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The Impact of Research and Development on Economic growth

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ABSTRACT

There have been a lot of studies by various economists to identify the sources of economic growth and a lot of factors have been identified as leading sources; human capital accumulation, total factor productivity and many others. This thesis suggests Research and Development R&D as one of the key sources of economic growth. Economies have resorted to various approaches to boost their growth. Some have chosen an inward oriented economy based on self reliance while others have chosen to import external goods and technology as much as possible. The focus of this research work is to determine the impact of Research and development (R&D) activities on the economic growth of a nation. The study makes inferences using economic empirical data, ideas in international economics, general management knowledge, business strategy and business development knowledge. It refers to the work of many renowned economists. A closer review is done on some selected papers, and best practice in R&D is examined by looking at the R&D frontier (USA) main focus on the United States patent industry. Also, the activities of a company involved in R&D are examined and two economies where there is little or no R&D are studied to see the differences, to make comparisons and to make recommendations on how R&D can be improved in a country.

FOREWORD

This Research is done based on empirical data and practical information. Initially I wanted to take a look at all the forms of R&D and see how they contribute to economic growth individually but this turned out to be very cumbersome and difficult to present in an easy manner, so as a result of this, I decided to look at R&D in a general form. Economists have used various methods in pointing out the role that R&D plays in economic growth. The method that is most widely used as observed from my research involves complex econometric models which are difficult to understand by ordinary business people. But this study presents the topic in a way that can be easily read and understood even by people without deep professional knowledge of Economics by using a model, case studies, examples and business strategy considerations.

The topic is one that can be beneficial to all branches of society. Not only do governments need to invest in R&D for economic growth, businesses and organizations can only remain competitive in a global economy by investing continuously in R&D. Furthermore, R&D increases personal human productivity by encouraging skill development.

First of all, my research is dedicated to God almighty for his tender mercies, guidance and protection and also to my late mother Bridget U. Izunwanne who left this world 15years ago. May God grant her gentle soul eternal rest. Also dedicated to my Loving father John Izunwanne who is always ready to give his wonderful advice and directions at any time. My sisters Dr Onyinye, BLDR Ogechi, Chinwe and Chinasa as well as my brothers Emeka and Chibuzor have always encouraged me in many ways.

I can not forget to mention my supervisor Professor Siri Pettersen Strandenes who was always ready to meet with me whenever I needed inputs and offered good directions on how to carry out the research. I am happy to present this research work and I hope it will be beneficial to individuals, organizations and governmental institutions especially developing countries.

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1. INTRODUCTION

Technological advancements brought about by technological innovations, have certainly contributed in a very important way to economic growth in the United States and Europe. Although existing studies have not been able to estimate this contribution with great accuracy, they have certainly indicated that the contribution has been significant. Moreover, although econometric studies of the relationship between R&D and economic growth have been subject to many limitations, Mansfield (1972) pointed out that there is reasonably persuasive evidence that R&D has an important effect on productivity increase in the industries and time periods that have been studied. According to him, additional research is badly needed to determine more adequately the impact of R&D on economic growth.

R&D involves the systematic study and application of knowledge or understanding to determine the means by which a recognized and specific need may be met. Often, the end result is the development towards the production of useful materials, devices, and systems or methods, including design, development, and improvement of prototypes and new processes to meet these specific requirements. Techniques that involve science, technology and mathematics are used in research and development. Businesses, educational facilities and government agencies usually establish specialized research and development centers or departments (investor glossary.com)

Diane et al, (2000) explains that governments are able to influence their nation's R&D efforts in three general ways. First, they can directly fund the R&D effort through grants, loans, appropriations or government contracts. Second, they can provide tax and financing incentives to encourage higher levels of private sector R&D. Third, they can use their power to create inter-organizational collaborations that vastly extend and expand the nation's collective R&D effort. University-industry collaborations are a principal type of these inter-organizational R&D efforts.

It is not uncommon to observe that organizations today often devote a specific percentage of their annual budgets to research and development. Spending on research and development is vital to continued growth and prosperity, both for a company and for a country or world.

Starting from the time of Schultz (1953), Research and development (R&D) has been considered a source of economic growth and productivity. Coe & Helpman (1995) used a panel of 22 countries over the period of 1971-1995 to determine the impact of R&D on economies. In their paper, their findings indicated that domestic R&D as well as foreign R&D shows positive effects on domestic productivity as well as total factor productivity and this is greater, the more open and smaller an economy is. Modern economic literature has developed a strong theoretical framework and relatively broad empirical findings suggest that the development of R&D can enhance economic growth by pushing the technological frontier and by creating economies of scale and scope. (Solow and Swan (1956), Romer (1986), and Aghion & Horwitz (1992, 1998)). The basic premise is that when R&D is performed by an individual or firm, a positive externality is created. R&D may result in ownership of intellectual property such as patents (Giersch, 1981).

It is observed that most of the empirical studies assessing the R&D-economic growth (productivity) relationship at the country level often fail to consider the possible simultaneity of these variables. Do more productive countries invest more on R&D or does the higher level of R&D investment lead to higher levels of productivity? Do both relationships occur at the same time? To answer correctly these question has crucial relevance for developing countries as it involves a very different set of policy recommendations regarding innovation and technology policies. More on this subject will be presented in the next chapter.

The Norwegian institute for studies in innovation, research and education programmes NIFUSTEP and the Alfred Research & Ethics organization in Australia describe the three primary types of research and development pursuits as follows:

1.1 Pure and Strategic Basic Research

This is theoretical work that is undertaken mainly to acquire new knowledge without a specific application in view. It is carried out for the advancement of knowledge, and is directed into specific broad areas in expectation of useful discoveries and provides the broad base of knowledge necessary for the solution of recognized practical problems

Basic R&D is also called fundamental and pure research. According to LBL human genome center (lbl.gov) the main motivation of this type of R&D activity is to expand man's knowledge, not to create or invent something. There is no obvious commercial value of this research. However, basic R&D has led to the advancement of scientific knowledge. Basic research is defined as theoretical work undertaken primarily to acquire new knowledge of the underlying foundation of phenomena and observable facts, without any particular application or use in view.

For example, basic research and development activities by renowned scientists have led to major discoveries that have made huge developmental impacts.; Gregor Mendel who studied pea plants in 1860, Wilhelm Rontgen who studied x-rays in 1895, Earnest O.Lawrence who invented the first functional cyclotron in 1931 among others. Therefore, although basic research is not initially directed towards a specific application, it has a very large practical impact later on as it forms the basis for more productive research work.

1.2 Applied Research

Applied research is also original work undertaken to acquire new knowledge but with a specific application in view. It is used to determine the possible uses for the findings of basic research and new methods or ways of achieving some specific and pre-determined objectives.

This class of research is the type that is inspired by technical challenges in the basic R&D programs. This is research that could lead to fundamental discoveries (e.g., new properties, phenomena, or materials) or scientific understanding that could be applied to solving specific problems or technical barriers impeding progress in technology development, energy supply and end-use. This "strategic" research applies knowledge gained from more fundamental science research to the more practical problems associated especially with technology R&D. Applied research is also an original investigation undertaken to acquire new knowledge but it is, however, directed primarily towards a specific practical aim or objective. (NIFUSTEP)

1.3 Experimental Research

This is systematic work using existing knowledge gained from basic and applied research as well as practical experience for the purpose of creating new or improved materials, products, processes or services. This is usually the main point at which R&D activities become useful. It also involves the commercialization of products and processes resulting from R&D activities.

This aspect of Research and development is the type that is directly affected by the entrepreneurial nature of the country or region in question. It involves the active utilization of R&D results and turning them into business ventures. It is systematic work, drawing on existing knowledge gained from research and/or practical experience, that is directed to producing new materials, products or devices, installing new processes, systems and services, or improving substantially those already produced or installed.

It is at this point that the results of R&D become visible. A company involved in this field will be discussed in the coming chapters.

In addition, R&D activities can be classified as public or private operations to develop a new process of doing things (Process R&D) or to develop a new physical product (Product R&D)

1.4 Public Research & Development

Public R&D which involves government's expenditure on R&D is said to have a direct impact on innovation that shows up as industrial productivity growth, it can also contribute indirectly, by complementing and hence stimulating private R&D expenditures, even if it was undertaken with other purposes in view (David et al, 1999). Government agencies sponsor research and development projects and programs because the knowledge gained is expected to be germane to their respective mission capabilities, as often is the case, for example, in areas such as military technology and logistics, and public health. It may also generate social benefits, in the form of knowledge and training "spillovers." These often are held to enhance private sector productive capabilities, and, specifically, to encourage applied R&D investments by firms that lead to technological innovations and from which will flow future streams of producer and consumer surpluses assigned to the staffs of public institutes and national laboratories (David et al, 1999).

Government R&D comes in various forms. Two main policy instruments may be identified: tax incentives that reduce the cost of R&D, and direct subsidies that raise the private marginal rate of return on investment in such activities. Although not strictly necessary, the primary difference in execution between the two aforementioned policy instruments is that the former typically allows the private firms to choose projects, whereas the latter usually is accompanied by a government directed project choice, either because the government spends the funds directly or because the funds are distributed via grants to firms for specific projects or Research areas.

1.5 Private Research & Development

In the context of economic globalization, technology is a key factor in enhancing growth and competitiveness in business. Firms which are technology-intensive innovate more, win new markets, use available resources more productively and generally offer higher remuneration to the people that they employ. High technology industries are those expanding most strongly in international trade and their dynamism helps to improve performance in other sectors (spillover). (Hatzichronoglou 1997).

Private firms and organizations often do not receive the full financial benefits from the effort invested in carrying out research and development activities, especially in countries with weak Intellectual Property Rights. Consequently, without some form of government intervention or financial incentive, the private sector will not invest the socially optimal amount in R&D (David et al, 1999). The implication is that governments should contribute to greater R&D investment to correct the externality of private firms by offering, say, tax incentives. Private research is carried out mostly by firms and private organizations in rich nations and nations with well-functioning patent systems.

Fiscal incentives are likely to be most helpful when designed to promote knowledge specific to the firm. It is important here to differentiate between general knowledge and specific knowledge. The first is non-exclusive, and has to do with the development of ideas and basic research. Such research is rarely profitable but has great externalities through enormous spillover effects, so there is a legitimate role for the state to take on its financing. Specific knowledge, on the other hand, benefits the firm directly. A well-functioning patent system would allow the firm to appropriate the benefits, but when such a patent system does not exist (or the risk of copying is great, as is more common in developing countries) R&D investment or tax incentives may be more suitable in encouraging private R&D (David et al, 1999).

1.6 The Research

The research focuses on experimental research and development activities and its impact on economic growth. Particularly on how research and development has contributed to economic growth in developed nations.

- *Approach and Limitations*

This research takes a practical approach to the topic through the use of the case studies listed below. The broad nature of the topic under consideration requires a sharp focus so I have decided to generally refer to all the classes of R&D i.e. basic, applied and experimental without distinction. In addition, the research focuses on total R&D of a nation whether public R&D or private R&D activities, process or product R&D. Also economic growth as far as this research is concerned, is measured using Gross domestic product.

- *Usefulness of the research*

This research is considered as one that will be very useful both for the governments of developed and developing economies because of the following reasons:

1. The research will expose the sectors that attract and require R&D the most
2. The research will show how R&D has contributed to economic growth in nations: The appropriate channels and mechanisms. A model is also introduced to illustrate this; the knowledge/Economic value filter model.
3. The research will reveal lessons to be learnt by developing countries i.e. how they can implement some of the R&D strategies used by developed economies.

- *Case studies*

Mentorship example: In this case study section, two cases are presented to see how developed economies have provided mentorship services to improve R&D performance and enhance economic growth. In the USA, the patent industry is presented and in Norway, a technology transfer company is presented.

- United States patent industry: This section will involve a study of the patent protection industry in the United States Research and Development industry; how private research has benefited from patent protection and resulted in economic growth and development in USA (A look at the beginning of the industrial era).

- Bergen Technology transfer Office (BTO): An example of University-industry collaborations will be introduced, to show the transfer mechanisms of experimental R&D and how it is carried out.

Country example: This section presents the state of R&D in two developing economies; Nigeria and Angola. The aim of this section is to compare R&D performance in developing countries and to be able to make recommendations for improvement based on practices in developed countries.

- Nigeria and Angola: The state of R&D in 2 developing countries: Nigeria & Angola will be studied, to see the characteristics of low R&D investments in a country and how this can have negative results. In addition, a comparison between Nigeria and Angola will be made.

    - *Main Hypothesis under investigation*

That Research and Development activities by private and public organizations, leads to economic growth.

2. Literature Review

2.0 Issues in measuring R&D and its impact on economic growth Zvi Grilliches (1979)

Grilliches (1979) concludes that there are two ways of measuring R&D and its contribution to economic growth; historical case studies and econometric estimates of production functions containing the R&D variable. He explains that productivity and its growth are best described in the context of a production function, Y=F (X1. . .), which describes the relationship between various inputs X and final output Y. Productivity is then defined as the ratio of output (Y) to some index of the total input X and its determinants are then discussable in terms of the list of variables included in X. For example, Y= GDP, X could be equal to R&D investments holding other variables constant. And growth or productivity can take the value of A=the ratio of Y to X. The mathematical form assumed for the production function F ( ), the particular empirical observations chosen to represent Y and X and the statistical methods used to infer the properties of F ( ) are dependent on the research being done.

Criticisms

Although econometric analysis is the most widely used method, the approach to a large extent is challenged by the fact that most of the variables of interest are affected by the same factors and therefore tend to move together over time, thereby making it more difficult to discern their separate effects. For example, with the equation above where Y= F(X. . .), A= ratio of output to input = productivity growth (A). In the health sector, a major product of R&D is the reduced amount of absenteeism due to sickness (Where labor is measured in hours). But while R&D affects the work force and increases the hours of work, it will increase output Y as well thereby affecting X and Y in a parallel manner and have no effect on A. As a result of this, it is quite difficult to establish causality using econometric analysis. R&D investments are themselves affected by the level of output and by past profits and productivity thereby warranting the use of more complex estimation techniques. However, this thesis work has decided to use a combination of case studies, empirical facts and a model to describe the role of R&D in Economic growth as much as possible.

The effect of R&D on (Y) GDP could be marginal i.e incremental, through induced changes in X (increase in R&D spending and investments) and indirectly by improving quality of life and individual productivity. This study generally shows these effects as much as possible.

