the output mix. Therefore, the faculty salary must be included in the multi-product cost function. On the other hand, de Groot *et al.* (1991) argued that academic market is quiet competitive and a variation on the faculty salary will only

reflect a variation in productivity; therefore, there is no point to calculate returns to scale at a given level of salary.

In our case, the faculty salary approaches some specific university characteristics, such as the academic staff structure and the age of the staff. These characteristics should be taken into account in the calculation of the total cost function. Nonetheless, the faculty salary coefficients must be analyzed only as a control variable, and not as a factor that explains variations in the cost function.

3. Methodology: the multi-product cost functions

We follow the seminal work of Baumol, Panzar and Willing (Baumol *et al.*, 1982) (hereafter BPW). The basic specification of the model is a flexible cost quadratic function (FCQ). The FCQ function becomes

$$C = \alpha + \sum_{i=1}^N \beta_i Y_i + \frac{1}{2} \sum_{i=1}^N \sum_{j=1}^N \delta_{ij} Y_i Y_j + \varepsilon \quad (1)$$

Where C is the university R&D expenditure, α , the constant term, the β_i 's and the δ_{ij} 's are scalars, and ε is an error term.

We also include both linear and quadratic terms for input prices, as well as the interaction terms with the different outputs. In principle this specification sacrifices the linear homogeneity property of the function with respect to factor prices, but according to Cohn *et al.* (1989) in the analysis of the characterization of HEIs, the linear homogeneity property is not relevant in the analysis of this kind of institutions. However, HEIs are labor-intensive firms; therefore the faculty salary is the most important input price and it could alter the output mix. By other hand, the faculty salary is a way to control for the unobservable heterogeneity across different universities cost functions. Finally, in the case of HEIs, it is reasonable to expect a positive bidirectional relationship between the quantity of output produced and the faculty compensation.

Economies of scale and Scope

Following the BPW model, we are able to distinguish the ray economies of scale, measuring the overall scale economies and the product-specific economies of scale, and the economies of scope, where we measure the degree of complementary between outputs.

The ray economies of scale: let $C(Y)$ be the total cost of producing the “N” outputs (Y_i), and let $C_i = \delta C(Y)/\delta Y_i$ be the marginal cost of producing the i^{th} output. Then the ray economy of scale coefficient, $S_n(Y)$, is defined by:

$$S_n(Y) = \frac{C(Y)}{\sum_{i=1}^N Y_i C_i(Y)} \quad (2)$$

Ray economies of scale exist if $S_n(Y)$ is greater than unity, and diseconomies of scale are present when $S_n(Y)$ is lower than one.

The degree of product-specific economies of scale with respect to product “i” at Y , $S_i(Y_i)$ is defined as:

$$S_i(Y_i) = \frac{C(Y) - C(Y_{n-i})}{Y_i C_i(Y)} \quad (3)$$

Where $C(Y_{n-i})$ is the cost of producing all the outputs except the i^{th} . If $S_i(Y_i)$ is greater (lower) than one, we say there exist economies (diseconomies) of scale of producing the Y_i . This measure is interpretable as the specific return to scale in increasing the production of the analyzed output.

The economies of scope exist when it is cheaper to produce Y_i in conjunction with Y_j , rather than the production of these outputs separately. The degree of economies of scope, $SC_t(Y)$, for a product set “t” is defined as:

$$SC_t(Y) = \frac{[C(Y_t) + C(Y_{n-t}) - C(Y)]}{C(Y)} \quad (4)$$

Where $C(Y_t)$ is the cost of producing only the outputs in the product set “t”, and $C(Y_{n-t})$ is the total cost of producing all the outputs except those in the subset “t”. Economies of

scope exist when $SC_t(Y) > 0$. If $SC_t(Y)$ is positive at Y , then the fragmentation of production to “t” and its complement would increase the total cost.

