European Union
European Social Fund
OPERATIONAL PROGRAMME
EDUCATION AND LIFELONG LEARNING
investing in knowledge society
MINISTRY OF EDUCATION & RELIGIOUS AFFAIRS
MANAGING AUTHORITY
Co- financed by Greece and the European Union
NSRF 2007-2013
programme for development
EUROPEAN SOCIAL FUND

The Knowledge stock of Greek R&D active manufacturing firms: Based on published financial accounts for the period 2001-2010[1]

A. Gkypali[a], A. Rafailidis[b+], and K. Tsekouras[a],

[a]*Department of Economics, University of Patras, University Campus, Rio, 26504, Patras Greece*

[+b]*Corresponding author:* arafail@teipat.gr

Department of Business Administration, Technological Educational Institute of Western Greece, 1st, M. Alexandrou, Koukouli, 26334, Patras, Greece

Abstract

In this paper we are concerned with methodologically approximating Greek R&D active firms' knowledge base. It is the first systematic effort to record and measure with high accuracy the knowledge stock of firms that report R&D expenditures at an annual basis, for a ten year period. In this line, a careful assessment of the available information has been required since there is a structural change in the financial standards literature. Based on the Schumpeterian premises of the importance of firm size and technological opportunities, some basic key findings on the anatomy of the distribution of Greek R&D firms' knowledge base with respect to firm size and technological opportunities are presented.

1. Introduction

Despite the fact that the degree of knowledge production is commonly approximated with the intensity of R&D activities, defined as the ratio of R&D expenditures to firm's annual sales, the most informative way of measuring such a production is to employ the firm's knowledge capital which encompasses a dynamic

[1] This research is implemented through the Operational Program "Education and Lifelong Learning" and is co – financed by the European Union (European Social Fund) and Greek national funds.

scope of knowledge production contrary to the static one provided by R&D intensity (Dierickx and Cool, 1989; Goto and Suzuki, 1989, Kumbhakar et al 2012). However, the availability of data for R&D expenditures on a yearly basis and for a significant time period is often an insurmountable barrier. This paper presents the methodological approximation of the knowledge base of Greek manufacturing firms that have been engaged in R&D activities during 2001-2010. More specifically, and based on firms' annual published financial accounts, it was possible to construct their knowledge stock for the period 2001-2010.

The next section is devoted in presenting the handling of information from the financial accounts, along with the adopted methodology for the construction of the GRD firms' knowledge stock. In section 3, the particularities and specificities of handling information of Greek published financial accounts is presented, while section 4 presents some basic findings regarding the knowledge intensity of Greek R&D active firms as they have been dictated by Schumpeterian patterns of innovation. Section 5 concludes the paper.

2. The construction of Greek R&D Manufacturing firms' knowledge capital

In order to get a grasp of a firm's knowledge base one has to approximate it, since it is not possible to have an accurate measure containing all the elements which comprise the firm's knowledge base. What one can do, however, is to exploit the firm's investments in the creation and/or acquisition of knowledge assets and construct its knowledge stock for a certain period of time. Towards this direction, and following the relevant literature, the most prominent way for the calculation of a firm's knowledge stock (Hall et al. 2010) is the perpetual method[2]:

$$K_{it} = (1-\delta)K_{i,t-1} + R_{it} \quad (1)$$

where K is the knowledge stock of firm i at time t, R denotes annual investments in the creation and/or acquisition of knowledge assets[3] at time t and δ is a suitably chosen (private) depreciation rate. Some issues need to be discussed at this point

[2] In order to assist the reader in understanding both the methodological approach, but also the handling of information derived from annual financial published accounts, Table 1 in the Appendix section lists all the variables employed in this endeavor along with a short definition.