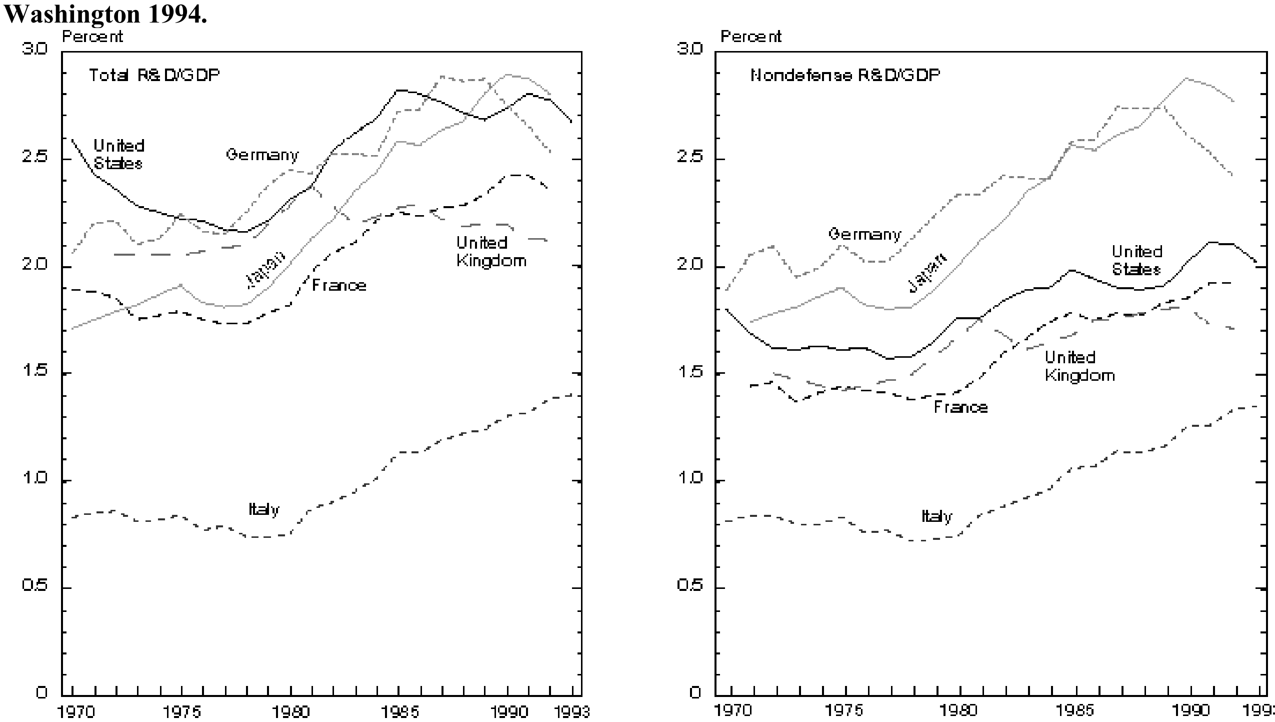
2.1 Research and Development R&D

R&D activities takes the form of Direct policies including direct funding of R&D, investment in human capital formation, extending patents protection and tax credits for R&D. It can be easily seen that R&D tax credits have become a popular policy tool, with many countries offering subsidies of this form. Recent empirical evidence suggests that R&D tax credits are an effective instrument, although there are many remaining questions about their desirability. Government promotion of R&D can be clearly observed because government policy promotes R&D in many ways. Around 32% of gross national expenditure on R&D in the United States in 1996 was funded by government (37.2% of this on defense). The government also promotes innovative activity in firms through direct spending on education and training, patent protection, regulation and competition policy. (Griffith 2009).

The definitions of R&D have already been explained in the introduction chapter so first, I will look at how R&D in an economy can be measured or gauged. According to the National science foundation in Washington, one way to do this is to gauge the Government's priority for R&D by comparing Federal outlays for R&D with Federal outlays for all purposes. Furthermore, the R&D/GDP ratio can be used to determine the relative emphasis placed on R&D activities by countries. Another useful measure is to compare the number of R&D scientists and engineers in a country with its total labor force. Use of these ratios bypasses many of the problems in interpretation caused by inflation, exchange rate fluctuations, different unit costs, and variations in the volume of research efforts. Caution must however be exercised in making international comparisons, because each country compiles its R&D and personnel data somewhat differently. The United States spends more on R&D than any other country (NSF Washington)

Figure 1 shows 19th century R&D expenditures as a percentage of GDP in the top developed economies of the world. The first graph presents the total R&D/GDP while the second graph in the figure excludes defense R&D/GDP. From the 1st figure, USA can be seen to spend more on R&D in the 80s and early 90s.The second figure shows non-defense R&D/GDP ratios and USA is showed to spend much less than Germany and Japan. This is probably because USA spends more on defense R&D when compared to other developed economies.

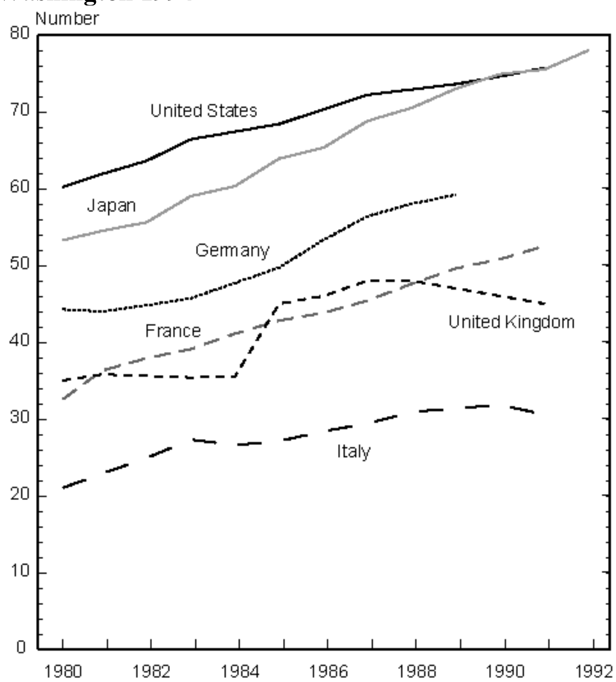
Figure 1: R&D expenditures as a percentage of GDP, by country. Source: National science foundation, Washington 1994.



2.2 R&D Scientists and Engineers/Labor Force Ratios

Another way of determining or measuring R&D activities in countries is by looking at the scientists and engineers in the labor force. Comparing the number of scientists and engineers employed in full time equivalent (FTE) R&D jobs with the total labor force results in a ratio higher in the United States than in the other industrialized market economies. There were about 76 FTE R&D scientists and engineers (S&Es) per 10,000 in the U.S. labor force in 1991 (NSF Washington 1994). The importance of human capital will be further discussed in later sections of this paper. Sjogren (1998) stressed the importance of human capital in the economic growth of a nation, and I say not just general knowledge but relevant knowledge that can promote growth. The USA has more of this than most countries (although Japan appears to be quite close in this area). This explains why USA is the main technology frontier.

Figure 2: Scientists and engineers in R&D per 10,000 labor force, by country: 1980-92. Source: NSF Washington 1994



2.3 *Economic growth*

In an attempt to define economic growth, several views will be considered. Firstly, a simplified view on economic growth explains it as an increase in value of the goods and services produced by an economy and is conventionally measured as the percent rate of increase in real gross domestic product or real GDP. Giersch (1981) in his book explaining economic growth explained that economic growth is a phenomenon that can be gauged by the long term rise in the volume and diversity of final goods per-capita with attention to sectoral structure and shifts. Romer (1990) said that economic growth is achieved whenever people take resources and rearrange them in ways that are more valuable, in other words, through R&D activities.

More views emphasize modern economic growth; Kuzmets (1973) mentions a fast rate of structural transformation, for instance a shift from the agricultural to the industrialized sector and then to the service sector. Stylized time series facts in growth theory by Kaldor (1961), maps a definition of economic growth as continued growth in aggregate production and in the productivity of labor with no tendency of the growth rate to fall and Growth is usually calculated in real terms, i.e. inflation-adjusted terms, in order to net out the effect of inflation on the price of the goods and services produced. Romer growth model (1990) and the Uzawa-Lucas model both stress the importance of the creation of human capital in promoting economic growth. In economics, "economic growth" or "economic growth theory" typically refers to growth of potential output, i.e., production at full employment which is brought about by growth in aggregate demand or observed output (International glossary of economics).

2.4 R&D as a Source of economic growth

Mansfield (1972) stated that although econometric studies of the relationship between R&D and productivity increase have been subject to many limitations, they provide reasonably persuasive evidence that R&D has an important effect on productivity increase in the industries and time periods that have been studied. There are many sources of economic growth but this thesis focuses mainly on the growth driven by R&D and R&D related activities. An article by Martin Neil Baily based on an OECD report done in 2003 on the sources of economic growth in OECD countries, revealed that R&D activities by the business sector, had high social returns and contributed to economic growth. According to the Solow model, economies exhibit sustained growth as a result of technological progress and population growth. Without Technological progress which is brought about by R&D, per capita growth will eventually cease as diminishing returns to capital set in (Jones, 2002).

Major technological innovations brought about by R&D activities; provide basis for sub-inventions and the continuous production of a variety of new knowledge which is a major driver of modern economic growth (Giersch, 1981). Modern economic literature has developed a strong theoretical framework and relatively broad empirical findings which suggest that the development of R&D can enhance economic growth by pushing the technological frontier and by creating economies of scale and scope. (Solow and Swan (1956), Romer (1990). The basic premise is that when R&D is performed by an individual or firm, a positive externality is created that benefits all of society and results in economic progress and growth. Griffith (2000) presents an empirical framework in which the rate of return to R&D is composed of an effect on productivity through innovation and an effect through increased potential for imitation. This second component will be particularly important for firms, industries and countries far behind the technological frontier. Innovation and technology transfer provide two potential sources of productivity growth for countries behind the technological frontier. A country's distance from the technological frontier is used as a direct measure of the potential for technology transfer, where the frontier is defined for each industry as the country with the highest level of total factor productivity (TFP). The further a country lies behind the technological frontier, the greater the potential for R&D to increase TFP growth through technology transfer from more advanced countries. TFP increases when people learn to obtain more output from a given supply of input i.e. clearly through technological improvements. Griffith (2000) provides econometric evidence that R&D expenditure plays a role in assimilating the research discoveries of others as well as its conventional role as a source of innovation. The size of the spillovers depends on one's own R&D activity.

2.4.1 Anna Sjogren (1998)

Sjogren (1998) concludes that a relative lack of R&D capital causes an economy to grow slowly during its transition to the steady state (a state in which those variables that are not constant grow over time at a constant and common rate especially labor and capital), while R&D abundance gives high growth rates during the transition. The purpose of the paper was to analyze how human capital accumulation and the development of new products and technology through investments in R&D interact in the determination of economic growth by providing incentives for each other. Unlike many research works that show only human capital accumulation or only R&D as contributors to economic growth, Sjogren constructs a model of economic growth based on the two frameworks. Her main point is that when human capital accumulation and R&D take place at the same time, it leads to economic growth.

- ***Method and Criticisms***

The research uses a lot of empirical data and econometric analysis to analyze an economy in which the individuals accumulate human capital and invest in R&D which is carried out by entrepreneurs and presented a model showing that output per capita of an economy is determined by the stock of human capital and the time share spent working. Long run growth rate is then said by Sjogren to be determined by the capacity of the economy to accumulate human capital and by the preferences of individuals. But the model shows that the R&D sector is of limited importance for growth and that the main driver of growth is the human capital accumulation. I agree partially with Sjogren's model, I agree that human capital accumulation interacts with R&D to produce economic growth, but I also think the R&D sector plays an equally important or even bigger role in economic growth than the model implies. There is a requirement for knowledge to be processed and transformed into relevant economically significant knowledge that can be beneficial to the economy. Developing countries like Nigeria and Angola are still unable to achieve this transformation and high skilled labor potential in these countries is not maximized. The USA specifically develops scientists and engineers and gives them the necessary tools to work because of the need for economically significant knowledge. I believe it is not enough for countries to just have people working, work should be channeled towards R&D and there should also be an avenue whereby this knowledge is developed. As will be seen in the model I present in this thesis, a system of transferring general knowledge into economically significant knowledge must be in place to generate economic growth and this is usually achieved through R&D investments involving well equipped research labs, knowledge transfer companies, etc. Furthermore, human capital is very broad and it will be challenging to determine the contribution of identified investments in advancing the state of knowledge in a particular area or related areas, this limitation is not identified by Sjogren in her model.

2.5 Is Economic Growth a Result of R&D or a cause of R&D?

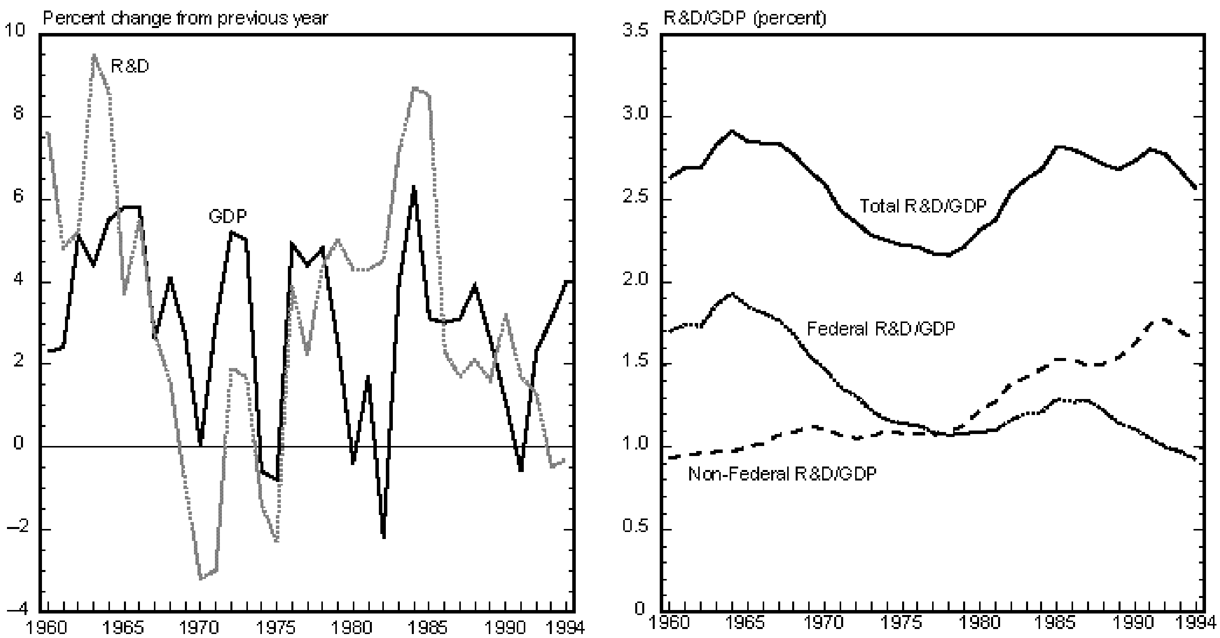
As regards whether R&D results in economic growth or is a result of economic growth, there is some empirical work in this area that supports the fact that there is a causal effect rather than resultant effect. This may not be too convincing but it shows causal relationship to an extent:

- U.S. R&D/GDP Ratio

The ratio of R&D expenditures to GDP may be used as a measure of the Nation's commitment to R&D. In 1994 total U.S. support for R&D is estimated to have reached $173 billion. This sum equals 2.6 percent of an estimated $6.74 trillion GDP, slightly lower than the estimated 1993 ratio.

A review of the U.S. R&D/GDP ratio over time shows a peak of 2.9 percent in 1964 with a gradual decline to 2.2 percent in 1978. This drop largely reflected Federal cutbacks in defense and space R&D programs, although gains in energy R&D activities between 1975 and 1979 resulted in a relative stabilization of the ratio at around 2.2 percent. Over the entire 1965-78 period the annual percentage increase in real R&D was less than the annual percentage increase in real GDP. In years that real R&D spending decreased, real GDP also fell, but at a lower rate. This can be said to show that there is a causal rather than a resultant effect, although R&D does not produce immediate effects (NSF report, 1994). As can be observed from the graph below, GDP growth movements follow R&D growth although not at a very fast rate.