4. Economies of Scale and Scope

Data and estimation of the multi-product cost function

For this empirical analysis we have created a dataset of 45 public universities in Spain for the period 2004-2008. The information comes from three different databases: (i) the information about the total university R&D expenditure and the information about the value of the R&D contracts come from a survey conducted yearly by TTO network in Spain. (ii) The Institute of Documentary Studies on Science and Technology (IDSST) provides the number of scientific articles published in JCR journals. (iii) The basic university characteristics are taken from the Rector’s Conference of Spanish Universities. Descriptive statistics are presented in table 1 and the evolutions of the main variables used in this analysis are presented in table 2.

Table 1 & Table 2

As we mentioned in section II, the variables used to calculate the Economies of Scale and the Economies of Scope are: (i) The total university expenditure on R&D (C(R&D)). (ii) The total value of the R&D contracts (TT). (iii) The JCR articles (R). And (iv) The average faculty salary (FS). From the equation (1) presented in section 3, the Quadratic Multi-product Cost Function becomes:

$$C_{it}(R\&D) = \alpha + \beta_1 R_{it} + \beta_2 TT_{it} + \delta_{11} R_{it}^2 + \delta_{12} R_{it} \cdot TT_{it} + \delta_{22} TT_{it}^2 + \rho_1 FS_{it} + \rho_{11} FS_{it}^2 + \rho_{1R} FS_{it} \cdot R_{it} + \rho_{1TT} FS_{it} \cdot TT_{it} + \varepsilon_{it} \quad (5)$$

We estimate a cross-sectional times-series generalized least squares controlling for heteroscedasticity¹. We also estimate the equation (5) without the faculty salary, and the results hold, almost constant. The estimation results are presented in table 3.

¹ In a previous estimation we used a simple OLS, and following Koshal and Koshal (1999), the residuals were tested for heteroscedasticity. The Breusch-Pagan test shows the presence of heteroscedasticity.

Table 3

The coefficients of the variables analyzed are statistically significant and have the expected sign. The outputs coefficients are positive and significant, implying that an increase in the level of each output will increase the total university expenditure on R&D. The interaction coefficient between the TT and research output is significant and negative, suggesting complementarity between these outputs. This result holds even when we analyze the multi-product cost function without the faculty salary as a proxy of the input price.

The faculty salary coefficient is negative and significant. This result is apparently contradictory, since one would expect that the total cost would increase as the faculty salary is higher. However, due that the faculty salary we are using does not correspond directly to the wage paid to teachers to do research and TT, this bidirectional relationship between the cost and the faculty salary does not apply. Nevertheless, the interaction coefficients between the faculty salary and the research and TT outputs are negative and significant. On the other hand, the coefficient of the interaction –Faculty salary and Research- is significantly higher than the coefficient of the interaction between the faculty salary and the TT output. This result could be explained by the fact that the faculty salary depends directly on their research skills. Similarly, a portion of the income from R&D contracts between HEIs and private institutions became part of the faculty salary. It is therefore reasonable to expect a complementarity relationship between the faculty salary and the different outputs analyzed.

Calculation of the Economies of Scale and the Economies of Scope

The calculation of the Economies of Scale and Scope is based on the estimated results of the multi-product cost function including the faculty salary (second column of table 3). From these results we have calculated the Ray Economies of Scale, the Product Specific Economies of Scale, and the Economies of Scope, using the set of equations 2-4 presented in the third section.

According to the results (table 4), the correlation coefficient between the total TT output and the marginal cost of TT $\left(MgC_{TT} = \frac{\partial C(R\&D)}{\partial TT}\right)$ is negative and equal to -0.402. Therefore, the marginal cost of TT decreases as the TT output increases. On the other hand, the correlation coefficient between the research output and the marginal cost of research $\left(MgC_R = \frac{\partial C(R\&D)}{\partial R}\right)$ is positive and equal to 0.178, which means that an increase in the research output will lead to an increment in the marginal cost of research. Moreover, the marginal cost ratio (MgC_R/MgC_T) increases with the level of outputs. This result implies that for HEIs with a high level of research and TT outputs is more expensive to increase the research output comparatively to the TT output.