[3] We follow the definition of R&D investments given by International Accounting Standards (IAS 38), where particular emphasis is given to the term 'intangible assets'. Therefore, we are interested in measuring the investments in knowledge creation and/or acquisition, as they are perceived and reported by Greek firms in their annual financial statements.

regarding the nature, or in other words, the decomposition of Greek firms' R&D expenditures as well as their initial level of knowledge capital stock.

First of all, and regarding the initial level of the Greek firms knowledge capital stock, the time period under examination is the decade 2001-2010. Within the sample of firms, quite many of them report R&D expenditures for the year $t_0 = 2001$. However, it is reasonable to assume that their R&D activities had been taking place before t_0. In order to cope with this issue we follow Hall et al. (2010) and calculate the knowledge capital stock at t_0 as follows:

$$K_{it_0} = \frac{R_{it_0}}{\delta_{is} + g_{ij}} \tag{2}$$

where δ_{is} is the depreciation rate of the *ith* firm which depends on the four sectors *s* established by OECD[4] and g_{ij} is the knowledge investments growth rate at the industry level *j*[5].

Turning now to the components of Greek firm's R&D expenditures, we need to discuss and elaborate a bit more on the process of their calculation. It is commonly known that published data for R&D expenditures of Greek firms do not exist in a systematic and organized manner. Therefore, and in order to gather such information, we have employed the annual published financial records of Greek firms for the period 2001-2010 identifying those who have reported expenditures of that sort. In the following paragraphs we will refer more elaborately to issues encountered during the management and construction of the annual R&D investments and thus, the Greek firms' knowledge stock during the period 2001-2010.

Essentially, annual R&D investments (R_{it}) are calculated employing two main components from the firms' published financial accounts, each one of them having different properties not only from an accountant's point of view but also from an economist's point of view. More specifically, the first source of identified R&D investments lies in the firm's published intangible assets. Within this category we have isolated those knowledge investments that the firm has capitalized, entailing not only expenditures on R&D but also on licenses, patents and other corresponding

[4] Hatzichronoglou (1997) defined four sectors based on their technological dynamism namely, (i) High-tech, (ii) Medium High-tech, (iii) Medium Low-Tech and (iv) Low-tech Sector. It should be noted that the depreciation rate varies from 12% to 8% and the more technologically advanced a sector is the more annual depreciation in its knowledge stock will suffer.

[5] It is calculated as the cumulative average growth for the period 1990-2000 and data are taken from the OECD ANBERD database.

permissions. Finally, the third source of R&D investments comes from the Income Statement where the firm reports annual expenses on R&D that have not yet been capitalized. In the following sections, a condensed but informative description will be presented in order for the reader to understand the procedures that have taken place for the construction of the knowledge stock database of Greek firms.

3. Handling of the Greek firms' published annual accounts

As it has been previously stated, the period of interest for the construction of the Greek firms' knowledge base is between 2001 and 2010. During that time, however, a major change has occurred involving the Standards that Greek firms were obliged to follow for the publication of their annual accounts. In particular, in 2004, a bill was passed obliging those firms which either directly participate in the stock market or are part of a Group to publish their financial accounts following the International Accounting Standards (IAS). The rest of the firms had the option to continue publishing their annual financial accounts following the National Accounting Standards (NAS).

The main differences regarding R&D expenditures measurement and publishing are the following: *(i)* Firstly, the IAS dictate that Research should be separated from Development, which in NAS this is not necessarily the case; (ii) secondly, the method for the valuation of (intangible) assets differs between the two standards in that the IAS dictate that the valuation of assets is done at their 'current price' taken the last day of the financial year, whereas the NAS dictate that the valuation of assets is done by selecting the lowest value between current and purchase price. One can see that the IAS tend to be less strict than NAS, and this had an impact on our R&D expenditures measurement; (iii) thirdly, the IAS are by philosophy less detailed than NAS and therefore, crucial information needed in order to calculate annual R&D investments and thus, Greek firms' knowledge stock had to be estimated[6].