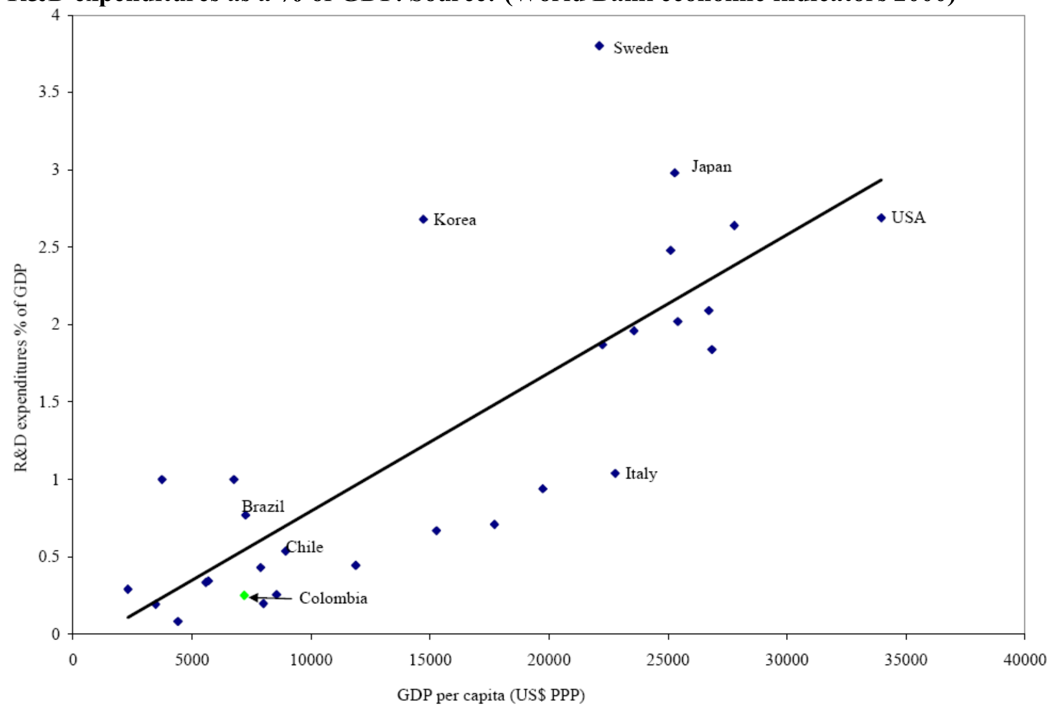
Figure 3: Annual changes in GDP and R&D/GDP ratio: 1960-94 based on constant 1987 dollars (source National science foundation Washington 1994)



- R&D expenditure and per capita incomes

Also evidence of causal rather than resultant effect is the relationship between Research and development expenditures and per capita incomes in developed economies. The graph below shows that wealthy economies do not necessarily invest in R&D. Countries are not prompted to invest in R&D as a result of their wealth, rather, R&D is seen by countries as a way to achieve total factor productivity. It may be even possible that countries that are wealthy may decide to reduce their R&D spending because they feel they have attained full technological potential but this is just a point of view.

Figure 4: R&D expenditures as a % of GDP. Source: (World Bank economic indicators 2000)



2.6 How does R&D contribute to Economic Growth?

R&D is completely different from ordinary investment in machines, first of all, is the fact that the knowledge derived from R&D activity is non-rival and partly non-excludable, which means that knowledge can be used simultaneously by two different persons without losing any of its content, and that it cannot always be prevented from being used by others. Hence the innovator cannot appropriate all the benefits from his new ideas. Part of it leaks out to others.

The mechanism by which R&D contributes to economic growth has been dissected by many economists. As explained above, Sjogren (1998) concludes that R&D activities results in the accumulation of human capital and new ideas and technologies which make economies to grow as a result. She carried out some empirical studies to determine how R&D contributes to economic growth. In the study, she captured the interaction between human capital and R&D by allowing for endogenous human capital accumulation in an economy where the number of products and technologies expands because of R&D activities. It was found that in the absence of scale effects, long run growth is determined by the capacity to accumulate human capital. A relative lack of R&D capital causes the economy to grow at a slow pace during its transition to the steady state, while a relative abundance of R&D capital gives high growth rates during transition.

Furthermore, the work of Sveikauskas (1986) on the contribution of R&D to productivity growth reveals another way through which R&D contributes to economic growth. According to Sveikauskas (1986), R&D plays an important role in at least two different ways. First, in the theory of industrial organization and also in the theory of international trade (Sveikauskas, 1986)

Research & Development is seen as a strategic variable by which firms gain competitive advantage, preserve market shares and through which governments give their domestic firms a competitive edge in international trade, either through cost reductions (in the case of process R&D) or through product differentiation (in the case of product R&D) (Sveikauskas, 1986).

R&D also has two practical effects (Sveikauskas, 1986). It can lead to new commodities, on which the innovator gains temporary monopoly profits (i.e. profits derived from the fact that he is the own producer, without competitors driving the profit down to zero), and it can lead to new knowledge (in the form of theorems, algorithms, models), which can facilitate subsequent innovations. Because of the impossibility of perfect price discrimination, a part of the monopoly rents from R&D activities, get transferred to other producers or the consumers.

An example is the fact that we all seem to derive a benefit from using computers which is greater than the price that we paid for acquiring them. Griliches (1979) called this first R&D spillover "rent spillover" to distinguish it from the second one, which has to do with the free transmission of knowledge and which he called "knowledge spillover". The non-appropriability of the entire benefits from R&D and the intertemporal externalities of R&D keep the benefits of R&D from below the discount rate and hence maintain the incentives to invest in R&D, and therefore assure sustained economic growth.

In growth theory and in popular management literature, R&D is seen as an investment in knowledge or in absorptive capacity and hence indirectly as a contributor to economic growth. R&D plays a central role in the new theory of economic growth, called endogenous growth theory, which is based on the idea that growth does not fall like manna from heaven but can be explained by R&D efforts leading to new products (consumer goods or investment goods) and new knowledge (Romer, 1990) and (Coe and Helpman, 1995),

Sveikauskas's empirical work on the impact of R&D on economic productivity or growth in the United States produced some results that points to a conclusion. (Details can be found in appendix ;table 5). Although he presented the research carried out mainly as regards the non-farm business sector, findings can still be said to be applicable to a large extent to all economic sectors. The results in the first column show the R&D stock of the sector in 1972 dollars, it can be seen that over the 1948-1982 period, the research stock grew at an average annual rate of 6.8%, 7.8% from 1948-1973 but slowed to 4.3% in the 1973-1982 period due to the post war era but overall, annual productivity increase was between 0.16 and 0.18 in the 1960s and after the post war era this went back to being the same. This contribution is quite significant in an economy.

2.6.1 Sveikauskas 1986

Sveikauskas presents the results of a BLS (Bureau of labor statistics in the US) study suggesting that the direct contribution of R&D to postwar productivity growth was between 0.1% and 0.2% annually in the non-farm business sector. The study calculated the real annual investment in R&D and estimated the R&D stock to determine the annual and long-term productivity effects of research spending in the private non-farm business sector. The preferred measure of R&D stock that was selected for the study included only privately financed research in product (R&D resulting in development of a physical and tangible product) and process research (R&D resulting in an improved process of doing things) and applied and basic research (explained above).

- ***Method and results***

The R&D stock was calculated using standard perpetual inventory methods which determine each year's net change in the R&D stock by allowing for new investment and depreciation. The information on the R&D stock and its assumed rate of return was combined to estimate the impact of research on productivity by calculating the research share of output in the private non-farm business sector and multiplying this share by the growth rate of the research stock. The impact of R&D on economic productivity can be clearly seen in column 6 of table 5 in appendix. The annual productivity contribution ranged between 0.16% and 0.18% in the 1960s. There was a slowdown in productivity in the 1970s, this is perhaps due to the staggering patent system in the US described by Hunt (2009) but in the early 1980s, the production contribution returned to the magnitudes reached in the 1960s.

- ***Criticisms***

Although the methods used by the research seem to be appropriate, the research is very narrow in scope. The limitation of the R&D stock to the non-farm business sector due to lack of data from the farm sector is understood but the limitation of the study to only privately funded research is not acceptable. (Sveikauskas 1986) claims that the reason for considering only privately funded research is due to the fact that it is the only type of research that directly affects productivity strongly. I tend to disagree with this notion. On the contrary, publicly funded R&D gives the most investment not only in less developed economies where private firms are not financially capable of huge investments, but also in developed economies. From a business strategy viewpoint, private organizations will invest in R&D for the benefit of their firm and will only calculate their benefits before they invest. This viewpoint is backed by David et al (1999). They state that private firms are only interested in investing in specific knowledge while government invests in general knowledge that has a broader effect on productivity.

My main point is that the research results would have been entirely different if publicly funded R&D was included. Investing in general knowledge can lead to accidental discoveries that can change and transform the entire economic landscape of a nation. Total R&D contribution to R&D growth would have been much higher than 0.18% if publicly funded research was included. Further, spillover effects were not considered at all, thereby creating a gap in the results of the research.

2.6.2 Rachel Griffith 2000

Griffith (2009) presents a paper on the importance of R&D to economic growth. The paper seeks to provide answers to many questions through empirical data and information. Griffith's approach is similar to the one used by Sveikhauskas 1986. She looks at how much output will increase when the level of R&D input increases.

- ***Methods and results***

This is done by estimating the elasticity of output with respect to capital stock (Rate of return to R&D times the share in the R&D stock in output). Griffith goes ahead to present other empirical findings on the above relation but in addition, she not only considers the private rate of return of R&D but the social spillover effects of R&D. Her results show that for a 10% increase in R&D expenditure, there will be a 0.7% increase in output (implying a 27% rate of return to R&D). The estimates of the social rate of return are higher due to the phenomenon of knowledge spillovers from inventors to other firms. This could be within the same industry, outside the industry, within the country or outside the country. Empirical data based on the work presented showed the social rate of return at the industry level from R&D conducted by the same industry to be between 17% to 30%. Spillovers to other industries showed a social rate of return of between 41% to 82%.

- ***Criticisms***

Griffith's empirical findings are based on the work of Teleckyj 1980, Griliches & Lichtenberg 1984a & 1984b, Sveikauskas 1981, Scherer 1982 and Griliches 1994. The paper has a broader scope when compared to Sveikauskas (1986). I believe that the contributions of R&D to economic growth and productivity cannot be observed in isolation, without taking into account spillover effects. However, in measuring the capital stock at the industry level and even also at the firm level, there is a risk of deciding on the appropriate lag structure (Because R&D effects are not seen instantly) and also there is a risk of finding the right weights for outside R&D to represent borrowed knowledge & spillovers. This was not accounted for in the research and I believe that there is not enough factual knowledge to enable accurate measurements & calculations so the results may be too optimistic or pessimistic.

2.7 Research & Development Productivity

Economists have realized that what really matters is not so much the amount of R&D effort as the output of that R&D effort. Innovation output can take the form of patents, publications, citations, the introduction of new products on the market, the adoption of new production processes or re-organizations of business operations. Publications and patents, unless weighted by citations for instance, do not distinguish good from bad. Patents moreover suffer from differences in patent propensities across industries. R&D in all OECD countries is performed primarily by three sectors: business, institutions of higher learning; primarily universities and government institutions (Lonmo & Anderson 2003). (A detailed breakdown of R&D spending by OECD members in shown in the appendix, see Table 4).

Lonmo & Frances, in their extensive research, discovered that there are high R&D performing economies; these are economies that show high productivity in their R&D activities and good GERD/GDP ratios (Gross expenditures on R&D/Gross domestic product). The countries are Austria, Denmark, Finland, Iceland, Ireland, Korea and Sweden. These countries reported that 20% to 30% of total R&D was done in higher institutions of learning, the government facilitates around 20% and the rest is done by businesses. By 1999, R&D in universities was about 20%, government R&D was between 10% and the remainder was done by businesses. Most remarkable is the fact that the countries with higher R&D performance showed significant increases in R&D spending in all categories. Also they report higher proportion of R&D investment going to research in the universities and other higher institutions. Thus it could be safe to say that in order to achieve productivity in R&D activities, there should be more focus on research in higher institutions as well as an all round investment pattern on all categories; science & engineering, defense, business, agricultural, manufacturing sector etc. Lonmo & Frances (2003).

2.7.1 Lonmo & Anderson 2003

Lonmo & Anderson (2003) presented a report based on OECD data on the R&D performance of countries. The report clearly illustrates the importance of R&D productivity in a country and the indicators of R&D performance. It is divided into sections explaining growth of OECD countries by R&D sector, growth in GERD VS GERD/GDP ratios, identification of countries that achieved significantly increased R&D performance during 1989-1999, discussion of the indicators of R&D performance and R&D growth by sector. Most of the countries that achieved growth in their economic sectors were said to have increased their GERD/GDP ratios significantly.

- ***Remarks & Criticisms***

This paper is very informative as it exposes more considerations that need to be made as far as R&D is concerned. As the paper implies, it is definitely not enough for government or businesses to increase GERD. There are more considerations that need to be enforced in other to make the Expenditures on R&D effective. As will be understood from a case study involving a technology transfer office in Norway, conscious efforts need to be taken to ensure that R&D efforts are successful and yield productive results.

- ***Specialization or Diversification***

This is definitely an issue in the analysis of the high performers identified by Lonmo & Anderson. I agree with their economic reasoning to some extent. Specializing in one industry could help a country achieve comparative advantage but at the same time, in my opinion, this can lead to a one-sided economy as can be seen in the case of Nigeria & Angola that only concentrate efforts in their oil industry.

In addition, the paper presents a ranking of countries based on their GERD/GDP ratios. Although this method can also show R&D performance, it may show a reduced amount for R&D expenditures because a country may experience an economic slowdown but may also commit a set amount to its R&D expenditure. Meaning that growth in GDP may increase faster than the increase in R&D expenditures. In ranking high performing R&D countries, it will be best to use an approach that measures GDP specifically allocated to R&D over a given period of time since ranking is a relative factor. This will fully reveal the increasing commitment a country makes to R&D as a proportion of its GDP over a given period of time as the growth in GERD/GDP ratio can be affected by many factors; for example economic slow down and Increase in GDP. Also, countries cannot be ranked in isolation to these considerations and further considerations of R&D scope (diversified or specialized), public & private, applied, experimental and basic research etc. These considerations are capable of producing different rankings of countries.

