ANALYSES OF THE R&D INTENSITY INDICATOR AND ITS RELATION TO THE INDUSTRIAL STRUCTURE OF COUNTRIES

Aymen A. Kayal
College of Industrial Management
King Fahd University of Petroleum & Minerals,
Dhahran, 31261, Kingdom of Saudi Arabia
akayal@kfupm.edu.sa

Abstract

One of the more widely used indicators of a country's commitment to research and development is the R&D Intensity (RI) and it is frequently used by analysts and policymakers for international comparisons, benchmarking, and goal setting. The indicator's weakness is that it reflects not just R&D performance, but also the industrial structure in which R&D was carried out. It is well observed that there are significant variations in R&D intensity within industrial sectors. Therefore, comparing nations using this aggregated R&D Intensity indicator is not reflecting the distinctiveness of each country's economy and particularly its industrial structure. It is believed that calculating a separate R&D Intensity for each industrial class will reveal a more representative indication of the focus of a country in that particular class. The only thing limiting the wide use of disaggregating RI is more studies that confirm the reliability of the results that are generated from using this approach. The current study attempted to find out if a disaggregated RI can actually be linked to certain logical output measures such as the Value Added. The analyses demonstrated the effectiveness of the approach and revealed limited but promising results that supported the assumptions of the study.

Keywords: Research Intensity, technology indicator, R&D, industrial structure, manufacturing sector, value added.

Introduction

A widely used indicator of a country's commitment to research and development is the ratio of R&D expenditure to its Gross Domestic Product (GDP). This particular ratio was termed "R&D Intensity" or "Research Intensity" (RI) and it is frequently used by analysts and policymakers for international comparisons, benchmarking, and goal setting. The underlying assumption is that R&D Intensity describes the level of dedication a nation has towards Research and Development activities. R&D Intensity is particularly used by all Organization for Economic Co-operation and Development member states (OECD) to analyze and compare performance in science and technology and it is reported annually in OECD official reports. The indicator's popularity stems from the fact that it's amongst the few that combine an input measure with an output measure.

The basic problem of the R&D Intensity indicator stems from its use as an overall indicator for the whole economy. The indicator's weakness is that it reflects not just R&D performance, but also the industrial structure in which R&D was carried out. It is well known that R&D expenditure vary from industry to industry [23], [24], [25]. In fact, OECD categorizes industries as high-technology, medium-technology, and low technology industries based on the industry's expenditure on R&D. Therefore, it is believed that comparing nations using R&D Intensity in its aggregated way - as it's frequently used- is not reflecting the specific industrial structure of each country. Economies that are dominated by industry sub-sectors like for example food packaging, oil and gas, lumber and wood might have firms that are globally competitive in these respected sub-sectors even when compared to same sub-sector firms from more industrialized countries. Yet, an aggregated R&D Intensity for these countries might not reflect this aspect because it's combining R&D expenditures from all the industries in the economy in one number. The success of an industry in a certain country usually stems from some competitive advantages that it enjoys because of availability of natural resources, human resources, or other forms of comparative advantages that tend to support the growth and success of companies that belong to that industry. However, not all industries in a country share this competitive advantage, and this is why no one country enjoys industrial dominance across all industrial classes [21].

A good number of practitioners and researchers believe that R&D Intensity is relatively an old measure that needs to be upgraded [8], [11], [25], [24]. One advance in this direction was to disaggregate the measure based on International Standard Industrial Classification (ISIC). This means that RI should be calculated for each industrial class. Country or firm comparisons can then be conducted at the industrial class level independently. With the current advances of information technology this aspect became an easy task. The only constraint to this approach is building enough scholarly studies in the field that supports its validity and reliability. The long standing concerns of researchers and practitioners regarding the limitations of the aggregated R&D Intensity indicator prompted the author of this paper to investigate the appropriateness of analyzing the indicator in its disaggregated way. In essence, by following the suggestions of the previous authors, the current study attempted to find out if the R&D Intensity (RI) can be logical linked to certain output measures such as the value added.

This paper discusses the various forms of R&D Intensity used today. The paper then disaggregated RI by industrial classes for each OECD country in order to study the relationship between a county's RI and its industrial structure. The analyses aimed at verifying a basic logical assumption for an association between RI values in a certain industrial class and the value added of that particular industrial class.

Literature Review

The R&D Intensity indicator is used in two primary ways. First, a high GERD/GDP ratio for a country is often believed to indicate technological progressiveness and commitment to knowledge creation. Second, it is used to characterize industries, high BERD/Value Added ratios for an industry are held to identify high technology activities. The terms "Research Intensity" (RI) and "R&D Intensity" are used in the literature to describe a nation/firm technological progressiveness, focus, and commitment to knowledge creation. This indicator is basically the ratio of R&D expenditure to some measure of output. All divergent calculations of R&D Intensity stemmed from the basic division of R&D expenditures (an input measure) divided by some economic measure of output such as GDP, sales, or value added depending on the level of analysis. For a firm, it is usually the R&D/Sales ratio. For an industry it is the ratio of business expenditure in R&D (known as BERD) to total production or value added. For a country it is usually expressed as gross expenditure on R&D (GERD) to GDP [3], [12], [16], [18], [22].