Shifting the attention towards the approach adopted in order, firstly, to calculate the annual R&D investments and based on that apply (1) and construct the knowledge stock of Greek firms in our sample. As previously stated, R&D investments at the firm level were not readily available by some institution at National

[6] These differences were made clear after several discussions with Professional and Academic Accountants.

and/or European level. Therefore, after the identification of the firms that report investments in the creation and/or acquisition of new knowledge in their annual financial accounts for the time period under examination, we had to further process the values reported, since depending on whether they were reported as assets or expenses they had to be treated differently. More specifically, for the expenditures reported as assets we were provided with the book values for the cumulative (i) R&D investments $\left(CR_t\right)$, (ii) depreciation $\left(CRd_t\right)$ and (iii) net value $\left(CRNV_t\right)$, and also cumulative (i) investments in various forms of industrial property rights such as licenses and patents $\left(CIPR_t\right)$, along with their corresponding depreciation $\left(CIPRd_t\right)$ and net value $\left(CIPRNV_t\right)$ for the year *t* or else

$$CRNV_t = CR_t - CRd_t \tag{3}$$

$$CIPRNV_t = CIPR_t - CIPRd_t \tag{4}$$

It becomes obvious from (3) and (4) that in their current form these values are not suitable for the calculation of annual firm R&D investments. Hence, these two categories that belong to firm intangible assets had to be treated the same way. In order to calculate the annual investments in knowledge creation and/or acquisition for the year *t* from the category of assets we applied the following

$$RD_t = CR_t - CR_{t-1} \tag{5}$$

and

$$IPR_t = CIPR_t - CIPR_{t-1} \tag{6}$$

The third category is reported in the Profit and Loss account and entails annual R&D expenses $\left(ARD\right)$ reported by the firm that are not yet capitalized. Hence, there is no particular handling of these expenditures, just adding them to the other two components of the annual R&D investments $\left(R_{it}\right)$. In sum, R_{it} is calculated as follows

$$R_{it} = RD_{it} + IPR_{it} + ARD_{it}, \qquad R_{it} \geq 0 \qquad (7).$$

The above formula is applied in the entire sample of Greek firms. In the following paragraphs some issues will be further discussed involving frequently encountered problems during the calculation of R_{it}.

3.1 Management of financial statements that continuously followed NAS

Essentially, the entire sample can be divided into two main categories, namely (i) those firms that publish their annual financial accounts continuously following the National Accounting Standards (NAS) and (ii) those firms that at one point within the time period studied made the transition to IAS. Regarding the first category, the main and most frequent problem is when for some reason the firm decides to depreciate the cumulative expenditures on either of the two categories of the intangible assets described above.

In more detail, from (7) one can see that the annual investments in knowledge assets cannot be less than zero. Therefore, the outcome of the difference in (5) and (6) should be non negative. Such a constraint is posed because in the process of constructing the firm's knowledge stock, the flows which fuel the augmentation of the firm's knowledge base cannot possibly be negative. From a theoretical perspective, knowledge base formation is fueled by knowledge flows which in turn, may entail augmenting, complementing, substituting, decaying or even destructing elements of knowledge. In any of the above cases it could never be argued that a knowledge flow could be subtracted from the firm's existing knowledge capital. At this point, it should be noted, that the treatment within the two components of intangible assets i.e. RD_t and IPR_t is somewhat different, for reasons concerning the realistic assumptions described above. More specifically, regarding firms' R&D investments, the knowledge flows can in no case be negative, in the case of investments in Industrial property rights a negative knowledge flow could imply not a decrease in knowledge but a decrease in the economic exploitation of it. However, this assumption can only hold if the outcome of (7) remains non negative. If not, then the handling of such cases is described below.