The calculated Ray Economies of Scale, the Product Specific Economies of Scale and the Economies of Scope based on a fixed level of R&D expenditure are presented in table 5. The results show that the Ray Economies of Scale disappear when the level of expenditure on R&D exceeds the threshold of 100% of the expenditure on R&D, in the same way, the research Specific Economies of Scale disappear in this level of R&D expenditure, while the TT Specific Economies of Scale remind greater than one till the level of R&D expenditure exceeds the threshold of 150%. The Economies of Scope also disappear when the level of R&D expenditure is higher than 100%.

The Ray Economies of Scale remind greater than one until the level of TT output (table 6) is lower than its average, while the specific economies of scale of the research and TT outputs are greater than one, even when the level of TT output exceeds the 200%. Likewise, the Economies of Scope remind positives until the level of TT output is greater than 200%. On the other hand, when analyzing the Economies of Scale and Scope based on the level of research output (Table 7) we have found that the Ray Economies of Scale, the Product Specific Economies of Scale and the Economies of Scope disappear when the research output is larger than 100%, meaning that HEIs with a large production of research outputs experiment diseconomies of scale and the subadditivity is negative constraint, which implies that the production of research and TT outputs separately will lead to lower cost.

There is a positive bidirectional relationship between the Economies (Global and Specific) of Scale and the Economies of Scope. This relationship is basically explained

by high correlation between the Economies of Scope and the Research Specific Economies of Scale (see graphic 2). While the degree of adjustment between the Scope Economies and the TT Specific Economies of Scale, although positive, is lower than in the case of the research economies of scale (see graphic 3).

From the graphic 1, we were able to identify two groups of HEIs. The first one composed of HEIs which neither presents Ray Economies of Scale nor Economies of Scope. The HEIs belonging to this group are characterized, with a few exceptions, by being the oldest and the larger HEIs in terms of the number of teachers and students. On the other hand, the second group consists of 26 HEIs that present Economies of Scale and Scope. This second group is characterized by having the newest and smallest HEIs. One of the main reasons that explain this result is that the newest and smallest HEIs are more flexible, allowing them to adopt more efficient production structures.

5. Conclusions

The objective of this paper is to calculate and analyze the economies of scale and scope in the production of research and TT outputs. We have used a dataset composed of 45 public Spanish universities in the period 2004-2006, where we find the different outputs of research and TT, as well as, the total cost of the production of these outputs. We have used the faculty prices to control for some specific characteristics of each HEI.

The results show that the marginal cost of research at the average output is 33.8 times higher than the TT marginal cost. Moreover, the marginal cost of TT decreases with increments of the level of TT output, while the marginal cost of research increases with increasing of its level of output. On the other hand, the marginal cost ratio (MgC_R/MgC_T) increases with the level of output, which means that for a HEIs with a high level of the output mix is less expensive to produce TT than research.

Our main findings show that there exist Ray Economies of Scale and Economies of Scope below the 100% of mean R&D expenditure. The TT Specific Economies of Scale remind higher than one until the mean R&D expenditure exceeds the 150%, while the Research Specific Economies of Scale disappear when the mean R&D expenditure is above 100%.

When analyzing the degree of economies of scale and scope for alternative levels of outputs we found that the Ray Economies of Scale, as well as the Specific Economies of Scale and the Economies of Scope disappear when the Research output level exceed 100%. While, the Specific Economies of Scale and the Economies of Scope exist, until the TT output level reach the 200%.

Finally, we were able identify two clearly differentiated kinds of HEIs. The first one characterized by grouping the oldest and biggest HEIs which do not have economies of scale or scope. And the second group which is composed by the newest and smallest HEIs which have Economies of Scale and Economies of Scope. One of the main reasons that explain this result is that the newest and smallest HEIs are more flexible, allowing them to adopt more efficient production structures.