BERD is that part of GERD where the expenditure on R&D is made, although not necessarily funded, by the business enterprise sector. In industrialized and semi-industrialized countries 60% - 80% of R&D expenditures are attributed to the business sector (BERD). More insights into this field can be found in OECD literature [13] [14]. A well observed aspect of BERD in OECD countries is that 80% of it comes from manufacturing. So in essence, when we measure R&D intensity of the business enterprise in a nation we are really describing R&D in terms of its manufacturing structure. From this point of view, particulars of industrial structures highly influence how R&D is planned and executed in a country [14].

Although there are a number of applications and ways and for calculating the R&D Intensity notion, many studies focused its analyses on the BERD/Value Added method. Table 1 provides an illustration of this kind of measure for the Manufacturing sector of OECD countries including a number of other non-OECD countries.

Table 1. Business R&D Intensity* 2009 (Ordered)

Country	R&D Intensity (BERD/VA)	Country	R&D Intensity (BERD/VA)
Israel	6.2	Australia (2006)	1.6
Sweden	4.5	Slovenia	1.4
Finland	4.0	Norway	1.3
Korea	3.9	Ireland	1.3
Japan	3.7	Czech Republic	1.3

United States	3.1	Spain	1.1
Switzerland (2004)	3.1	Russian Federation	1.0
Germany	2.9	Portugal	1.0
Denmark	2.9	Italy	0.9
Austria	2.7	New Zealand	0.8
Iceland	2.4	Hungary	0.8
Total OECD	2.4	South Africa (2005)	0.8
France	2.3	Estonia	0.8
Belgium	2.1	Chile (2004)	0.4
Luxembourg	2.0	Turkey	0.4
EU27	1.8	Greece	0.3
United Kingdom	1.8	Slovak Republic	0.3
Canada	1.6	Poland	0.3
Netherlands	1.6	Mexico (2005)	0.3

*(BERD as a percentage of value added in industry)
OECD, Main Science and Technology Indicators database, June 2009 [15].

The example provided in Table 1 is widely used in OECD publication and it's the one drawing most concerns because it calculates a ratio for each country by aggregating data from all of its industrial classes.

In an effort to provide data for structural analyses, OECD classifies manufacturing industries according to technology intensity using the ISIC (Rev. 3) breakdown of activity, and based on the average R&D Intensity of each class [17]. Table 2 illustrates the technology classification of the manufacturing sector that OECD uses.

Table 2. Technology Classification of the Manufacturing Industries Based on Average R&D Intensity

Industry	**ISIC (rev. 3)**	**R&D Intensity** Total[a]
Total manufacturing	15–37	2.5
High-technology industries		
Aircraft and spacecraft	353	14.2
Pharmaceuticals	2423	10.8
Office, accounting, and computing machinery	30	9.3
Radio, television, and communication equipment	32	8.0
Medical, precision, and optical instruments	33	7.3
Medium-high-technology industries		
Electrical machinery and apparatus nec	31	3.9
Motor vehicles, trailers, and semi trailers	34	3.5
Chemicals excluding pharmaceuticals	24 excl. 2423	3.1
Railroad equipment and transport equipment nec	352 + 359	2.4
Machinery and equipment nec	29	1.9
Medium-low-technology industries		
Coke, refined petroleum products, and nuclear fuel	23	1.0
Rubber and plastic products	25	0.9
Other nonmetallic mineral products	26	0.9

Building and repairing of ships and boats	351	0.9
Basic metals	27	0.8
Fabricated metal products, except machinery and equipment	28	0.6
Low-technology industries		
Manufacturing nec and recycling	36–37	0.4
Wood, pulp, paper, paper products, printing, and publishing	20–22	0.3
Food products, beverages, and tobacco	15–16	0.3
Textiles, textile products, leather, and footwear	17–19	0.3

ISIC = International Standard Industrial Classification; nec = not elsewhere classified

a: Aggregate R&D intensities calculated after converting R&D expenditures and production with 1995 gross domestic product purchasing power parities.

NOTE: R&D intensity is direct R&D expenditures as percentage of production (gross output).

SOURCES: Organization for Economic Co-operation and Development, ANBERD database, Science and Engineering Indicators 2008 [12]

Godin [4] traced the evolution of the R&D/sales ratio in the 1960s through its use as an indicator of research or technological intensity. An important modification of this indicator has been the addition of "acquired technology;' calculated as the R&D embodied in capital and intermediate goods used by an industry, and computed via the most recent input-output table. The method for calculating acquired R&D is to assume that the R&D embodied in a capital good is equal to the capital good's value multiplied by the R&D intensity of the supplying industry [20], [25].