When the cumulative expenditures were depreciated, for instance at time *t+1* they are replaced with the cumulative expenditures of the previous year *t* so as to minimize the knowledge flow and equate it with zero or in other words $CR^*_{t+1} = CR_t$ and thus, $RD^*_{t+1} = 0$, i.e. the knowledge flow for the year *t+1=0*. However, if the cumulative investments of the firm increase at a later year, for instance at *t+2*, then the annual knowledge flows are calculated based on the original values, that is $CR_{t+2} - CR_{t+1} = RD^*_{t+2}$, and then, the difference is added in the replaced value of the year which had suffered the depreciation or in other words, $\left(CR^*_{t+1} + RD^*_{t+2}\right) - CR^*_{t+1} = RD^*_{t+2}$.

3.2 Management of financial statements that switched at some point to IAS

As it was previously stated, a significant number of firms in our sample have made the transition at some point within the time framework under investigation from NAS to IAS. This transition has impacted our measurement for several reasons that have been mentioned above. In order to handle the measurement problems created by the transition, some rules had to be followed so as to have a unifying, to the extent possible, adjustment procedure given the occurring structural break.

First of all, it should be mentioned that the NAS had distinct codes in which expenditures were reported not only for R&D but also for IPR, whereas in IAS the category of "Intangible assets" is more aggregated and many other expenditures are also reported. In addition, the bill passed in 2004 dictated that when the firms made the transition, they were advised to publish their financial statements following both standards in order for their investors to get acquainted with the differences. Furthermore, the period 2004-2006 had been characterized as a transitional period in which the IAS and NAS had quite many similarities. For investments in knowledge assets during this period extra information was provided and, more specifically, we were provided with cumulative (i) expenditures in intangible assets, (ii) depreciation and (iii) net value. It should be mentioned at this point, that normally when publishing financial statements following the IAS and with respect to assets, firms only report the net value of its assets.

Based on the above facts a two step-procedure was set up in order, firstly, to estimate the cumulative expenditures on knowledge assets for the period 2007-2010, and, secondly, to adjust these expenditures to the equivalents when they were published following the NAS. More specifically, the cumulative Net Value is calculated as $CNV_t = CE_t - Cd_t$ where CE_t is the cumulative expenditure in intangible assets at year t and Cd_t is the cumulative depreciation. In order to estimate the cumulative expenditures for the period 2007-2010 we first calculated the average growth rate of the cumulative depreciation for the period 2004-2006. Then we applied the following formula:

$$Cd_t = Cd_{t-1}\left(1+\phi_{t_0,t-1}\right) \tag{8}$$

where φ is the average growth rate of the cumulative depreciation of Intangible Assets investments for the period 2004 (t_0) until the last available year $t-1$. Having estimated the cumulative depreciations for all years we calculate the cumulative annual expenditures in intangible assets as $CE_t = CNV_t + Cd_t$. What remained was to adjust the cumulative investments in intangible assets to the corresponding values of the categories following NAS. For that purpose, we used the base year 2004 where firms published their annual financial statements following both standards. More specifically we estimated the following:

$$CE_{t_{NAS}} = \left(\frac{CR_{2004} + CIPR_{2004}}{CE_{2004}} \right) CE_t \qquad (9)$$

where $CE_{t_{NAS}}$ are the adjusted cumulative expenditures in intangible assets expressed in NAS values and at year *t*, CE_t are the cumulative expenditures expressed in IAS values, CE_{2004} are the are the cumulative expenditures expressed in IAS values for the year 2004 and $CR_{2004} + CIPR_{2004}$ is the sum of cumulative expenditures on R&D and IPR for the year 2004 expressed in NAS values. Last but not least, we should mention the case where a firm published R&D expenditures in its Income Statement and after the transition to IAS. Again we use the reference year and we estimate the following:

$$IARD_{t_{NAS}} = \left(\frac{ARD_{2004}}{IARD_{2004}} \right) IARD_t \qquad (10)$$

where $IARD_t$, are the reported expenses expressed in IAS values at year t, $IARD_{2004}$ are the reported expenses expressed in IAS values at year2004, $IARD_{t_{NAS}}$ are the estimated expenses in R&D expressed in NAS values at year t, and ARD_{2004} are the annual expenses reported and expressed in NAS values.