2.8 *R&D in the frontier reviewed: The United States.*

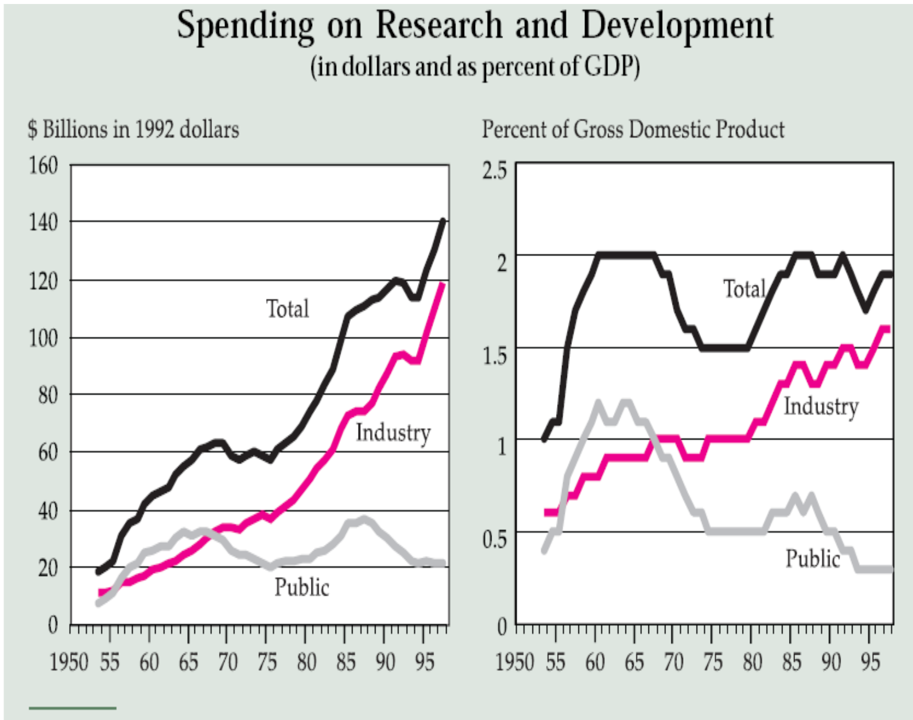
According to the result of the survey carried out by the Bureau of Economic Analysis (BEA) and the National Science Foundation (NSF) to illustrate how spending on R&D affects U.S. GDP, gross Domestic Product (GDP), it was discovered that GDP would become nearly 3 percent higher each year between 1959 and 2004--$284 billion higher in 2004 alone--if research and development (R&D) spending were treated as investment in the U.S. national income and product accounts. (Arden L Bement director National Science Foundation Washington).

In the United States, the R&D satellite account developed by the Commerce Department's BEA and the NSF's Division of Science Resources Statistics (SRS), is responsible for producing data and analysis on the science and engineering enterprise. The 2007 R&D satellite account presented first time industrial and regional details and the Major findings concerning R&D in the United States as seen on their database include:

- R&D accounts for 5 percent of real GDP growth between 1959 and 2004, and 7 percent between 1995 and 2004. This ramp-up in R&D's contribution helps explain the pick-up in economic growth and productivity since 1995.
- Information, communication and technology (ICT) and biotechnology-related industries account for two-thirds of the business sector's R&D contribution to GDP growth between 1995 and 2004.
- Recognizing R&D as investment boosts the level of state GDP the most in New Mexico (8.2 percent) and in Maryland (6.2 percent) between 1998 and 2002.
- In 2004, the value added of majority-owned foreign affiliates of U.S. Multinational companies MNCs rises by $26 billion, or 3.1 percent, with R&D capitalization. The value added of majority-owned U.S. affiliates of foreign MNCs rises by $28 billion, or 5.5 percent. For U.S. parent companies, value added rises by $148 billion, or 6.7 percent.

Current data shows a significant role of R&D spending in improving the competitiveness of industries such as information technology, pharmaceuticals and other manufacturing industries. According to the US Commerce Secretary Carlos, present estimates demonstrate the importance of R&D as one key source of innovation in the U.S. economy. Figure 5 below shows the spending on R&D in the United States over time. Total spending has been on the increase from 1950 until 1995 as shown below and spending as a percentage of GDP has been fluctuating. This can be due to GDP growth over the years.

Figure 5: Spending on Research and development. In USA. Source: Bureau of Economic Analysis: National Income and Product Accounts; National Science Foundation and author's calculations.



R&D accounts for 5 percent of real GDP growth between 1959 and 2004, and 7 percent between 1995 and 2004. This ramp-up in R&D's contribution helps explain the pick-up in economic growth and productivity since 1995(National science foundation, Washington)

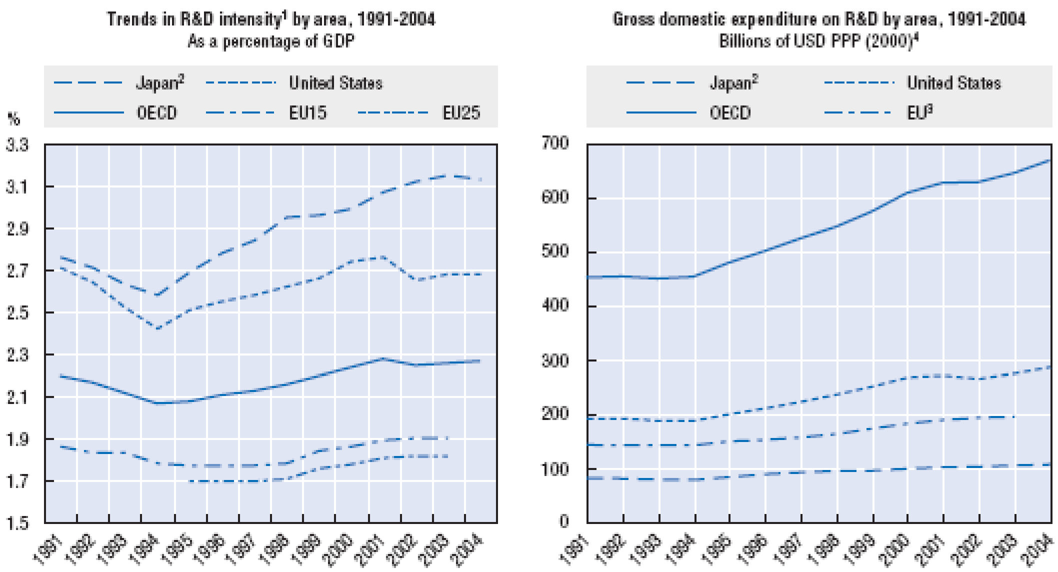
Following the endogenous growth theory, it can be said that R&D expenditures translates to a significant improvement in the GDP based on purchasing power parity. Between 1995 and 2000 the GDP of the United States grew from 2% per annum towards 4.8% per annum (2.8% per annum change) at the same time the savings rate dropped from 4% to 2% (2 % change). Economists believe that the growth was funded by savings and subsequent investments in R&D

2.8.1 Changes in R&D composition in various countries as well as recent trends

R&D activities in a country are also affected in the event of any economic change, for example a recession, change in economic policy or political problems. Over the years, there have been a lot of changes in R&D expenditures by different economies. The figure below shows R&D

trends in major OECD countries over the years from 1991-2004. The first graph in figure 6 below shows the gross domestic expenditure on R&D as a percentage of GDP while the second graph in the figure shows the gross domestic expenditure on R&D in terms of purchasing power parity (PPP). USA still maintains the lead in overall terms despite fluctuations in spending, probably caused by economic downturns.

Figure 6: R&D trends in major OECD regions, 1991-2004.

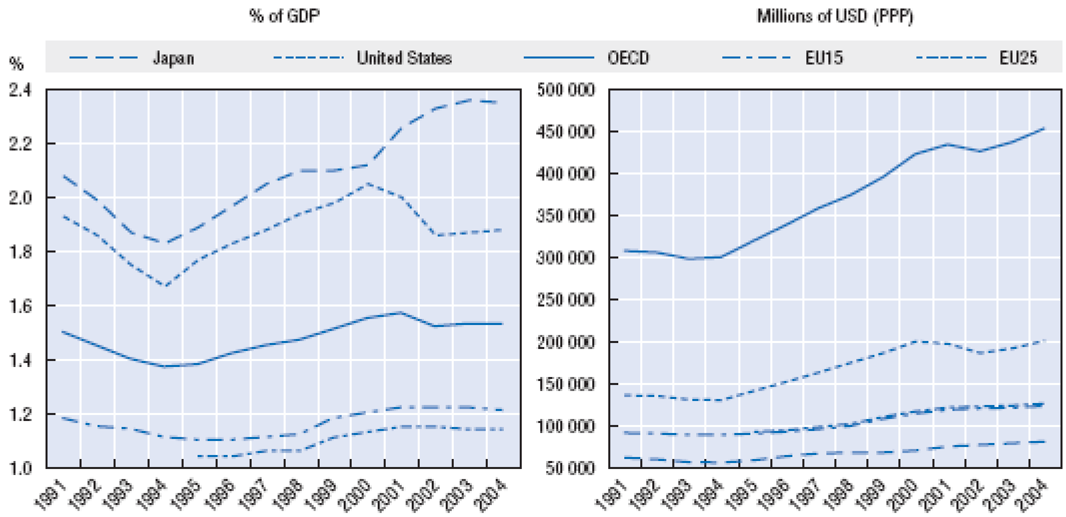


1. Gross domestic expenditure on R&D as a percentage of GDP.
2. Data are adjusted up to 1995.
3. Data are EU15 to 1994 and EU25 from 1995.
4. USD of 2000 in purchasing power parities (PPP).

Source: OECD, Main Science and Technology Indicators Database, June 2006.

StatLink: http://dx.doi.org/10.1787/505288083604

Figure 7: Business R&D spending in major OECD regions, 1991-2004



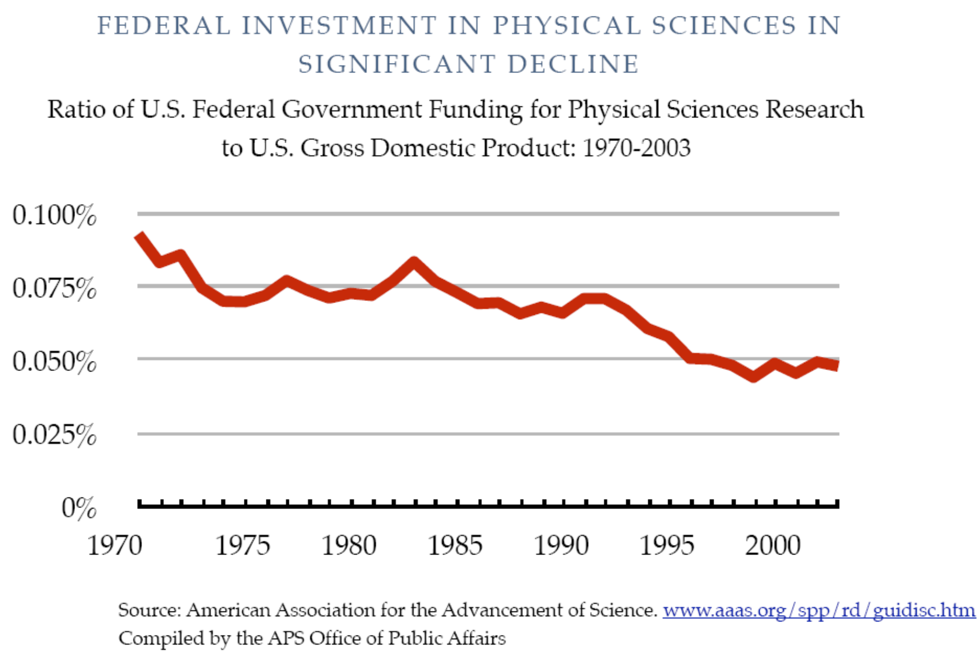
1. Data are adjusted for Japan up to 1995.

Source: OECD Main Science and Technology Indicators Database, June 2006.

StatLink: http://dx.doi.org/10.1787/352551751058

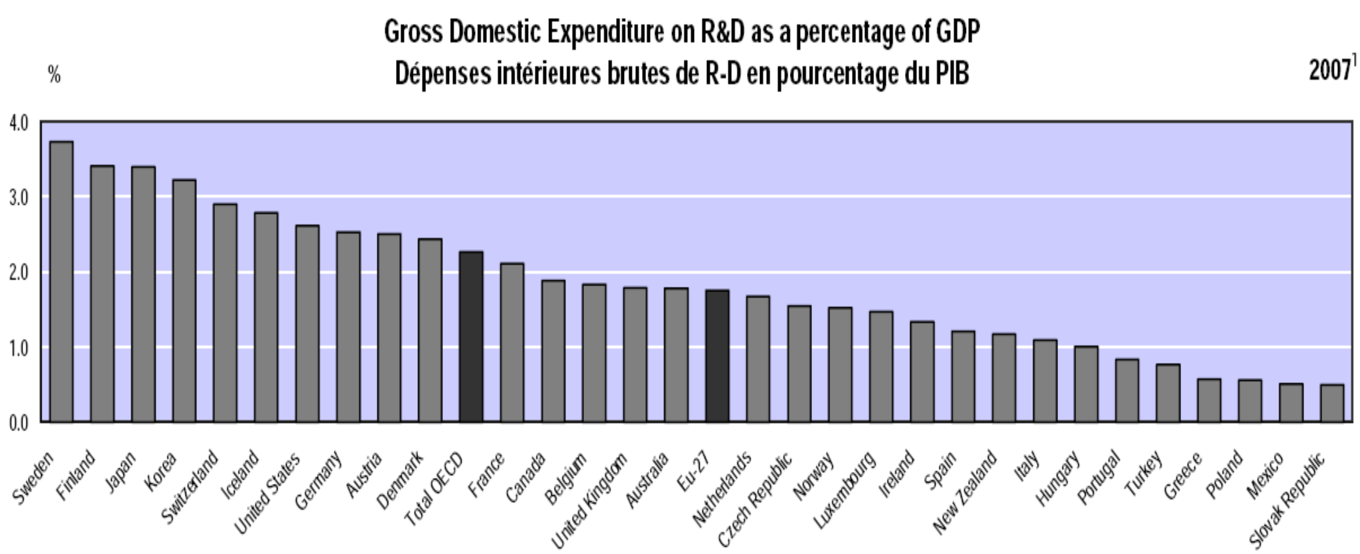
- Since the 1980s there has been a dynamic shift in the source of funding for R&D U.S. private sector investment in R&D now far exceeds federal investment in R&D, providing over 68 percent of all domestic R&D. However, private funding tends to cycle with business patterns and focus on short-term results. Of these private funds, 71 percent of these private funds were for development, not basic research.
- Between 1995 and 2002, China doubled the percentage of its GDP invested in R&D, from 0.6 to 1.2 percent. Also, China intends to increase the proportion of science spending devoted to basic research by more than 200 percent, to about 20 percent of its science budget, in the next 10 years.
- From 1995 to 2002, Japanese businesses increased their R&D spending from 2.12 percent to 2.32 percent of GDP.
- European businesses increased their R&D spending from 1.15 percent to 1.17 percent of GDP.
- U.S businesses, however, actually decreased their level of spending, from more than 2 percent to 1.87 percent of GDP.

Figure 8: Declining investment in physical sciences in the USA



The United States despite many years of high performing R&D has reduced spending on physical science R&D. Also, it is not just a matter of doing R&D but also of doing good R&D. It would be better to compare not just the amount spent on R&D but also the productivity of R&D in future research. Recent 2007 data shown in figure 9 places USA as 6th in R&D spending.