Ulku [26] examined the relationship between R&D intensity, rate of innovation, and growth rate of output in four manufacturing sectors of 17 OECD countries. His findings suggest that the knowledge stock is the main determinant of innovation in all four manufacturing sectors and that R&D intensity increases the rate of innovation in the chemicals, electrical and electronics, and drugs and medicine sectors. Griffith et al., [5] provided evidence that R&D Intensity, human capital and trade have a positive impact on total factor productivity (TFP) in the manufacturing sectors of 14 OECD countries. Becker and Pain [1] studied United Kingdom's manufacturing industries and highlighted the importance of industry characteristics in determining R&D Intensity. They found that the main explanations for the comparatively low level of R&D seen during the 1990s appear to be weak output growth, the declining level of government funding for private industry, and the appreciation in the real effective exchange rate since 1996 [1]. Walwyn [31] provided a case study when he studies the desired RI for South Africa, based on its present industrial structure and a set of assumptions in respect of the country's transition to a knowledge economy.

Criticisms of the R&D Intensity indicator

A well observed international phenomenon in science policy is the increased number of national and regional governments establishing explicit targets for levels of R&D spending. These targets were often expressed as a goal of increasing R&D Intensity or as achieving a specific ranking among OECD countries. Increased levels of R&D funding were viewed as an input to an innovation process that will improve economic performance [24]. But in reality, a country's R&D Intensity might be largely a reflection of its industrial structure. It is well observed that countries with high R&D intensities have a high share of their business R&D and a significant part of their economic output in high technology sectors. [24].This facet makes the RI measure biased because the largest RI values are in High-technology as seen in Table 2. In 2006, OECD area High-technology industries accounted for more than 52% of total manufacturing R&D. They accounted for over 67% of total manufacturing R&D in the United States and for 42% in Japan [15].

Since high R&D Intensities are often associated with High-technology industrial classes, then countries with industrial structures that are built on Medium-technology and Low-technology will most probably have lower R&D Intensities. The argument is that, in most countries, factor condition and natural resources shape the industrial structure of the country. Often the resulting industrial structure is dominated by Medium-low-technology and Low-technology industries. Many Medium-low-technology and Low-technology industrial classes like mining, iron and steel, textile, shipbuilding, and paper are capital intensive but don't require high levels of R&D expenditures. The capital intensiveness of such industries is due to labor, process, energy, raw material, or equipment. Although the processes and equipment used in such industries are considered mostly high in technology, they are developed and produced by companies operating in other High-technology industries like machinery and equipment which is not classified in the same industrial class [2], [20], [23], [29].

Therefore, when comparing total business research and development intensity across countries it is important to take into account differences in their industrial structure, because, most often, it is very difficult for a country to raise its R&D Intensity significantly without fundamentally changing its industrial structure. In its latest edition of Science, Technology and Industry Scoreboard 2011 [17], [18] the OECD recognized the structural differences and tried to overcome it by adjusting the R&D Intensity using the OECD industrial structure's sector value added shares as weights instead of the actual shares used in the calculation of the unadjusted measure of R&D Intensity. This might be a step in the right direction but it's yet to be validated. Nevertheless, the author believes that, when dealing with proxies it's better to simplify its calculation than complicating it. In this context, this study is an attempt to further increase knowledge regarding the basic approach of using the RI indicator.

Hughes [7] analyses of U.K. data showed that the intra-industry distribution of R&D Intensity is fairly dispersed, and that any simple ranking of industries by R&D intensity is misleading. Aled Iorwerth [8] investigated why Canada's R&D Intensity level was often low when compared to other OECD countries. Iorwerth argued that, although aggregate research intensity is, in some sense, 'low', it is not accurate to conclude that individual Canadian industries are undertaking too little research. There are industries in Canada, particularly some of the more research-intensive, high-tech industries that are very research intensive by world standards. But these industries are relatively smaller (as a proportion of GDP) in Canada than in the U.S for example. For these industries, it is not clear whether further increasing research intensity within firms would be attainable because of their already high research intensity by world standards [8]. This implies that when research intensive industries are relatively small within an economy its input measure (BERD) will be small relative to an overall output measure (GDP or Value Added). Matieu and Potterie further confirmed the argument made by Iorwerth, and they suggested that inferences made from R&D Intensity should be taken with a degree of caution [11].

Firms operating in the manufacturing sector develop and utilize specific technologies that are embodied in their products, processes, and services. However, R&D and technology development are usually influenced by the type of technology and its pace of technological progress [9]. In this sense, the way firms within a specific industrial sector plan, finance, conduct, and manage R&D is related to both industry specifics as well as technology and firm specifics. A number of previous studies have established the understanding that sector specifics influences R&D efforts [19], [27], [30] and [32]. In reality, decisions on R&D expenditure at the firm and industry level are often based on factors such as product life cycles, product margins, R&D gain, industry level competition, cluster-level resources, and research incentives [6]. Furthermore, Lee and Noh [10] conclude that the effect of R&D intensity on firm growth varies according to industry sector specifics.

The criticisms pointed out above were behind the motive of the current study. The author believes that RI is a very useful construct for scholarly research but it desperately needs a valid and reliable indicator. This study was designed to be a small step in that path. In essence, by following the suggestions of the previous authors, the current study disaggregated the R&D Intensity back to its industrial classes, and then sought to find out if it can be associated with another variable that reflects the value of each industrial class to the economy.