After having completed all the adjustment procedures we apply (7) somewhat differentiated and specifically:

$$R_{it} = E_{it} + IARD_{it}, \qquad R_{it} \geq 0 \qquad (11)$$

where E_{it} is the equivalent knowledge flow from the category of intangible assets expressed in NAS values and $IARD_{it}$ are the annual expenses expressed also in NAS values.

4. Greek R&D manufacturing firms' knowledge intensity

In this section the interest is shifted in presenting detailed characteristics of the constructed knowledge stock as they have emerged from the survey of the Greek R&D manufacturing firms. More specifically, the mapping of the knowledge intensity is attempted, which is defined *as the degree of involvement of knowledge in business activities either through its integration directly into GRD firms' outputs or indirectly through their inputs*. In order to explore the extent of the of knowledge intensity two indices are employed: the ratio of knowledge capital per employee $(KNEMPL)$ and the ratio of knowledge capital to GRD firms' total assets $(KNASS)$. Specifically the indices are defined as:

$$KNEMPL = \frac{\text{Knowledge Capital}}{\text{Total Number of Employees}} \tag{12}$$

and

$$KNASS = \frac{\text{Knowledge Capital}}{\text{Total Assets}} \tag{13}$$

In figures 1 and 2 the basic descriptive statistics of the two indices are presented respectively, both for the total sample of GRD firms as well as for the three[7] technological sectors (High-tech, Medium-tech and Low-tech). Even though the relevant differences *among* the three technological sectors are expected and follow the findings of the relevant literature, *within* each technological sector one can observe great discrepancies. On the other hand, it should be noted that these asymmetries follow the distributional specificities of R&D expenditures identified by Cohen and Klepper (1992; 1996). Given that the distribution of R&D expenditures is the one that essentially underlies the distribution of Knowledge Capital, the abovementioned knowledge capital asymmetries could be reasonably interpreted based on the findings of Cohen and Klepper (1996).

However, it is worth mentioning that the higher values, in average terms, of both KNEMPL and KNASS indices that correspond in the High-tech sector. More specifically, the average value of the KNEMPL index in the High-tech industries is approximately eight times higher than the corresponding value in the low-tech industries and approximately three times higher than the Medium-tech sector. The discrepancies in the KNASS index are lower. In particular, the average value of the index in the case of GRD high-tech firms is about two times higher than the corresponding value of the GRD medium-tech firms and three times higher than the corresponding value of low-tech firms. The differential sectoral values of KNEMPL and KNASS indices could easily be interpreted from the corresponding differential

[7] For analytical purposes the medium-high tech sector and the medium-low tech sector have been merged into one medium tech sector.

values in terms of employment-capital intensity indices of the three technological sectors examined.

Table 2 presents the basic descriptive statistics of the joint distribution of KNEMPL and KNASS indices, in relation to GRD firms' size. A complete picture of the distribution of both these indices as they were approximated by kernel densities estimates is presented in figures 3 and 4 respectively. KNEMPL and KNASS indices are differentiated in terms of size and technological sector, which provides a strong hint for the existence of a severe underlying heterogeneity with respect to Greek manufacturing firms' R&D activities. It could be argued that the existence of heterogeneity is to be expected, since the field research covers the entire Greek manufacturing. However, it should be taken into consideration in subsequent analyses employing the particular dataset. According to the Schumpeterian hypotheses, large firms should exhibit greater average values compared to smaller firms. In this particular case though, this hypothesis does not seem to be confirmed. On the contrary, on average terms, small firms present greater value of the KNEMPL index, however, with great variation existing among them.