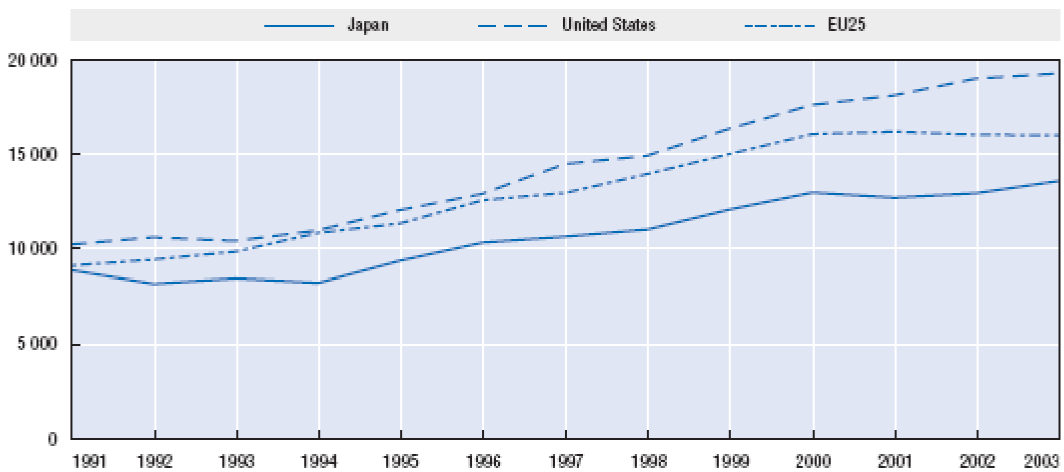
Figure 9: Expenditures on R&D. Source: (OECD main science & Technology indicators 2008)



2.8.2 Trends in patenting in OECD countries

The figure below from the 2006 OECD report shows trends in patenting in thousands for OECD countries. The United States which is the R&D frontier can be seen to be maintaining the lead as far as patenting is concerned. In a study which will be seen in this paper, the patent industry in the United States has highly contributed to economic growth and prosperity in the nation. This contribution was higher in previous times due to the economic phenomenon of Total factor productivity, economic potentials and economies of scope.

Figure 10: Trends in patenting



Source: OECD Patents Database, June 2006.

StatLink: http://dx.doi.org/10.1787/448323182654

According to the OECD 2006 reports, there are many factors that can account for the slowdown in patenting in recent times and in major offices of the world. Cost cutting efforts by companies may have affected patenting. Difficult economic climates of the early years of the decade may have made firms to file fewer patent applications to avoid the costs of filing, maintenance and litigation fees. It can be seen that among EU firms, the ratio of patenting fell after 2000. The ratios for Japanese and US patenting did not decrease but remained stable between 2000 and 2002.

2.9 R&D Collaborations and networks (Schluga & Barber (2006))

Schluga & Barber (2006) studied the structure of R&D collaboration networks in the first five EU Framework Programmes (FPs). R&D collaborations and networks are alliances that involve pulling economic and financial resources together by organizations or countries to fund R&D activities. In Europe, the main examples are the European Framework Programmes (EFPs) on Research and Technological Development (RTD). "This consists mainly of universities and research organizations. The EU co-funds projects of limited duration that mobilize private and public funds at the national level. In these FPs, the European Union has co-funded thousands of transnational, collaborative R&D projects; and they are specifically aimed at supporting transnational collaboration and coordination in research, and projects supporting transnational mobility for training purposes (Schluga & Barber, 2006). Since their inception in 1984, six EFPs have been launched and the most recent one commenced in 2007. The main objective of these activities has been "to strengthen Europe's science and technology capabilities and to promote European international competitiveness through coordinating national policies, integrating national research communities, improving the integration of marginal actors, and bringing together actors with the most advanced resources and capabilities. This has created a pan-European network of actors performing joint R&D" (Schluga & Barber, 2006).

Comments

This paper highlights the benefits of R&D collaborations very clearly and studies a typical example of R&D collaborations; The European Framework programmes. Collaborations like this are definitely beneficial from a strategic standpoint. Knowledge creation and knowledge diffusion are definitely valuable for economies. The paper goes into more complex analysis of the EFPs but then fails to point out the strategic considerations involved in networks and alliances. Similar to business alliances and networks, R&D collaborations help mitigate costs, they facilitate knowledge exchange and knowledge transfer between the parties involved but they are challenging to manage. Peng (2006) points this out in his book on global strategy. Making alliances succeed requires developing social capital and putting necessary structures in place to facilitate fast decision making and cooperation. This topic is beyond the scope of this paper but is definitely a point to be considered in forming R&D collaborations.

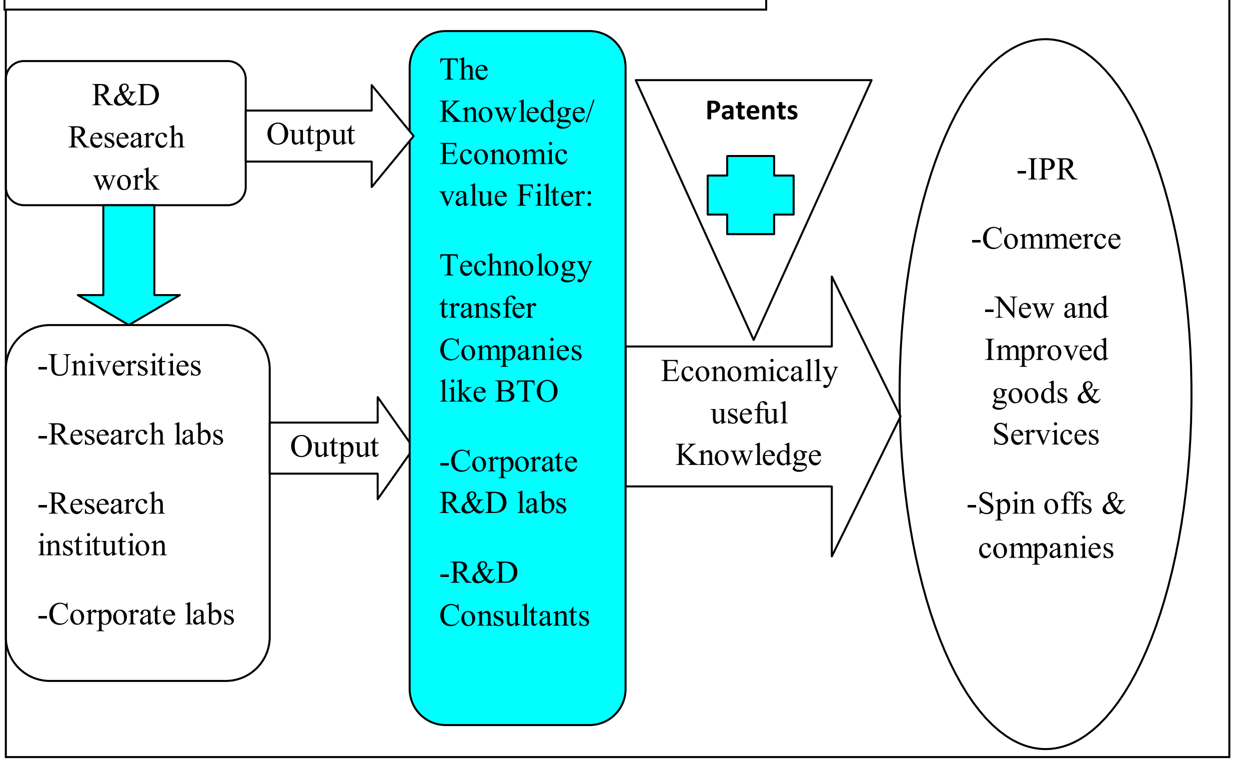
3. Mentorship and Facilitatorship case studies

This section presents examples of how countries enhance Economic growth by providing mentorship and facilitatorship. In the USA, the patent industry has been encouraged through patent reforms and in Norway, technology transfer offices have been put in place as will be shown in this chapter. Also, a model illustrating how these provisions enhance economic growth is described below.

The Knowledge/Economic value filter and Economic growth model

I have come up with a model that provides a good illustration of the various sections in this thesis; which is the methodology through which R&D investments translates into economic growth and productivity.

Figure 11: Knowledge/Economic value filter &



This model shows that in order for R&D to lead to economic growth, there has to be an interaction between R&D work and other economic sectors. The model shows Universities, interacting with knowledge filters like R&D consultants, technology transfer offices, the patent industry and the commercial sector.

The Mechanism: R&D work is being carried out in Universities, research labs, research institutions and corporate labs. The knowledge/ economic value filter is in place to preserve, test and develop the output that comes from the universities and other institutions where R&D work is carried out. It is the work of the economic value filters to select the useful innovations and turn them into beneficial entities for the economy. This is further facilitated by patents. The patent industry plays a huge part in the transition from useful knowledge into spin offs. This is because inventors are afraid of losing the rights to their inventions and they will only be encouraged if there is a system in place to protect their own interests. The R&D output in the figure above that is judged to have potential economic value (i.e., the output that passes through the knowledge/ economic value filter) can be turned into intellectual property to be subsequently commercialized (if it turns out to have sufficient commercial value), it can also be indirectly commercialized by increasing the absorptive capacity or knowledge base of the company. This is why globally competitive companies carry out R&D activity. The commercialization of an R&D output can be done through the expansion of the activities (new or improved goods and services) in existing firms, or via spin-off to new entities as is mostly the case with the company to be discussed in the next session, or via licensing of innovation to other firms.

Translating research results into economic activity is the only way that R&D activities can become useful. Today new firms have increasingly become the vehicle to translate research into economic growth; this can be seen in the greater role of small business and entrepreneurship from the late 90s onwards. In international business, the role of knowledge management cannot be over emphasized. Multinational companies pay close attention to this in order to stay competitive. BTO is a typical example of a knowledge filter and the inspiration for developing the model was based on its operations. The lack of the components in this model is a major reason why there is poor economic growth in the countries that will be examined in the next section; Poorly functioning R&D institutions, lack of/or poorly functioning technology transfer offices, poorly functioning patent system and non receptive commercial sector.

3.1 The nature of the United States Patent industry system

Many observers and scholars believe that Research and development conducted in the U.S industry is and has been a relevant ingredient to the Nation's economic growth. In recent past, the United States spent more money on R&D activities than does any other country; in fact, it spent more than Japan, Germany, France, the United Kingdom, and Italy combined. For example, the United States spent $138 billion on R&D in 1992. Comparable R&D expenditures-based on purchasing power parity exchange rates-were $57 billion for Japan, $30 billion for Germany, $21 billion for France, $17 billion for the United Kingdom, and $12 billion for Italy (OECD 2006).

The U.S. Constitution grants Congress the power "to promote the progress of science and useful arts, by securing for limited times to authors and inventors the exclusive right to their respective writings and discoveries." Thus, the Constitution permits the government to offer an incentive, in the form of a temporary monopoly, to artists and inventors. Congress quickly took advantage of these powers, passing the first patent act in 1793. The act was drafted by Thomas Jefferson, who was himself a prodigious inventor. The role of patents envisioned in a Constitution essentially follows economic intuition. It usually costs more, in terms of effort and money, to discover something new than it does to duplicate someone else's discovery. Inventors may work on their discoveries for a variety of reasons. But so long as one of the motivations is the prospect of financial reward, inventors will be concerned about the possibility that others will imitate their discoveries. If an invention can be imitated quickly, the inventor will soon be forced to compete with other suppliers, ones that did not incur the development costs he or she bore. This competition will reduce, possibly even eliminate, the profits an inventor can earn from his or her discovery. In such an environment, then, a discovery not protected by a patent gives the inventor only a fleeting advantage over his or her competitors. Obtaining a patent can reduce this competition because it gives the inventor a temporary monopoly to produce his or her invention. Thus, by helping to ensure a reasonable economic return to inventive activity, patents provide an important incentive to engage in research and development (European Patent Office)

- ***The Patent Industry in the United States***

For more than half a century, the United States has led the world in scientific discovery and innovation. It has been a beacon, drawing the best scientists to its educational institutions, industries and laboratories from around the globe (Hunt, 1999). However, in today's rapidly evolving competitive world, the United States can no longer take its supremacy for granted because the importance of R&D cannot be over-emphasized. Nations from Europe to Eastern Asia are on a fast track to pass the United States in scientific excellence and technological innovation if they have not done so already. The R&D sector is so important to USA "*Not only do our economy and quality of life depend critically on a vibrant R&D enterprise, but so too do our national and homeland security.*" -- Hart-Rudman Commission on National Security, 2001

3.1.1 Robert Hunt 1999

Hunt (1999) presented a paper on the U.S patent industry. His paper was directed towards the patent reform and based on empirical data on the reaction of the US economy towards the patent reforms. Although the first patent act was passed in 1793, the patent industry went through a lot of restructuring and reforms. Hunt stated that during the late 1970s and early 1980s, businessmen and policy makers became concerned about the apparent deterioration of America's comparative advantage in high technology industries at the same time, there was considerable dissatisfaction with how federal courts were invalidating patents. Complaints led to the creation of a federal appeals court to hear the appeals of patent cases and a subsequent relaxation of the patentability criteria. This led to a surge in R&D activity and the apparent improvement in American technological competitiveness. Both private R&D spending and patent activity in the industry increased significantly during the 1980s and 1990s. But Hunt argues that it is difficult to identify exactly which change led to the improvement in American technological competitiveness.

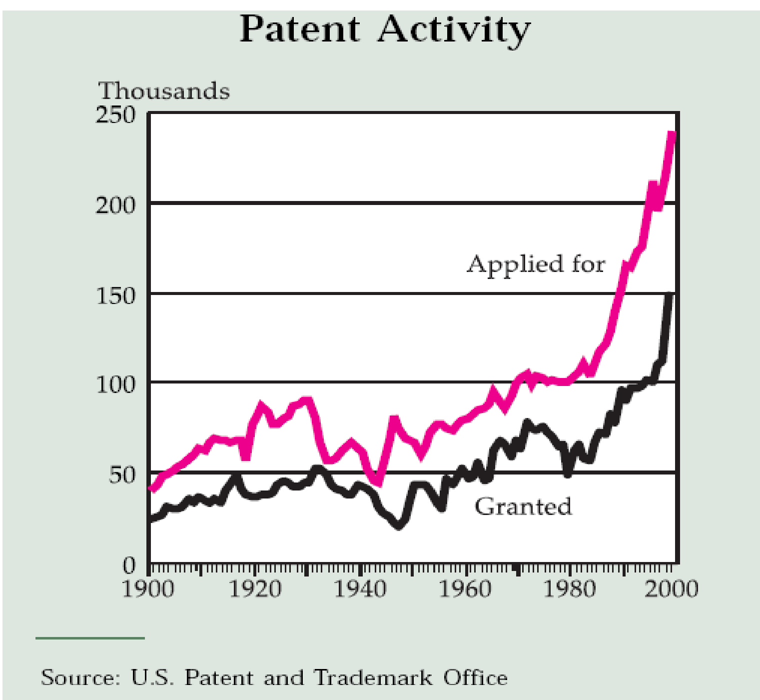
He presents the fact that during the same period of patent reforms, a large and sophisticated venture capital market emerged and there was a dramatic restructuring of the US manufacturing sector and therefore the economic boom may not have been totally due to the patent industry through the patent reforms.

- ***Criticisms***

Hunt appears to be saying the same thing in different ways. Business strategy intuition suggests that the patent reforms may have indirectly contributed to the other macroeconomic events that led to economic growth. Spill over effects can be very widespread. In the case that will be presented next, it can be seen that R&D leads to a spiral effect on many industries at the same time. For example, the fact that there are many technological innovations may have led to the emergence of the sophisticated venture capital market. Investors are always willing to invest in businesses with good potentials for success and superior novel innovations. Furthermore, the manufacturing sector may have also been helped by the patent reforms. The follower strategy could apply in this case; it implies that an improvement in one industry could lead to an improvement in related industries at the same time. As one industry braces up in order to measure up with the other and to leverage on the success in the other industry (Peng, 2006).