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Table 1. Descriptive statistics

	<i>Obs</i>	<i>Mean</i>	<i>Std. Dev</i>	<i>Min</i>	<i>Max</i>
<i>R&D expenditure (thousands)</i>	202	56,557.57	43,928.44	4,871.00	201,529.00
<i>Value of R&D contracts (thousands)</i>	213	8,030.12	10,464.78	38.00	82,998.08
<i>JCR Publications</i>	228	658.24	538.01	79.00	2,529.00
<i>Faculty salary (thousands)</i>	228	61.41	11.37	27.85	86.23

Table 2. Evolution of the multi-product cost function

	<i>R&D expenditure</i>	<i>Value of R&D contracts (€)</i>	<i>JCR Publications</i>	<i>Faculty salary</i>
2004	46,553.61	5,273.98	553.51	57.51
2005	53,361.94	7,196.04	623.54	59.74
2006	55,707.40	8,507.26	679.86	61.52
2007	59,893.08	9,536.93	727.97	62.82
2008	64,520.06	9,713.39	708.15	65.57

Table 3. Estimation results of the Multi-product cost function

	Without Faculty Salary	With Faculty Salary
<i>Value of R&D contracts</i>	3.516 (0.534) ^{***}	3.277 (0.625) ^{***}
<i>Value of R&D contracts</i> ²	$9.76 \cdot 10^{-06}$ ($5.91 \cdot 10^{-06}$) [*]	$-1.26 \cdot 10^{-05}$ ($6.53 \cdot 10^{-06}$) [*]
<i>JCR Publications</i>	70.963 (7.0542) ^{***}	85.050 (14.818) ^{***}
<i>JCR Publications</i> ²	0.007 (0.004) [*]	0.010 (0.004) ^{**}
<i>Value of R&D contracts</i> * <i>JCR Publications</i>	-0.003 (0.0005) ^{***}	-0.001 (0.0005) ^{***}
<i>Faculty Salary</i>	-. (199.362) ^{***}	-1061.619 (199.362) ^{***}
<i>Faculty Salary</i> ²	-. (1.956) ^{***}	14.791 (1.956) ^{***}
<i>Faculty Salary</i> * <i>Value of R&D contracts</i>	-. (0.008) ^{***}	-0.032 (0.008) ^{***}
<i>Faculty Salary</i> * <i>JCR Publications</i>	-. (0.252) ^{**}	-0.593 (0.252) ^{**}
<i>Constant</i>	2145.225 (1546.595)	20615.731 (6447.973) ^{***}

Note: Standard errors are in Parenthesis. *, **, *** denotes the significance at 90%, 95% and 99%, respectively

Table 4. Marginal Cost of Research and TT for different levels of output

	MgC _{TT}	MgC _R	MgC _R /MgC _{TT}
Min - 50%	2.194	69.929	31.875
50% - 100%	2.119	71.709	33.840
100% - 200%	1.367	71.517	52.303
200% - Max	1.326	75.133	56.679

Table 5. Degree of Scale and Scope Economies for alternative proportions of R&D expenditure

% of mean R&D expenditure	<i>Sn</i>	<i>Stt</i>	<i>Sr</i>	<i>Scope</i>
<i>Min - 50%</i>	1.192	1.825	2.120	1.439
<i>50% - 100%</i>	1.067	1.851	1.504	0.613
<i>100% - 150%</i>	0.865	1.077	0.737	-0.353
<i>150% - Max</i>	0.815	0.695	0.786	-0.346

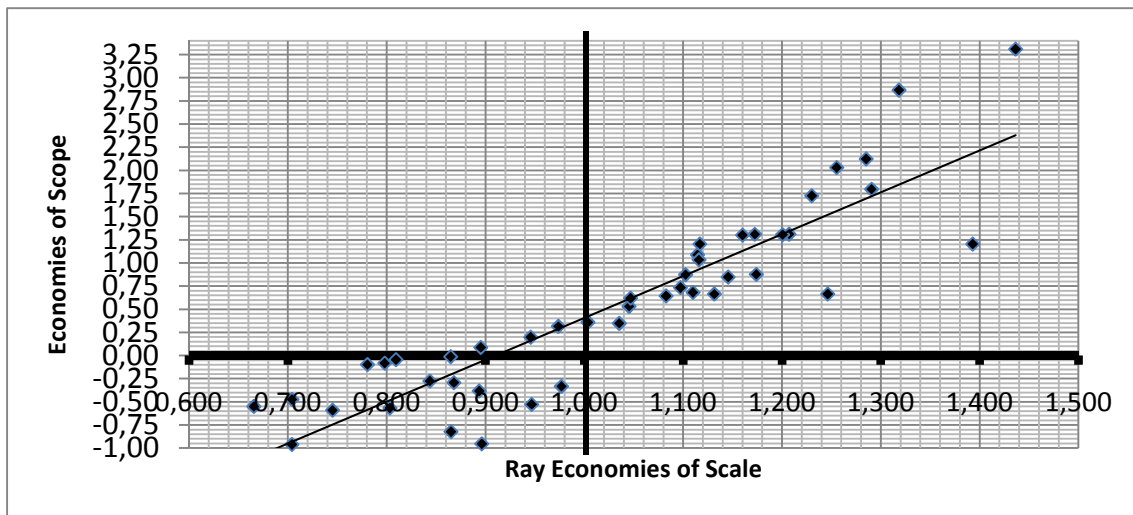
Table 6. Degree of Scale and Scope Economies for alternative proportions of TT output