Methodology and Hypothesis

The study attempted to observe if high value added industries in a national economy will correspondingly have high R&D Intensities. This notion stems from the logical assumption that a successful industrial class in a certain country, as measured by the value added to the manufacturing sector, will also have a high RI in that particular class when compared to other countries. The author believed that isolating each manufacturing industrial class in each country helps in providing a more reflective RI and hence better assessment and comparison analyses.

The study limited the population of its analyses to OECD member countries because these countries represent both industrialized and industrializing countries that have economies large enough to accommodate all industrial sectors and manufacturing classes. Furthermore, OECD countries conduct, fund, and collect information on research and development in regular bases which is not true for many non OECD countries.

The industrial structure of each country in this study refers to the composition of industries in the manufacturing sector only. Thus, for instance, mining, agriculture, or services share in the economy is not taken into account. This was done to isolate the manufacturing sector in each OECD country in order to have a more focused analysis. The focus on the manufacturing sector stemmed from the fact that, in OECD countries 80% of business expenditure on R&D (BERD) comes from manufacturing sector [14]. The manufacturing sector can be conveniently represented by ISIC (rev3) classes 15-37.

The statistical unit of analyses was each OECD country. Two variables were extracted for each country, R&D Intensity and Value Added from STAN databases of OECD. The data collected was from 2000 to 2008 for each OECD country and ISIC classes 15-37. An average was calculated for each country's manufacturing classes for both variables to represent the whole time period 2000-2008. The time period 2000 to 2008 was believed to be representative for two reasons, 1) its relatively recent, and 2) it doesn't include the affects of the recent economic crises that OECD countries faced after 2008.

Definitions of the variables used from STAN data bases are:

BERD is Business Enterprise Research and Development in current prices.

VALU is Value added in current prices.

PROD is Production (gross output) in current prices.

R&D Intensity at the industrial class level

According to OECD guidelines, R&D intensities at the industrial class level have been calculated in two ways. The first expresses R&D expenditures BERD as a percentage of value added while the second expresses BERD as a percentage of production.

R&D Intensity (to manufacturing) measured as BERD/Value Added to manufacturing

This indicator is calculated as the ratio of R&D expenditures in a certain industry to value added in that industry and it's calculated as follows:

$$100 * (BERD\_i / VALU\_i) \qquad (1)$$

where (i) is a class number

R&D Intensity (to production) measured as BERD/ Production (gross output)

This indicator captures the R&D Intensity by calculating R&D expenditures in a certain industry as a share of production in that industry and it's calculated as follows:

$$100 * (BERD\_i / PROD\_i) \qquad (2)$$

where (i) is a class number,

Value Added at the industrial class level

This indicator shows the share of nominal value added by industry in the total manufacturing. The indicator attempts to reveal the importance of each industry in the economies of OECD countries and its used to represent the industrial structures of OECD countries.

Value Added (to manufacturing)

This indicator shows the value added contributed by each manufacturing sector to total manufacturing and it's calculated as follows:

100 * (VALU_i / VALU_manuf) (3)

where (i) is a class number, and VALU_manuf is value added of the whole manufacturing sector.

Value Added (to production)

This indicator is calculated as the ratio of value added over production for each industry and it's calculated as follows:

100 * (VALU_i / PROD_i) (4)

where (i) is a class number

Caution should be observed when associating the two ratios R&D Intensity and Value Added. As seen in the equations above, the two ratios use the variable VALU_i in their calculations. Having the same value as the nominator in one ratio as well as the denominator in the other ratio will impair the correlation test. For this reason the author decided to use only the RI which uses formula (2).

Industrial structure

This study defined the industrial structure of a country based on ISIC. The International Standard Industrial Classification of all economic activities (ISIC) developed and used by United Nations (UN) consists of a coherent and consistent classification structure of economic activities based on a set of internationally agreed concepts, definitions, principles and classification rules [28]. According to the ISCI (Revision 3) taxonomy, the total industrial structure of a country is composed of all economic activities such as Agriculture, Mining, Manufacturing, Real Estate, Education etc. In this study the industrial structure under investigation was the manufacturing sector which is composed of classes 15-37. Table 3 presents the manufacturing sector in terms of numbers and titles according to the ISIC Rev.3. Thus, in what follows, the R&D Intensity of each country is not the R&D Intensity of the whole economy but of each manufacturing class, i.e. it is total R&D expenditures of the manufacturing class expressed as a percentage of production of the class.