Focusing on the KNASS index, it is worth mentioning that medium sized firms exhibit slightly greater average values, again with great variation existing among them, while the existing differences between size classes are evidently smaller than the corresponding KNEMPL index. It should be noted that, in every case, significant heterogeneity exists with respect to KNEMPL and KNASS indices within each size class, which raises questions as to the core of Schumpeterian hypothesis, as well as with respect to the rather arbitrary boundaries that differentiate small, medium and large GRD firms. Regarding the higher average values of the KNEMPL index that refer to large firms, it should be mentioned that according to Cohen and Klepper (1996), and while the absolute values of their R&D expenditures which are the principal input of the constructed Knowledge Capital are clearly greater than the corresponding of medium and small firms, the scale or in other words the size of large firms eventually leads to smaller analogies of any knowledge measure relative to firm size. In other words, it is about an R&D idiosyncrasy that Cohen and Klepper (1996) have identified.

5. Conclusions

In this paper the methodological approach that required particular handling of the information provided in order to construct the Greek R&D active firms' knowledge stock has been presented. More specifically, in order to develop a knowledge stock time series for the Greek R&D active firms, additional knowledge inputs haven been taken under consideration besides annual R&D investments. Therefore, the developed knowledge stock covers a wider portion of firms' knowledge base than depicting solely their R&D stock.

The firms' knowledge intensity profile has been sketched with respect to traditional characteristics of firm size and technological opportunities. An interesting finding of this first basic anatomy of Greek R&D active firms, which concerns the R&D investments distribution that have been recorded in the relevant literature for greater and more developed national contexts also apply in the case of Greek R&D firms. These idiosyncrasies are depicted in the knowledge intensity indices of these firms.

At this point it is worth mentioning that, at least for the National context, no previous attempt for the recording and measuring the Greek firms' knowledge base has been made. In any case however, the construction of a database for the Greek R&D active knowledge stock firms may be of particular use not only for academic and research purposed but mostly for policy design and implementation purposes.

References

Cohen, W. and Klepper, S. (1992) 'The Anatomy of Industry R&D Intensity Distributions,' *American Economic Review*, **82**, 773-99, Cohen, W. M. and Klepper, S. (1996) ‘A Reprise of Size and R&D’, *Economic Journal*, **106**, 925-51.

Dierickx, I. and Cool, K. (1989) ‘Asset stock accumulation and sustainability of competitive advantage’, *Management Science*, **35**, 1504-1511.

Goto, A., and Suzuki, K., (1989). “R&D capital, rate of return on R&D investment spillover of R&D in Japanese manufacturing industries”, *Review of Economic Statistics,* **71**, 555- 564.

Hall B., Mairesse J., and Mohnen P. (2010), “Measuring the Returns to R&D”, in “*Handbook of the Economics of Innovation*”, ch. 24, eds “Hall B. and Rosenberg N.”, North-Holland, Amsterdam

Hatzichronoglou, T. (1997), “Revision of the High- Technology Sector and Product Classification”, *OECD Science, Technology and Industry Working Papers,* 1997/02, OECD Publishing. http://dx.doi.org/10.1787/134337307632

Kumbhakar, S., Ortega-Argilés, R., Potters, L., Vivarelli, M., and Voigt, P., (2012). “Corporate R&D firm efficiency: evidence from Europe’s top R&D investors”, *Journal of Productivity Analysis*, **37**, 125-140.

Appendix

Table 1. Variables definition employed in the construction of the Greek R&D firms’ knowledge stock