% of mean TT output	<i>Sn</i>	<i>Stt</i>	<i>Sr</i>	<i>Scope</i>
<i>Min - 25%</i>	1.229	1.483	2.364	1.808
<i>25% - 50%</i>	1.105	1.459	1.628	0.748
<i>50% - 100%</i>	1.039	1.808	1.278	0.310
<i>100% - 200%</i>	0.919	1.250	1.046	0.099
<i>200% - Max</i>	0.780	0.975	0.684	-0.538

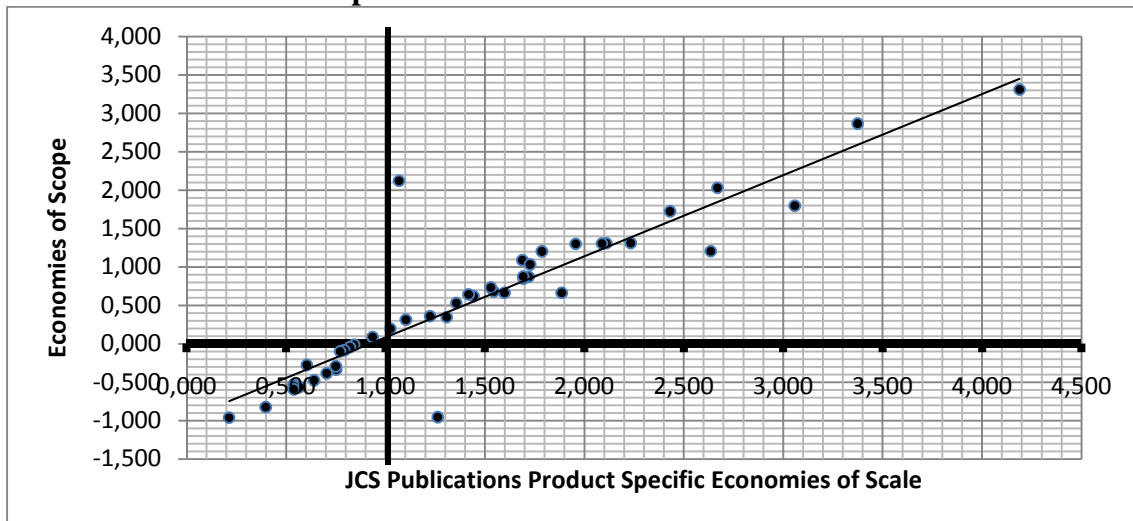
Table 7. Degree of Scale and Scope Economies for alternative proportions of Research output

% of mean R output	<i>Sn</i>	<i>Stt</i>	<i>Sr</i>	<i>Scope</i>
<i>Min - 25%</i>	1.333	1.412	2.922	2.523
<i>25% - 50%</i>	1.160	1.793	1.902	1.036
<i>50% - 100%</i>	1.061	1.694	1.373	0.474
<i>100% - 200%</i>	0.852	0.979	0.788	-0.307
<i>200% - Max</i>	0.751	0.743	0.713	-0.251

Graphic 1. Relationship between the Ray Economies of Scale and the Economies of Scope



Graphic 2. Relationship between the Research Product Specific Economies of Scale and the Economies of Scope



Graphic 3. Relationship between the TT Product Specific Economies of Scale and the Economies of Scope