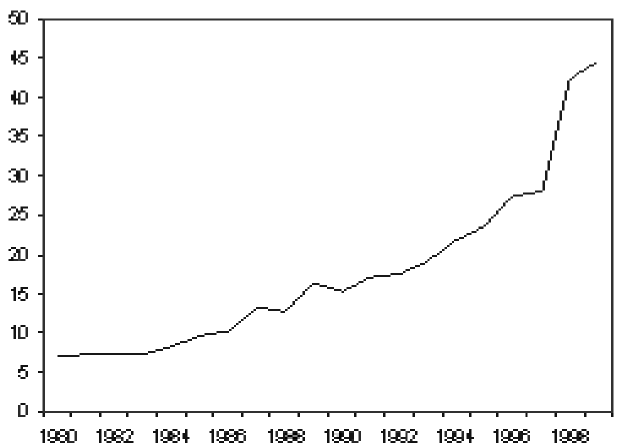
In his conclusion, Hunt stressed and I agree that more empirical research is needed to show that the relaxing of the patent law that occurred in the 1980s led to the increase in R&D.

Figure 12: Patent activity in United States



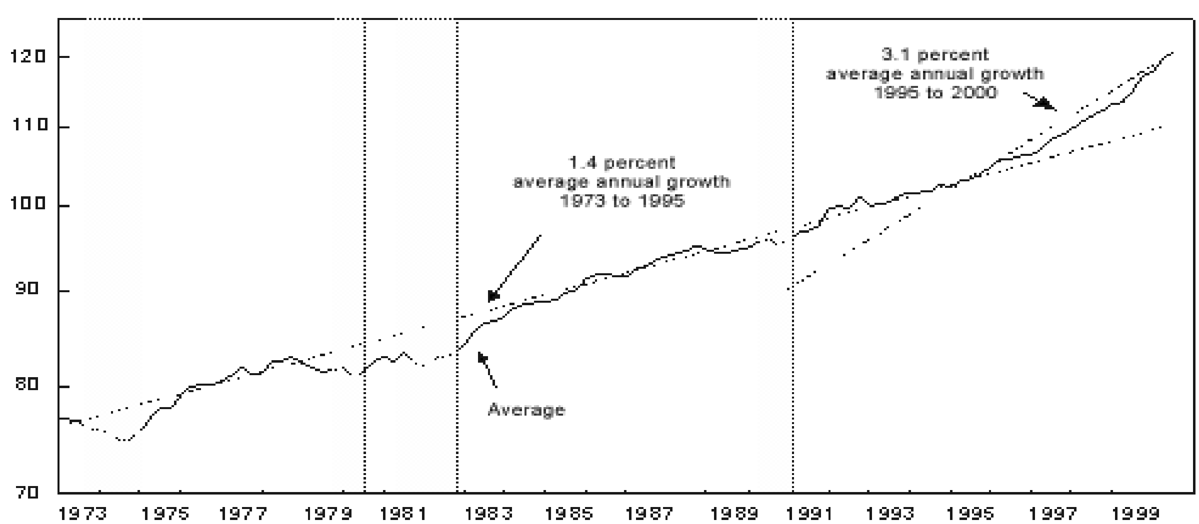
R&D can be safely said to be the bane of the economic growth that was experienced in the United States especially in the recent past. A look at the patent industry shows to a great extent, the boom in this industry especially in the 1990s. The graph in figure 11 below shows that patenting increased at a fast pace and with a wide margin and over a short period of time. As pointed out by Hunt (1990) there was indeed a surge in patent activity after the patent reforms in the 80s.

Figure 13: Patents granted for Information Technology applications in thousands per year. Source: Council of Economic Advisors, based on data from the Department of commerce (Patent and Trademark Office)



The sharp increase in the number of patents filed and granted increased sharply as can be seen above and this is believed by many scholars to be responsible for the productivity increase and economic growth experienced in the US. The figure 12 below shows that from 1998, there was also a sharp increase in productivity and subsequent economic growth. A 3.1% average annual economic growth was experienced in the US economy at the same time that there was a boom in the patenting industry (R&D activities).

Figure 14: US productivity growth increase. Output per hour in the non farm business sector index, 1992=10.



From the graph above, it is seen that the US experienced exceptional growth at the period in which R&D became very prominent following patent reforms in the United States. Also worthy of note is the growth in the productivity of labor in the US. The table 1 below shows that there was an increase in labor productivity in the 90s. An all round economic growth was experienced at this time especially in the manufacturing, agriculture, wholesale trade and IT sectors that had the highest R&D investments. It is possible that Hunt (1999) is not completely right in saying that the patent reforms had nothing to do with economic growth. R&D plays a huge role in human capital development and accumulation (Sjogren 1998) and this can be observed in the figure below. With the patent reforms, labor productivity improved significantly.

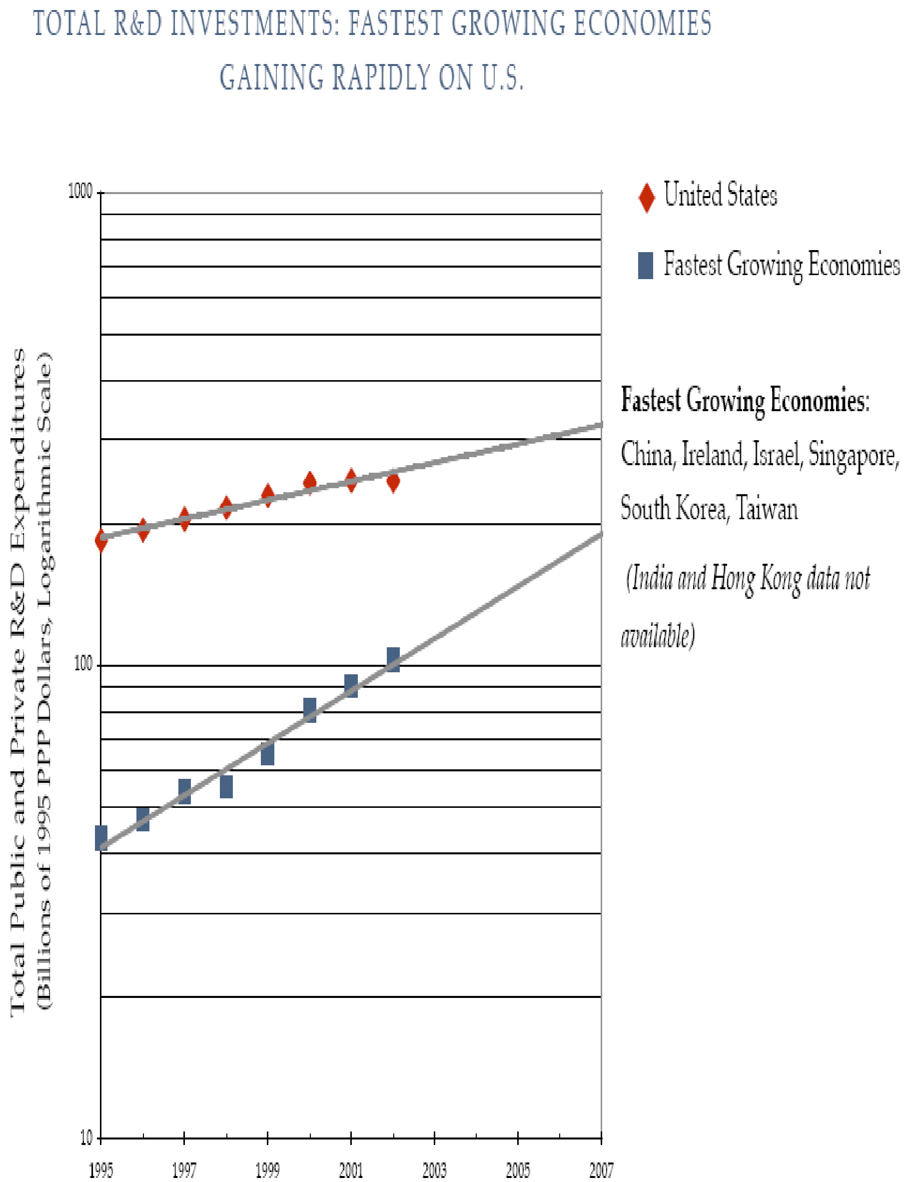
Table 1: Labor productivity growth in US industries. Per full-time equivalent employee. Average annual percent changes, selected periods.

	1989-95	1995-99	Difference
Private Industries [a]	0.88	2.31	1.43
Agriculture	0.34	1.18	0.84
Mining	4.56	4.06	-0.50
Construction	-0.10	-0.89	-0.79
Manufacturing	3.18	4.34	1.16
Transportation	2.48	1.72	-0.76
Communication	5.07	2.66	-2.41
Electric / Gas / Sanitary	2.51	2.42	-0.09
Wholesale Trade	2.84	7.84	4.99
Retail Trade	0.68	4.93	4.25
FIRE	1.70	2.67	0.97
Services	-1.12	-0.19	0.93
Intense IT users	2.43	4.18	1.75
Less intense IT users	-0.10	1.05	1.15
Source: Council for Economic Advisors (2001), based on data form			
Bureau of Economic Analysis			

The performance of the American patent system was highly remarkable in the late 90s. Spending by industries on research and development, measured in inflation-adjusted dollars or as a percent of gross domestic product, was very high and productivity which is a strong indicator of economic growth was on the increase.

But despite the fact that the United States has been leading the way in the area of Research and Development, Fast growing economies are fast catching up due to the fact that there has been a realization of the fact that R&D boosts economic growth. The figure below illustrates these recent trends.

Figure 15: R&D investments in fast growing economies catching up with USA



3.3 *Bergen Technology Transfer office (BTO)*

This case study is one that involves specifically the experimental aspect of research and development whereby ideas are developed into technological innovations and subsequently commercialized into a physical product or process to be useful to the society. According to previous works of economists, this activity has the ability to boost economic growth in a rapid way according to Herbert Giersch (1986). It also involves entrepreneurship.

Audretsch et al (2006) describe very comprehensively how entrepreneurship fosters economic growth. By serving as a conduit for knowledge spillovers, entrepreneurship is the missing link between investments in proprietary knowledge and economic growth. The knowledge spillover theory of entrepreneurship provides not just an explanation of why entrepreneurship has become more prevalent as a crucial source for comparative advantage, but also why entrepreneurship plays a vital role in generating economic growth. Entrepreneurship is an important mechanism permeating the knowledge filter to facilitate the spill over of knowledge and ultimately generate economic growth. The endogenous theory has made entrepreneurship and R&D a must for any country seeking economic growth.

3.3.1 Audretsch et al 2006

Audretsch et al (2006) stresses the importance of distinguishing between general knowledge and economically useful knowledge in explaining economic growth. This is probably the R&D problem facing developing countries like Nigeria and Angola presented in the next chapter. As observed from statistics, Nigeria does have R&D institutions and carries out some level of R&D but there seems to be a gap. I like to think of this gap as the knowledge filter gap. The knowledge filter as it is called is the main border between ordinary knowledge and economically useful knowledge. A lot of useful knowledge is wasted due to the absence of knowledge filters; this is also why a country that invests highly in R&D may not necessarily achieve economic growth.

Audretsch et al (2006) presented a paper on the role of filters or obstacles that prevent knowledge from resulting in economic activity although he did not particularly distinguish between the knowledge filters that he suggested, nor did he highlight their major contributions in his paper, the industrial revolution was based in part on these so called knowledge filters from business intuition and my further research. Knowledge filters helped in turning ordinary knowledge into economically useful knowledge. In his paper, he presented the modes through which the USA turned knowledge into business ventures they used mainly; land grant universities, corporate research and development labs as major vehicles of basic industrial research, a rapidly increasing share of college education, research university, the dramatic increase in research and development spending, and the shift of basic research toward the universities.

General Information about BTO

As a commitment to fostering economic growth and development through Research and Development, oil rich Norway has seven technology transfer offices (TTOs). These technology transfer offices are involved with the development of R&D for useful purposes. The 7 TTOs are located in major cities and districts in Norway. Oslo (The capital of Norway), Bergen, Trondheim, Stavanger, Tromsø etc. There is cooperation between the seven TTOs to facilitate high performance and the TTOs are linked to universities but they also work with other research institutions. Although they are not really owned by the government, they are funded and supported by the government to a large extent.

About Bergen Technology Transfer office

Bergen Teknologioverføring as it is known in Norwegian language (BTO) is a technology transfer company servicing eight research institutions in Bergen, Norway. The company is owned by the University in Bergen Norway, Bergen University hospital and the institute of marine research but it works with other research institutions. BTO's mission is to stimulate the creation of new jobs, and to facilitate the delivery of research results to the commercial sector thus leading to economic growth in the economy. The company appears to be implementing the strategies explained by Audretsch et al (2006) by encouraging entrepreurship in the country. BTO is a typical example of the knowledge filters he talked about. Since it's founding in December 2004, BTO has been involved in the launching of 16 spin-off companies (see appendix D), and has licensed several technologies. Today, several innovative technologies are in the pipeline or are already available for licensing.

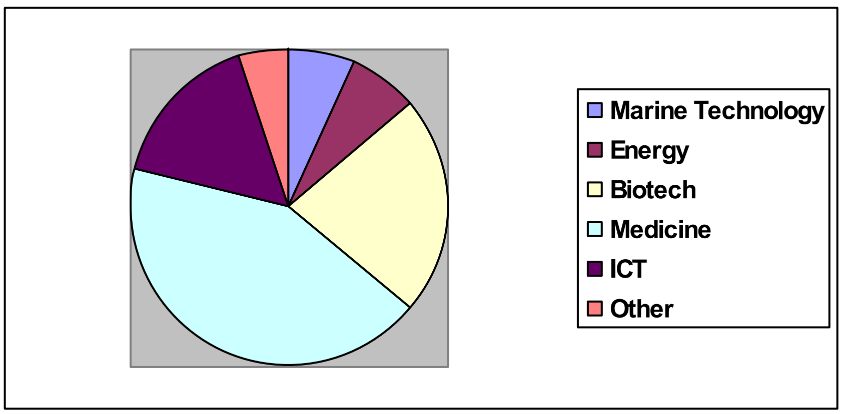
With only 5 years of operation, the company has already evaluated approximately as many as 350 ideas. These ideas are generated by scientists working behind the scenes carrying out thorough research to develop proprietary ideas that will become invaluable to the society.

- ***Fields of Research and development***

The scientists carry out these R&D activities on virtually every field of life; science, engineering, business etc. This basically depends on the scientists interests.

- Life science/medical technology
- Marine technology
- Energy and petroleum technology
- Materials/chemistry technology
- ICT/software

Figure 16: BTO deal flow (Research areas by scientists)



About 50% of the R&D outputs are in the end, found to be commercially interesting after carrying out a feasibility analysis. This step ensures that knowledge is not wasted and also it ensures that only productive knowledge is utilized so as not to waste economic resources. The activities of this organization within just 5 years of operation, reveals the dynamic and effective nature of R&D.