Table 3. Manufacturing Sector Classes (ISIC Rev3)

15 Food products and beverages	27.2-32 Non-ferrous metals
16 Tobacco products	28 Fabricated metal products, except machinery and equipment
17 Textiles	29 Machinery and equipment, n.e.c.
18 Wearing apparel, dressing and dyeing of fur	30 Office, accounting and computing machinery

19 Leather, leather products and footwear	31 Electrical machinery and apparatus, n.e.c.
20 Wood and products of wood and cork	32 Radio, television and communication equipment
21 Pulp, paper and paper products	33 Medical, precision and optical instruments
22 Printing and publishing	34 Motor vehicles, trailers and semi-trailers
23 Coke, refined petroleum products and nuclear fuel	351 Building and repairing of ships and boats
24X Chemicals excluding pharmaceuticals	353 Aircraft and spacecraft
2423 Pharmaceuticals	352A9 Railroad equipment and transport equipment n.e.c.
25 Rubber and plastics products	36 - Manufacture of furniture
26 Other non-metallic mineral products	37 Manufacturing n.e.c. and recycling
27.1-31 Iron and steel	

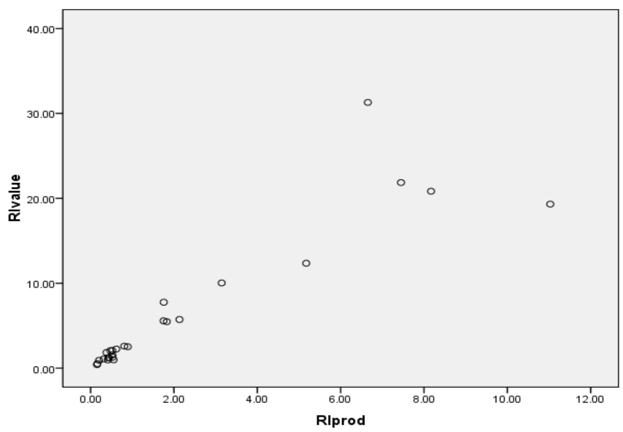
Hypothesis of the Study

Industry is a strong driver for R&D, and R&D expenditures should be relatively high in industries that demand it. In other words, it is assumed that companies operating in a particular manufacturing class which is considered high value added to a certain national economy should be spending relatively high levels of R&D to maintain it. This relative higher level of expenditure is considered a focus and it's assumed to be captured by the R&D Intensity. The position (or performance) of a certain country in a particular manufacturing class was captured using the value added variable defined above.

The main objective of this study was to investigate if the RI indicator can support a basic logical association with another output indicator. For this purpose, an assumption was made of the relationship between the two variables RI and Value Added summarized as: countries that have high R&D Intensity in a specific class should also hold a high Value Added in that specific class, and vice versa. This logical assumption was formulated in the following hypotheses:
H1: R&D Intensity and Value Added are positively correlated

Analyses and Results

This section focuses on testing the relationship between the two variables; R&D Intensity and Value. As an initial step in the analysis a correlation test was conducted to see if there were differences between the two variations of measuring the R&D Intensity. The average R&D Intensity (to manufacturing) measured as (BERD/Value added to Manufacturing) for all OECD countries was calculated for each manufacturing class and then correlated with the corresponding average R&D Intensity (to production) measured as (BERD/ share of Production). The correlation found was very high (0.907) and statistically significant at the (0.01) level. Fig. 1 shows the test results.



Correlations

		RI Prod
RI Value	Pearson Correlation	**.907****
	Sig. (2-tailed)	**.000**
	N	**26**

**. Correlation is significant at the 0.01 level (2-tailed).

Fig. 1 Correlation Test results for RI

This very high correlation between the two RI ratios indicates that they are reflecting the same thing, and that either one could be used as the RI.

Correlation between R&D Intensity (to production) and Value Added (to production) for each class in all OECD countries

To test the hypothesis of the study, a correlation test was conducted between R&D Intensity to production (using equation 2) and Value Added to Production (using equation 4) for each manufacturing class in all OECD countries. Since the sample size was small (below 30) normality could not be assumed. However, the data are ratios and hence, the parametric test of correlation Pearson was used. A one tailed test was used because the study was only interested in the logical positive correlation between the two variables.

The test was conducted on each manufacturing class separately and it revealed that only eleven (11) manufacturing classes out of the 26 had a statistically significant positive correlation coefficient between the two variables R&D Intensity and Value Added. The 11 classes that supported the hypothesis are presented in Table 4 which shows the significant correlation coefficients and P-values. Three of the classes were High-technology category; three were Med-high-technology, three Med-low-technologies, and two Low-technologies. Class 19 also had a significant relationship but its coefficient was negative, indicating a discrepancy in the assumed relation between RI and Value Added.

Table 4. Correlation RI using BERD/Prod and Value Added to Production

Industry	Correlation Coefficient	P value (1-tailed)	Technology Level
17 Textiles	**0.400***	**.033**	***Low***
19 Leather, leather products and footwear	-0.399*	0.037	*Low*
22 Printing and publishing	**0.461***	**0.013**	***Low***
2423 Pharmaceuticals	**0.479****	**0.006**	***High***
25 Rubber and plastics products	**0.388***	**0.023**	***Medium-low***
28 Fabricated metal products, except machinery and equipment	**0.463****	**0.009**	***Medium-low***
29 Machinery and equipment, n.e.c.	**0.327***	**0.045**	***Medium-high***
31 Electrical machinery and apparatus, n.e.c.	**0.701****	**0.000**	***Medium-high***
32 Radio, television and communication equipment	**0.703****	**0.000**	***High***
33 Medical, precision and optical instruments	**0.521****	**0.003**	***High***
351 Building and repairing of ships and boats	**0.450***	**0.030**	***Medium-low***
352+359 Railroad equipment and transport equipment n.e.c.	**0.508***	**0.011**	***Medium-high***

*. Correlation is significant at the 0.05 level (1-tailed).
**. Correlation is significant at the 0.01 level (1-tailed).