Symbol	Description
K_{it}	The knowledge stock of firm *i* at time *t*
δ	A suitably chosen (private) depreciation rate ranging from 12% to 8%
R_{it}	Annual investments in the creation and/or acquisition of knowledge assets
g_{ij}	knowledge (R&D) investments growth rate at the industry level
NAS	National Accounting Standards
IAS	International Accounting Standards
CR_t	Book values of Cumulative expenditures on R&D following NAS at year t
CRd_t	Book values of Cumulative depreciation of R&D investments following NAS at year t
$CRNV_t$	Book values of Cumulative Net Value of R&D investments following NAS at year t
$CIPR_t$	Book values of Cumulative expenditures on Industrial Property Rights following NAS at year t
$CIPRd_t$	Book values of Cumulative depreciation of Industrial Property Right investments following NAS at year t
$CIPRNV_t$	Book values of Cumulative Net Value of Industrial Property Right investments following NAS at year t
RD_t	Annual flow of R&D investments following NAS
IPR_t	Annual flow of Industrial Property Right investments following NAS
ARD	Annual *expenses* of R&D following NAS
CE_t	Book values of Cumulative expenditures on Intangible Assets following IAS at year t
Cd_t	Book values of Cumulative depreciation of Intangible Assets investments following IAS at year t
CNV_t	Book values of Cumulative Net Value of Intangible Assets investments following IAS at year t
φ	average growth rate of cumulative depreciation of Intangible Assets investments for the period 2004 (t_0) until the last available year $t-1$
$IARD_t$	Annual expenses reported following IAS and adjusted to NAS values.
E_{it}	Equivalent knowledge flow from the category of intangible assets expressed in NAS values

Table 2. Basic Descriptive statistics of the KNEMPL and KNASS variables

KNEMPL			
	Average	Min	Max
Small	34.697	34	986.105

Medium	16.473	15	192.999
Large	21.980	152	358.442
	KNASS		
Small	7,84%	0,02%	77,50%
Medium	9,18%	0,01%	83,98%
Large	8,07%	0,10%	76,98%

Figure 1. Knowledge Capital per employee: Distribution based on technological opportunities

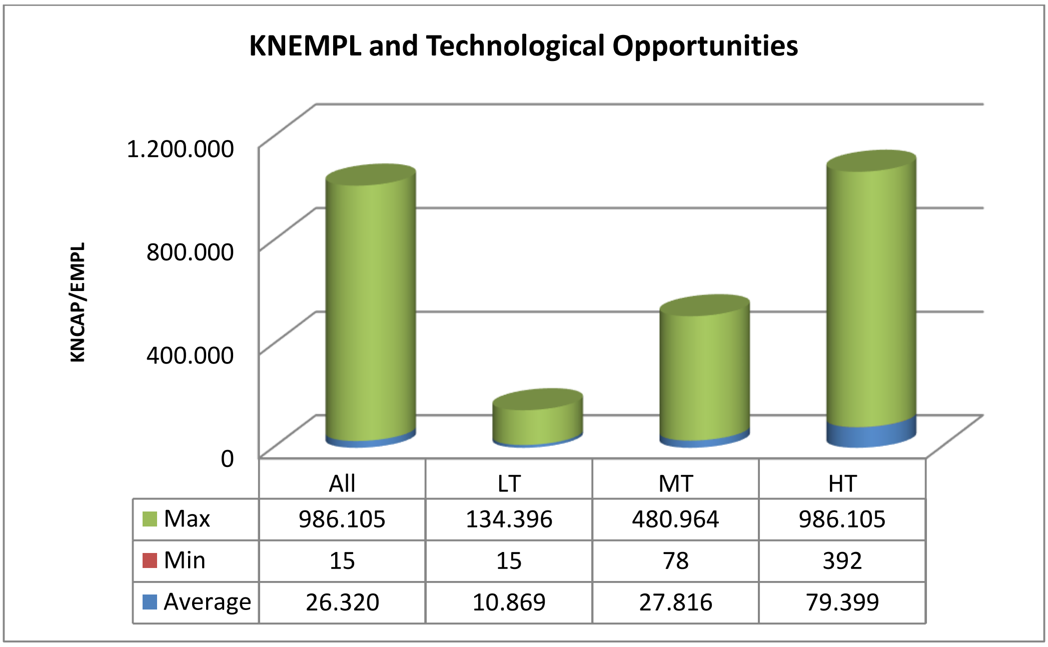

Figure 2. Knowledge Capital as a percentage of Greek R&D active firms’ Total Assets