- ***Commercialization***

So far the company has entered into 16 - 17 license agreements and has been involved in establishing 18 spin out companies based on results of R&D activities (List of spin offs in appendix). These companies have provided employment to individuals and added value to the society. List of the companies established is added in the appendix. The commercialization process involves a lot of work because, development of the technology could be challenging depending on its complexity. Challenges faced by BTO involves developing good network with industry partners, getting industry partners involved in licensing the technology even before patent filing is successful; this is risky due to breach and default risks on the part of the licensee. Also BTO has to gain the trust of the inventor and this is sometimes quite challenging.

- ***Patents***

As seen in the first case study of the United States patent industry, patents were really substantial in the development of the R&D industry and subsequent economic growth of the United States. Following a restructuring of the researchers act in Norway in 2003, researchers are no longer allowed freedom to do what they like with their research output. Employer's investors' act has made it mandatory for them to report their invention to their employer. The employer then takes up the invention and is in charge of the Intellectual property rights. In Norway, the law ensures that there is an equal treatment of researchers and as an encouragement to researchers, they are entitled to one third of the net revenue after patenting and indirect costs associated with further development of the technology and licensing agreements with industry participants on their invention. They can also hold shares in the company established based on their invention. On the other hand, BTO is allowed to own shares in the companies that they help to establish due to their efforts in commercialization of the innovation.

In an effort to encourage owners of the technology innovations, BTO files patents on behalf of the owners of the technological innovations. They also use external patent agencies to complete the patent application process. The company has been successful with some patents and currently handles approximately 20 pending patents. BTO has a policy to file patents of which the technology has been screened and found to be dependable and believable and therefore has a plan for commercial utilization. Although this is quite restrictive, the company aims to have a clear strategy to work only with superior technological innovations. This is in line with the work of scholars mentioned in the literature review section which stresses the need not just for R&D but for effective R&D.

- ***More on contributions***

BTO has successfully contributed to economic growth. Although most of the contributions will be in the long term, R&D investments do not have immediate effects (Grilliches, 1979) there is definitely a huge potential in the operation of the TTOs in Norway.

Job Creation: With the spin offs and licensing agreements, BTO has definitely created employment in Norway.

Human capital accumulation: This in conjunction with human productivity increase is one of the contributions of BTO. The researchers working on developing novel solutions and technological innovations enhance the quality of human capital in Norway.

Improved GDP and quality of life: Apart from job creation, the high quality medical products that have been introduced into the market have contributed to the welfare of citizens and will definitely decrease the number of absenteeism due to sickness thereby improving output by increasing no of hours worked. Particularly, the medicines produced for the marine industry has been able to improve the quality of marine life for example fish deaths has been reduced and fish accounts for a huge amount of exports from Norway to other countries thereby indirectly leading to higher GDP.

A major challenge for the case studies presented in this thesis is the fact that R&D results cannot be measured completely and accurately due to the spillover effects and the intangible nature of the benefits it provides like; knowledge creation, increased productivity and general improvement in living conditions.

4.0 Country Example

- **Research & Development in Nigeria & Angola**

Developing economies like the ones mentioned above are often plagued by the same symptoms and as a matter of fact have a lot in common as far as investments in R&D is concerned. Research is the only source for generating and advancing the frontier of knowledge, skills training and expertise for manpower, and therefore, the most important factor which, facilitates and accelerates economic development and improved living conditions in society. Sabo Bako, (2005).

In this section, I will take a look at the state of R&D in the 2 economies and then show a comparison and common challenges facing both countries. Despite numerous economic studies showing evidence of the benefits of promoting research and development for economic development, many emerging markets still lag behind in terms of basic and applied R&D, science education and fostering home-grown technology. Despite the little amount of R&D activities carried out especially in Nigeria, Much of the technological advances still occur through the adoption of technology created elsewhere (Alo, 1995). This is partly due to the challenge which will be explained in this section. Although not part of the comparison, Colombia has a similar situation. The public agency in charge of promoting science and technology is typically small and not given a central role in the development of the country**.** The university R&D results of Nigerian universities are not used by the productive sector; more detail will follow in the next section.

4.1 The Nigerian Economy

- ***General Information***

Nigeria can be said to be the giant of Africa, a country with a population of over 120 million. With more than 250 ethnic groups speaking about 4000 dialects, there is a huge diversity within the country itself in terms of culture and religion and it could be correct to say that Nigerian citizens show allegiance to their tribe first before Nigeria as a nation, thus it would be difficult to ever classify Nigeria as a Nation-State. Main ethnic groups are Igbo, Yoruba and Hausa, while English is the official language. Country size is 577,355sq miles i.e. almost triple the size of California and almost bigger than the whole of Western Europe. There are 36 states in Nigeria, plus Abuja the federal capital territory. Nigeria has one of the highest literacy rates in Africa and is a prolific member of the African Union. Since Nigeria joined the United Nations, it has consistently committed itself to the cause of peace keeping and peace making; she sent her troops to participate in the UN peace mission in the Congo only days after its independence in 1960. The country is a major world leader in international peace keeping with the highest number of men and women risking their lives in the interest of peace.

Nigeria has a population of 18 million students in Nigerian schools at primary, secondary and university levels, this figure is more than the total human population of South Africa, Ghana, Kenya, Egypt, Morocco, Tanzania and the school population of France, Britain and Spain. The Educational system adopted is the 6-3-3-4 (six years of primary education, a two-tier 3 year junior, 3 year senior secondary education and four years of University education). There are about 35 government funded Universities in Nigeria today excluding polytechnics, private universities and colleges of education. While literacy stands as one of the highest in Africa, the goal of the present government is to eradicate illiteracy as soon as possible.

Nigeria is also a leader in sports and has made its mark in the past as well as in recent times. The National football team "The super eagles" has made the country famous in sports. Dozens of Nigerians are professional athletes in the international scene and play in clubs across Europe and USA.

- **Oil Industry in Nigeria**

German engineers were the first to drill the first oil well in Nigeria, and ever since, a lucrative industry has sprung up. Oil is the main stay of the Nigerian economy and the bedrock of economic growth so far. Statistics show that oil accounts for more than 80% of the country's foreign exchange earnings. Nigeria is a member of OPEC (The organization of Petroleum exporting countries) and holds the highest office of Secretary General. Elected for a record sixth term.

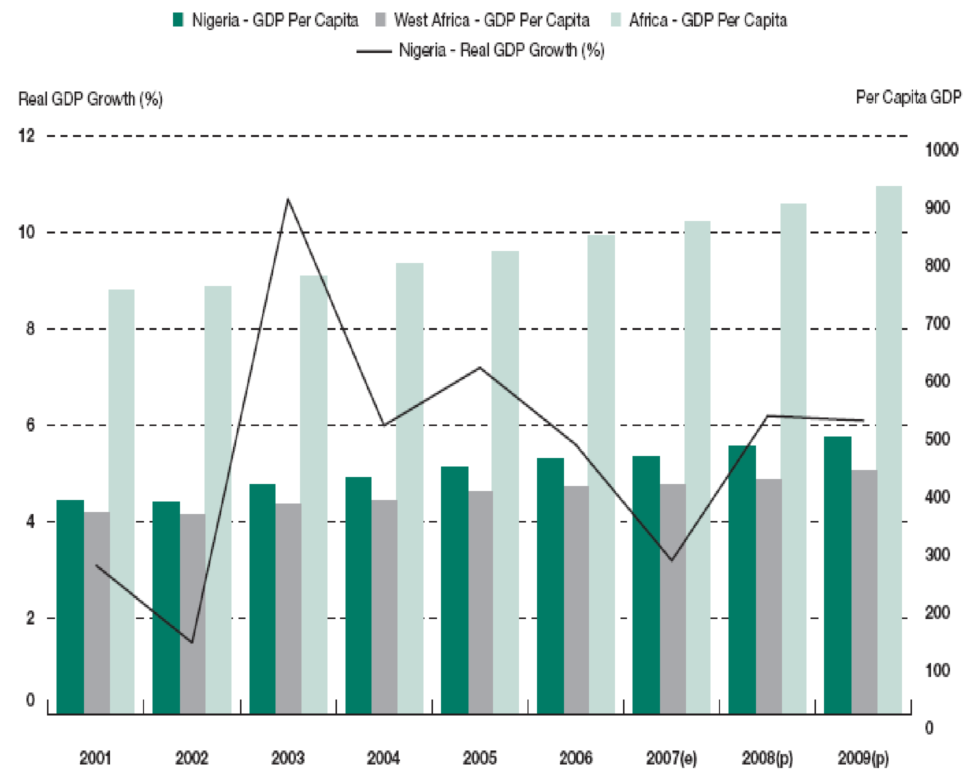
Nigeria's oil reserves are the ninth largest in the world with a vast wealth of unexplored natural gas reserves which is the fifth largest in the world. Dozens of European and American businesses are currently exploring joint venture businesses in gas production. Nevertheless, today, Nigerians themselves have realized the danger of over dependence on one economic sector no matter how lucrative. There is a high level of unemployment. In recent times, effort is being made to improve the agricultural and manufacturing sector due to the huge potential that lies therein. Unlike China and Japan, Nigeria has fertile large arable land; various schemes are being established to incorporate the contribution of other sectors towards the goal of economic growth in the Country. In my opinion, the missing link and the key to the successful development of other economic sectors in Nigeria is Research and Development.

- ***Gross Domestic Product in Nigeria***

Oil rich Nigeria has experienced a lot of mismanagement in the past and this has continued in recent times to some extent. However, the country has adopted strategies to deal with this problem as well as ways to achieve the millennium development goals alongside other African economies. Nigeria has been greatly helped by the high world oil prices, through which it has been able to undertake bold economic reforms. However, recent developments in the oil price as well as the political unrest in the country's oil producing region (Niger delta) have jeopardized these reforms to a reasonable extent. The Real GDP growth of Nigeria averaged 6.5% between 2003-2007 but reduced from a high of 10.7% in 2003 to 7.2 per cent in 2005, 5.6% in 2006 and an estimated 3.2% in 2007. This was largely as a result of the disruptions in the oil production sector as a result of the crisis in the Niger delta.

The non-oil sector, performance has been very encouraging, with growth of 8.6% in 2005, 9.4% in 2006 and an estimated 9.8% in 2007. This shows high potential for improvement.

Figure 17: Real GDP in Nigeria over the years



Source: Domestic authorities' data; estimates (e) and projections (p) based on authors' calculations.

StatLink http://dx.doi.org/10.1787/316756370031

4.1.1 The State of R&D in Nigeria

According to statistics, most of the commercializable industrial R&D in Nigeria is carried out by government-owned research institutes due to capital intensive nature of the projects but these institutes perform poorly due to the fact that they are not managed properly. Main output involves a lot of data collection without basic, applied or experimental research (explained in chapter 1). On the other hand is the university research. The problem here is that only a limited amount of university research reaches a commercial state (Bako 2005). Programs at the universities have not responded adequately to the developmental needs of Nigeria. Normally, the bulk of research at the universities is conceived in terms of publications and career advancement and tends to have little social relevance. Notwithstanding this, appreciable research is done, and an awareness of the need for more research at Nigerian universities has been created (Bako 2005). Research at Nigerian universities has been said to be mainly basic research, not applied. Moreover, it is presumed that many academics are not carrying out research relevant to local problems. In the 1970s, basic research and applied research at universities were estimated at about 6 and 24% of the national research capacity, respectively (Alo 2005). In recent times, these percentages are still glaringly low and should be significantly increased if research is expected to contribute significantly to the development in the nation.

A survey carried out by Bako (2005), revealed that University-based research in Nigeria is commonly designed in such as way as to solve specific problems applicable to Nigeria's productive sector. Eighty percent of the projects analyzed in the survey were of this nature; the other 20% of the respondents considered their research a normal scientific endeavor. However, it is a bit discouraging that only 19% of the applied research was commissioned by the productive sector. The majority of the studies were at the initiative of the researchers themselves as it is in most countries. It is not surprising therefore that the industry demand for local R&D is low. Only 21.7% of respondents in the survey carried out had their project results actually applied in the productive sector. This could be due to absence of technology transfer offices. Also, although many of the investigations were in basic research, some results deserved patents. Unlike some universities in the developed countries, none of the first-generation universities in Nigeria had a patent office. The need for copyright protection is ignored because few research results are ever adopted. Commercialization of research results, therefore, is still in its infancy at most Nigerian universities.

In Bako's study, only 10% of the research projects had been commercialized. The attitudes of the productive sector to research results (64%) ranked with poor communication links between the two sectors (64%). The lack of clear-cut enabling polices was also considered an important factor (49%). Other possible factors, such as socioeconomic or political factors, bureaucracy, scarcity of university- based research results, and inadequate personnel, were not really considered as important.

An analysis of the demand for university-based research showed that the expertise of only about 30% of researchers across the universities were in demand in the productive sector. The table 2 below presents a brief summary of the survey to the question of the reasons why the productive sector does not utilize the research results of universities.

A relatively large number of respondents seem to believe that poor funding of research, poor or indifference attitude of industrialists to results of university research and bureaucracy are the top reasons why the productive sector does not use the research results of universities. The problem of bureaucracy is a problem that is also faced by EU research projects as will be seen later in this paper. More detailed description of the results of the survey by Bako (2005) is shown in appendix B Tables 8, 10 & 11.

Table 2: Constraints to use of University research results by the productive sector.

Constraints	Yes	%	No	%
Poor funding of research	118	91.5	11	8.5
Lack of clear-cut enabling policies	63	48.8	66	51.2
Poor or indifferent attitude of Industrialist to	83	64.3	46	35.7
results of university	16	12.5	113	87.6
Poor or indifferent attitude of university scientist	41	31.8	88	68.2
Bureaucracy	83	64.3	46	35.7
Poor communicatio0n between universities and the	7	5.4	122	94.6
productive sector	22	17.1	107	82.9
Paucity of University-based research results	47	36.4	82	63.6
Inadequate research personnel	29	22.5	100	77.5
Economic reasons (e.g SAP)	6	4.7	123	95.3
Political reasons	7	5.4	122	94.6
Security reasons				
Other				

Source: Chapter 17, University Based Applied Research and Innovation in Nigeria. httt.///research.yahoo.com.appliedreseaerch+NigerianUnivesities8Presearch

According to David Okongwu in his book on 50 years of technology transfer in Nigeria, Nigeria's efforts at R&D and technology transfer have to contend with not only the widening innovation gap between it and the developed countries, but with the nation's poor culture of innovation, rapid changes in innovation and the shortening life span of innovation cycles (Okongwu 2005). There are no identifiable knowledge filters in operation as well so knowledge obtained or developed could go to waste.

The annual allocation to the federal universities system is just 1% of Nigeria's total revenue. In 1986, this represented 0.6% of the gross domestic product (GDP). The proportion of the nation's resources allocated to universities increased slightly in the 1990s (Table 3). The

National Policy for Education stipulates that at least 80% of federal allocation to education must be devoted to higher education (Alo, 2005).

Table 3. Recurrent allocation to Nigeria's Federal University System.

	Allocation (million NGN)	% of national revenue	% of GDP
1986	394.9	1.10	0.64
1987	304.5	0.90	0.39
1990	634.6	1.30	0.74
1991	699.9	1.02	0.70

Notes: GDP, gross domestic product. In 1995, 78.5 Nigerian naira (NGN) = 1 United States dollar (USD).

The first-generation universities receive a large proportion (>50%) of the total grants to the Nigerian university system (Table 4). Each university in the group draws 0.23% of the nation's GDP, on average. These institutions are expected to account for a significant proportion of the university-based research and development (R&D) (Alo 2005). But even these investments may not be sufficient enough to boost R&D activities and subsequently economic growth.