The results reveal that the hypothesis of the study was only supported in eleven classes out of the 26. This result indicates that the logical assumption regarding the relationship between the RI and the Value Added variables was not evident in all the manufacturing classes. Whoever, the partial statistical support for the hypothesis does not rule it out because there are a number of factors that could have contributed to such findings as discussed in the conclusions section.

Correlation between R&D Intensity (to production) and Value Added (to manufacturing) for each class in all OECD countries

As an investigative analysis, the same test was repeated only this time Value Added relative to manufacturing which is measured using equation (3) was used instead of Value Added share of production measured using equation (4). This analysis revealed conflicting results. Most of the coefficients were negative, five were negatively significant, and only three were positively significant. Table 5, shows the classes that had significant correlation coefficients. This result indicates that using the first approach produces more logical results.

Table 5. Correlation RI (BERD/Prod) and Value Added (relative to Manufacturing)

Industry	Correlation Coefficient	P value (1-tailed)
17 Textiles	-0.531**	0.006
19 Leather, leather products and footwear	-0.386*	0.042
21 Pulp, paper and paper products	**0.582****	**0.002**
22 Printing and publishing	**0.367***	**0.042**
26 Other non-metallic mineral products	-0.463**	0.007
272+2732 Non-ferrous metals	**0.686****	**0.000**
31 Electrical machinery and apparatus, n.e.c.	-0.329*	0.044
352+359 Railroad equipment and transport equipment n.e.c.	-0.432*	0.029

*. Correlation is significant at the 0.05 level (1-tailed).
**. Correlation is significant at the 0.01 level (1-tailed).

Conclusions and Recommendations

The results indicated that the logical assumption regarding the relationship between the RI variable and the Value Added variable was supported in 11 out of 26 manufacturing classes. This result was achieved when using RI (to production) and Value Added (to production). Therefore, results of the analyses were, to some extent, positive but not conclusive. Notwithstanding the outcome, the study still added new knowledge to the use of the R&D Intensity. The statistical support for the hypothesis in 11 classes does provide promising implication about the validity of this indicator. Furthermore, it was very encouraging that statistical significance was found in all the four technology levels of the manufacturing classes; Low-technology, Medium-low-technology, Medium-high-technology, and High-technology. This means that the R&D Intensity can be used to analyze countries regardless of the technology level of the class. Furthermore, there are a number of factors that could have contributed to this limited support:

1- Countries might be focusing their R&D efforts on particular industrial classes that are not yet having major economic value or impact on the economy. This can explain a relatively high RI even when the Value Added was low.
2- Many Medium-low-technology and Low-technology manufacturing classes indirectly pay for R&D efforts when they buy equipment, tools, and processes to use in their production facilities. If the RI measure can capture this “acquired technology” aspect then different results might emerge.
3- Other economic, environmental, or social factors might be having an effect of the basic logical association that was assumed by this study. In other words, some industries in some countries might by enjoying high Value Added which is simply not related to R&D Intensity but to other factors.

Two additional but minor outcomes that stemmed from this study was that:

- Both methods of calculating the RI ratio provide outcomes that reflect the same phenomena, and hence, both could be used as the RI notion.
- RI (to production) correlates better with Value Added relative to production than with Value added relative to manufacturing.

RI is a very valuable technology indicator that should be further understood and refined before using it in scholarly studies and modeling. The author would like to state that this current study was exploratory in nature and that future studies in this area should further investigate the usefulness and applications of R&D Intensity indicator. In general, the author believes that the R&D Intensity indicator would be better appreciated if it's used in its disaggregated form for in-depth case studies that account for country specific factors in the analyses.

This study has limited its analyses to correlation tests between the RI and Value Added, but future studies could further investigate the relationship between RI and other input or output related measures to find significant meaningful relationships. With some care, patent or innovation counts can also be associated with RI since they are often employed as measures of innovative output. Furthermore designing more complex analyses and using other statistical techniques could also proof worthwhile.

Acknowledgement: The author would like to acknowledge King Fahd University of Petroleum & Minerals for its support.

References

[1] Becker B., and N. Pain, “What Determines Industrial R&D Expenditure in the UK?” Discussion papers-National Institute of Economic and Social Research. April 2003

[2] Fagerberg, J., D. Mowery, & R. Nelson, (Eds.) (2006). *The Oxford handbook of innovation*. OUP Oxford.

[3] Godin, B., The Most Cherished Indicator: Gross Domestic Expenditure on R&D (GERD), Canadian Science and Innovation Indicators Consortium CSIIC. 2003.