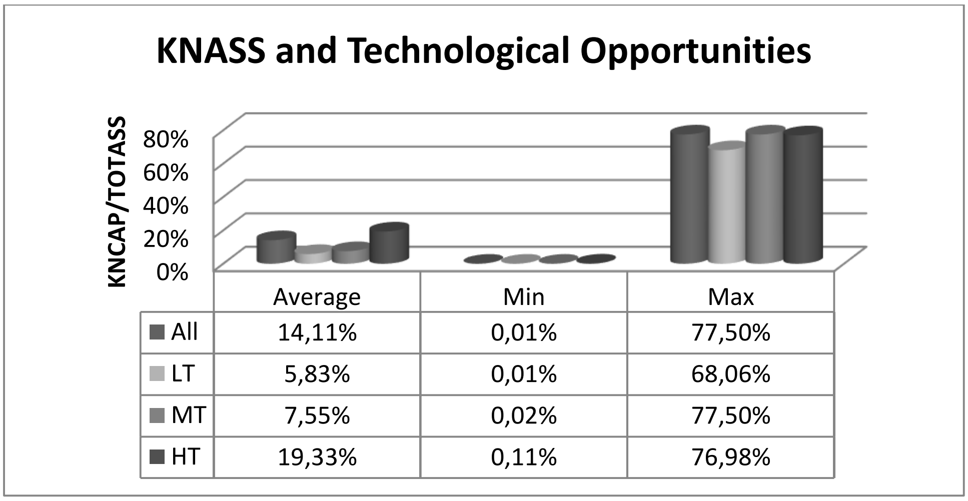

Figure 3. Kernel density estimates of KNEMPL variable

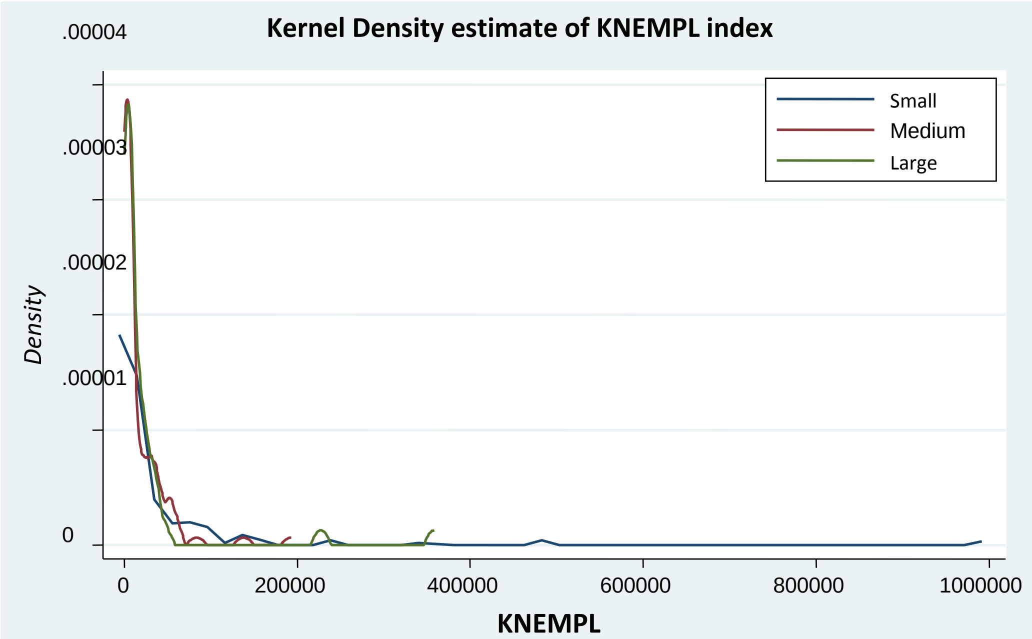

Figure 4. Kernel density estimates of KNASS index