[4] Godin, B., “The obsession for competitiveness and its impact on statistics: the construction of high-technology indicators”. *Research Policy*, 33(8), 1217-1229. 2004

[5] Griffith R, S. Redding, and J. Van Reenen, “Mapping the two faces of R&D: productivity growth in a panel of OECD countries”, Working Paper No. 02/00, (The Institute for Fiscal Studies, London). 2001

[6] Hartmann, G., M. Myers, and R. Rosenbloom, “Planning Your Firm’s R&D Investment”, *Research Technology Management* 49 (2), 25–36, 2006.

[7] Hughes, K., “The interpretation and measurement of R&D intensity — A note” *Research Policy*, Volume 17, Issue 5, October 1988

[8] Iorwerth, A., “*Canada’s Low Business R&D Intensity: The Role of Industry Composition”*, Department of Finance, 2005.

[9] Kayal, A., “Measuring the Pace of Technological Progress: Implications for Technological Forecasting,” *Technological Forecasting and Social Change*, Volume 60, Issue 3, March 1999.

[10] Lee, C., and J. Noh, “The relationship between R&D concentration and industry R&D intensity: A simple model and some evidence,” *Economics of Innovation and New Technology, 18* (4), 353, 2009.

[11] Mathieu, A. and B. van Pottelsberghe de la Potterie, “A *Note On The Drivers of R&D Intensity*,” CEB Working Paper N° 08/002 June 2008. Université Libre de Bruxelles – Solvay Business School – Centre Emile Bernheim, 2008.

[12] National Science Board, “*Science and Engineering Indicators 2008”*. Arlington, VA: National Science Foundation (volume 1, NSB 08-01; volume 2, NSB 08-01A).

[13] OECD, Frascati Manual: Proposed Standard Practice for Surveys on Research and Experimental Development, 6th edition, OECD Publishing, 2002.

[14] OECD, *Main Science and Technology Indicators*, OECD Publishing 2006.

[15] OECD, *Science, Technology and Industry Scoreboard 2009*, OECD Publishing, 2009.

[16] OECD, *Main Science and Technology Indicators*, Volume 1, OECD Publishing 2010.

[17] OECD, *Science, Technology and Industry Scoreboard 2011*. OECD Publishing, 2011.

[18] OECD, *Main Science and Technology Indicators*, Vol. 2011/2, OECD Publishing. 2012.

[19] Pavitt, K., “Sectoral patterns of technical change: Towards a taxonomy and a theory”, *Research Policy*, Volume 13, Issue 6, December 1984

[20] Papaconstantinou, G., N. Sakurai, and A., Wyckoff, “Domestic and international product-embodied R&D diffusion”, *Research Policy*, *27*(3), 301-314. 1998.

[21] Porter, M. E.,"The Competitive Advantage of Nations", Free Press, New York, 1990

[22] Sandven, T., “Understanding R&D performance: A note on a new OECD indicator” *Studies in Technology Innovation, and Economic Policy* (STEP), Oslo, December, 1994

[23] Sandven, T. and K. Smith, “Understanding R&D Intensity Indicators - Effects of Differences in Industrial Structure and Country Size”, IDEA Paper Series No 14, *Studies in Technology Innovation, and Economic Policy* (STEP), Oslo. 1998.

[24] Sheehan, J. and A. Wyckoff, “Targeting R&D: Economic and Policy Implications of Increasing R&D Spending,” (STI Working Paper 2003/8) *Science and Innovation*. OECD Directorate for Science, Technology, and Industry, 2003.

[25] Smith, K., “*Measuring innovation”.* In: The Oxford Handbook of Innovation. Oxford University Press, New York, pp. 148-177. 2005.

[26] Ulku H., “R&D, Innovation, and growth: evidence from four manufacturing sectors in OECD countries”, Oxford Economic Papers 59, Oxford University Press (2007)

[27] Utterback, J and S. Fernando, “Innovation, competition, and industry structure”. *Research Policy*, Volume 22, Issue 1, 1993.

[28] United Nations. Statistical Division, International Standard Industrial Classification of All Economic Activities (ISIC). No. 4. UN, 2008.

[29] Von Tunzelmann, N., and V. Acha, “Innovation in ‘low-tech’industries.” In: The Oxford handbook of innovation. 2005

[30] Wakelin, K., “Productivity growth and R&D expenditure in UK manufacturing firms”, *Research Policy*, Volume 30, Issue 7, August 2001.

[31] Walwyn, D., “A target for South Africa's business expenditure on research and development based on industry structure”, *South African Journal of Science*, *104* (9-10), (2008).

[32] Wu, J., “Technological collaboration in product innovation: The role of market competition and sectoral technological intensity”, *Research Policy*, , Volume 41, Issue 2, 2012

References

Bean, A. S., 1995. Why some R&D organizations are more productive than others. Research-Technology Management, January-February, 25-29.

Becker B., and Pain N., 2008. What determines industrial R&D expenditure in the UK?” The Manchester School, 76(1), 66-87.

Ettlie, J., 1998. R&D and global manufacturing performance. Management Science, Vol. 44, (1), 1-11.

Fagerberg, J., Mowery D., and Nelson R., (Eds.) 2006. The Oxford Handbook of Innovation. OUP Oxford.

Godin, B., 2003. The most cherished indicator: Gross domestic expenditure on R&D (GERD), Canadian Science and Innovation Indicators Consortium CSIIC.

Godin, B., 2004. The obsession for competitiveness and its impact on statistics: the construction of high-technology indicators. Research Policy, 33(8), 1217-1229.

Griffith R, Redding S., and Van Reenen J., 2001. Mapping the two faces of R&D: productivity growth in a panel of OECD countries. Working Paper No. 02/00. The Institute for Fiscal Studies, London.

Hartmann,G., Myers M., and Rosenbloom R., 2006. Planning your firm’s R&D investment. Research Technology Management 49 (2), 25–36.

Hughes, K., 1988. The interpretation and measurement of R&D intensity — A note. Research Policy. Volume 17, Issue 5.

Iorwerth, A., 2005. Canada’s Low Business R&D Intensity: The Role of Industry Composition. Department of Finance. Canada.

Kayal, A., 1999. Measuring the pace of technological progress: implications for technological forecasting. Technological Forecasting and Social Change, Volume 60, Issue 3, 237-245.

Lee, C., and Noh J., 2009 The relationship between R&D concentration and industry R&D intensity: A simple model and some evidence,” Economics of Innovation and New Technology, 18 (4), 353.

Mathieu, A., and Van Pottelsberghe de la Potterie B., 2008. A *note on the drivers of r&d intensity*. CEB Working Paper N° 08/002 June 2008. Université Libre de Bruxelles – Solvay Business School – Centre Emile Bernheim.

National Science Board, 2008. Science and Engineering Indicators 2008. Arlington, VA: National Science Foundation (volume 1, NSB 08-01; volume 2, NSB 08-01A).

OECD, 2002. Frascati Manual: Proposed Standard Practice for Surveys on Research and Experimental Development, 6th edition, OECD Publishing,.

OECD, 2006. Main Science and Technology Indicators, OECD Publishing.

OECD, 2009. Science, Technology and Industry Scoreboard 2009, OECD Publishing.

OECD, 2010. Main Science and Technology Indicators. Volume 1, OECD Publishing.

OECD, 2011. Science, Technology and Industry Scoreboard 2011. OECD Publishing.

OECD, 2012. Main Science and Technology Indicators. Vol. 2011/2, OECD Publishing.

OECD-STI., 2011. STAN Indicators. Collection of Calculation Formula. www.oecd.org/sti/industryandglobalisation/47447210.pdf

Pavitt, K., 1984. Sectoral patterns of technical change: Towards a taxonomy and a theory. Research Policy. Volume 13, Issue 6, 343-373.

Papaconstantinou, G., Sakurai N., and Wyckoff A., 1998. Domestic and international product-embodied R&D diffusion. Research Policy, 27 (3), 301-314.

Porter, M. E., 1990. The Competitive Advantage of Nations. Free Press, New York.

Sandven, T., 1994. Understanding R&D performance: A note on a new OECD indicator. Studies in Technology Innovation, and Economic Policy (STEP), Oslo.

Sandven, T., and Smith K., 1998. Understanding R&D Intensity Indicators - Effects of Differences in Industrial Structure and Country Size. IDEA Paper Series No 14, Studies in Technology Innovation, and Economic Policy (STEP), Oslo.

Sheehan, J. and Wyckoff A., 2003. Targeting R&D: economic and policy implications of increasing R&D spending. (STI Working Paper 2003/8) Science and Innovation. OECD Directorate for Science, Technology, and Industry.

Smith, K., 2005. Measuring innovation. in: Fagerberg, J., Mowery D., and Nelson R., (Eds.), The Oxford Handbook of Innovation. Oxford University Press, New York, pp. 148-177.

Ulku H., 2007. R&D, innovation, and growth: evidence from four manufacturing sectors in OECD countries. Oxford Economic Papers 59, Oxford University Press.

Utterback, J and Fernando S., 1993. Innovation, competition, and industry structure. Research Policy. Volume 22, Issue 1, 1-21.

United Nations, 2008. Statistical Division, International Standard Industrial Classification of All Economic Activities (ISIC). No. 4. UN.

Von Tunzelmann, N., and Acha V., 2005. Innovation in ‘low-tech’industries. in: Fagerberg, J., Mowery D., and Nelson R., (Eds.), The Oxford Handbook of Innovation. Oxford University Press, New York.

Wakelin, K., 2001. Productivity growth and R&D expenditure in UK manufacturing firms. Research Policy. Volume 30, Issue 7, 1079-1090..

Walwyn, D., 2008. A target for South Africa's business expenditure on research and development based on industry structure. South African Journal of Science, 104, (9-10), 340-344.

Wu, J., 2012. Technological collaboration in product innovation: The role of market competition and sectoral technological intensity. Research Policy. Volume 41, Issue 2, 489-496.