Table 4. Recurrent appropriations to Nigeria's six first-generation universities (1981–92).

University	Total (million NGN)	Proportion of total (%)	Mean % of GDP
Ibadan	769.4	10.2	0.25
Lagos	712.0	9.5	0.23
Nsukka	763.1	10.2	0.25
Zaria	762.5	10.2	0.24
Ife	734.6	9.8	0.24
Benin	529.5	7.0	0.18

Total	4271.1	56.9	
Notes: GDP, gross domestic product. In 1995, 78.5 Nigerian naira (NGN) = 1 United States dollar (USD).Proportion of total allotment to the Federal Universities System.			

The table above shows a relatively low commitment to R&D in Nigeria compared to OECD countries seen in previous sections. Even worse, Nigeria is not only lacking in R&D activities and investments, but also unable to successfully capture technology that is transferred, ensuring that it is fully internalized to enable it to grow and create similar new technologies on its own (A strategy used by Japan and China). The predominance of Know-How/Technical Assistance and dearth of patent license agreements reflect the very weak indigenous technological capability in the economy (Okongwu 2005)

Nigeria's national R&D intensity as presented by the National bureau of statistics, under the S&T ministry is about 0.06% compared to South Africa 0.70%, China 1.40% and India 1.2% (Okongwu). Of all technology inflow into Nigeria, Asia accounted for about 31% between 2001-2006 while the UK and Western Europe accounted for 59%, inflow from Asia has been on the increase. The indications are that throughout this decade and the next, the upsurge from Asia (mainly China and India) will continue, and the inflow from Europe will gradually diminish to secondary importance (Alo 2005). This is mainly due to the changing trends in R&D discussed in the previous sections. Emerging markets especially in Asia are beginning to be more proactive as far as R&D investments is concerned.

4.2 Federal Republic of Angola

- ***General Information***

Angola is a country with unlimited potential. The country has a wide land mass, more than three times the size of California; it extends for more than 1000 miles along the south Atlantic in South West Africa. It shares borders with the Democratic Republic of the Congo and republic of Congo to the north and east and Namibia to the south. The country has a lot of desert areas and a plateau averaging 6000 ft above sea level. Total area is 481,350 sq miles. The country has a population of about 13 million with a growth rate of 2.0%. Although the country has been ravaged by a war that destroyed much of its infrastructure and led to the death of millions of Angolans, the country is sub-Saharan Africa's leading oil producer since April 2008 (SARUA 2008).

Education in Angola is compulsory and free for eight years of study but children are unable to go to school due to the fact that there is problem of lack of school buildings and the presence of land mines in some areas. The damages of war still plague this country to a large extent.

However, the huge potential of this country has been recognized by developed countries and there has therefore been a huge influx of FDI in the country especially by European and American economies. In recent times, Asia has also increased its presence in the country. The country is endowed with a lot of natural resources just like Nigeria. Apart from the oil industry, Angola has vast stretches of fertile land like most countries in Africa and one of the largest unexplored oil deposits in the world.

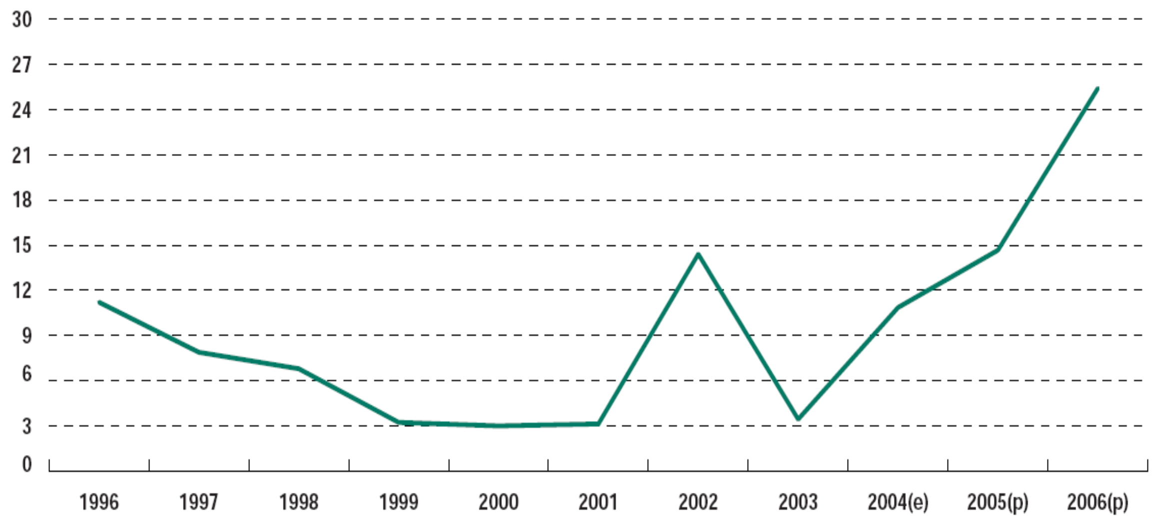
Portugal ruled over Angola for 400 years therefore, both countries share some cultural aspects. The language is Portuguese and the main religion is Christianity and the Roman catholic church is highly predominant in Angola.

- ***Gross Domestic Product in Angola***

It is impossible not to notice the rapid economic growth being experienced in this country despite the destructions caused by many years of war; the country's economy has grown since it achieved political stability in 2002. In figure 14 shown below, the GDP of Angola is relatively high compared to other African economies. This is not due to R&D but due to the increase in commodity prices with the oil industry and Diamond production. The Growth in GDP being witnessed in Angola is almost entirely due to the oil production in the country. The country is rated amongst the fastest growing economies in the world today. The economy grew 18% in 2005, 26% in 2006, and 17.6% in 2007 and is expected to have growth rate of over

10% for the rest of the decade (SARUA 2008). However, just like the Nigerian economy, there is a high dependence on the oil sector and the other sectors are left behind with huge untapped potential. This potential can only be fully reached through research and development activities (Bako, 2005)

Figure 18: Real GDP growth in Angola



Source: IMF and National Institute of Statistics data; estimates (e) and projections (p) based on authors' calculations.

4.2.1 The State of R&D in Angola

The 27 year long civil war came to an end in 2002 but left a lot of devastating impacts on the country. In Angola today, the total investments in R&D and R&D related activities is negligible compared to OECD member nations and even other African countries. Angola is ranked 102nd in business investment in R&D (appendix table 7). Also, there is very low subsidy for firm-level research and development. It is ranked 94th in this criteria (appendix table 8). There is very little information on the R&D investments done in this country. However, most of the R&D performed in Angola is done by the multinational companies and is mostly in the field of oil businesses (OECD 2006). Besides, the country lacks the needed expertise to be able to capture the technological expertise of the multinational companies within its borders (Appendix Table 7). Public expenditure on education as a percentage of gross national income is 2.8% (SARUA 2008) which is very low. The country has only one publicly funded university and does very little to protect intellectual property. According to the World economic forum 2005 data, the country ranks 104th in the protection of intellectual property. This explains why there is a low level of innovation in the country. The key research performing institution in Angola is the University Agostinho Neto. The University was created in 1976, a year after Angola had become an independent country. In addition to the University other research institutes in the country include the Cotton Scientific Research Centre in Catete, the Agronomic Research Institute in Huambo (founded in 1962), the Institute for Veterinary Research in Lubango (founded in 1965), the Angola Medical Research Institute in Luanda (founded in 1955), and the Angolan Directorate of Geological and Mining Services in Luanda (founded in 1914).

R&D Workforce and R&D output

According to the UNESCO Global Education Digest, there was a total of 1 285 academic teaching staff in Angola in 2004. Over the 2000 – 2007 period, the total number of scientific publications that are listed in the ISI database from Angola was very low, with just 90 publications (which translates into 12.5 papers per year). In 1998 the total head count of R&D personnel at national research institutions in Angola was 211 (SARUA 2008). The country has the same characteristics as Nigeria when it comes to R&D productivity. Although it does not have as many research institutes as Nigeria, the institutes that it has are not productively involved in R&D activities but are more involved with data collections and scientific publications.

Angola has scientific collaborations with Brazil in the health sector, with Japan in the ICT telemedicine, e-learning, e-commerce and corporate governance sector and with Norway, in the energy, education and good governance sector. But there is a very low absorption capacity. The country is not sufficiently able to absorb technology from these collaborations as well as from the multinational companies that operate within its territory. Table 7 in the appendix shows that Angola is rated 103rd in Firm-level technology absorption.

4.3 Angola and Nigeria Compared

Angola and Nigeria have a lot in common as regards their investments in R&D as well as the development and advancement of R&D activities. Both economies are not able to satisfactorily benefit from R&D in the multinational companies operating within their territories and even though they have a huge potential for economic growth, this potential has not been fully realized and optimized. Both countries are top oil exporters and should be able to make good investments in R&D to boost productivity. However Nigeria is still relatively highly rated in comparison to Angola as can be seen in tables 7-9. Although at varying degrees, the two countries face a lot of challenges in implementing R&D. Bako (2005) stated and I agree that the main problems that could be facing the two economies are;

- Funding (Poor public sector funding for R&D): It is quite ironic that these top oil exporters are unable to devote funding for R&D in their economies.
- Private sector funding capability for R&D: this is almost non-existent, due to the fact that there is poor intellectual property protection as well as the high capital intensive nature of R&D investments.
- Poor academic orientation: Low access to sound education especially in Angola with an inadequate number of universities. However, Angola's ministry of education is working on improving the management of its higher education system.
- Poor intellectual property protection
- Inadequate infrastructural facilities
- Low absorptive capacity: inability to retain and develop knowledge from abroad.

An overview of the main observations presented above from my investigations is presented below to facilitate the comparison between the two countries. On a scale of 1-10, the countries are rated thus in my opinion:

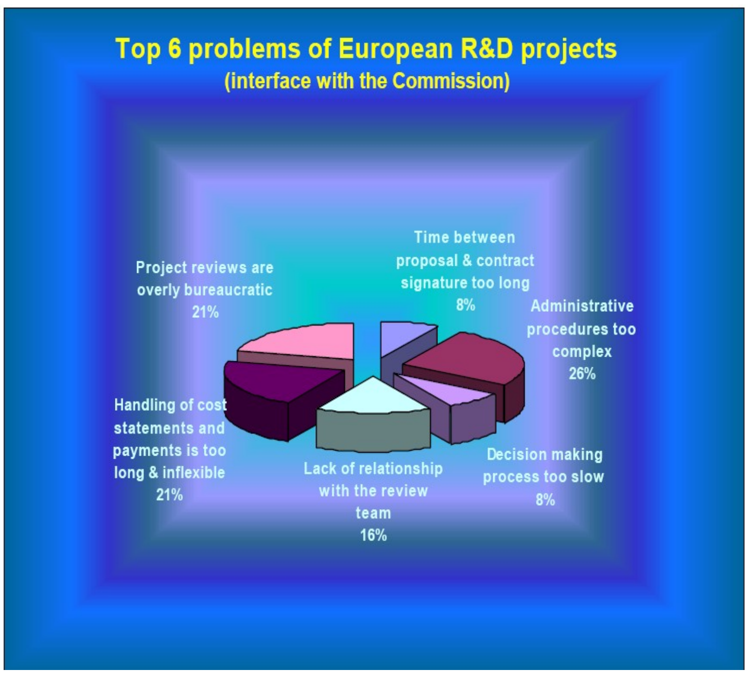
Table 5: Subjective comparison between Angola & Nigeria

Criteria	Angola	Nigeria
Oil dependence (one sided Economy)	8	8
R&D activities	4	6
R&D knowledge assimilation from Multinationals	4	6
R&D Personnel working in the country	4	6

Protection of intellectual property	4	6
R&D Data on country	3	6
Potential for improving Future R&D performance	5	7
R&D institutions	4	6.5

A survey was carried out by Filos (1999) to find out the main challenges of R&D related projects in the EU. The problems are illustrated below in figure 15. They include: bureaucracy in R&D project reviews, complex administrative procedures, lack of relationship with project review team, slow decision making process, inefficient cost handling and R&D project approval process period is too long.

Figure 19: Challenges of European R&D. Source: Erastos Filos research Brussels



The problems above shown from Erastos's results are not only peculiar to European countries, they are also a relevant part of the problem of Angola and Nigeria, and these findings reveal that R&D administration poses a significant general challenge for all countries and therefore should be given close attention. However, I believe that these problems are likely to affect public R&D projects more than private R&D projects.

Opportunities for Angola and Nigeria

The two economies have a lot of potential to become high R&D performers. They are both well endowed with natural resources. Nigeria: Oil rich nation, gold, coal etc and Angola: Oil rich as well, diamond production and etc. In addition, they both have the availability of cheap skilled manpower, big market for innovations that address local challenges and the Internet which is a vast reservoir of knowledge can serve as input into technological innovations. Lots of multinational companies use the internet to facilitate operations within and outside their territory. It is an amazing communication tool that can make collaboration between African researchers and their global peers relatively easy. If these potentials are well utilized, the countries will achieve balanced economic growth not just a one-sided volatile growth due to oil production.

4.4 Lessons to learn for Angola and Nigeria

Without a deliberate receptor programme to capture technological innovations from multinational companies, and a culture that encourages spirit of enquiry and freedom of thought, an all round economic growth may be very far away from these two countries (Okongwu 2005). With R&D activities, innovation will sprout, technology will develop and entrepreneurialism will flourish and there would be rapid growth in all economic sectors. One strategy to achieve this state is to aggressively establish knowledge and software innovation parks in strategic areas of the country (Okongwu 2005).

In this knowledge intensive century, a vibrant technology transfer office is imperative to elevate Nigeria and Angola to the rank of innovation-oriented nations. In Nigeria's capital FCT Abuja, there is presently a technology transfer office although not yet as functional as the ones in developed countries. As a prescription, technology transfer strategy capable of making Nigeria a global leader and a "power house" must embody the following operational objectives (Okongwu, 2005): Upgrading technological governance; enthroning a culture of innovation, strengthening intellectual property system; development of human capital with strong entrepreneurial base.

Developing countries are still able to learn a few lessons and improve their economy by adopting a lot of strategies successfully used by developed economies. Some years ago Mansfield (1972) compared the R&D outcomes in the United States and Japan and concluded that the Japanese were gaining higher returns than the Americans from applied R&D because of the greater reliance on imported technology and process R&D as opposed to product R&D. Developing countries can borrow the strategy of the Japanese by customizing imported technology to suit demands in their own economies. To acquire, adapt, and internalize technologies from any corner of the globe will result in a common good for the African continent.

Innovation intensity

There has to be an increase in innovation intensity in the two countries being considered. For the last ten to fifteen years, innovation surveys have been launched in the European Community and other OECD countries. Unfortunately, no such survey has been done for Africa. The idea is to measure innovation by the percentage of enterprises that introduce new products or processes, and possibly a quantification of the innovation intensity, as measured for example by the share in total sales due to innovative products (Bailey 2001). Adapting a measure of monitoring innovation intensity can lead to competition among the firms operating in these economies and will spur them to become more innovative. R&D activity is said to benefit productivity and subsequently economic growth by increasing options for consumers and improving general well-being. The patent industry needs to be improved very significantly in order to generate confidence in inventors.

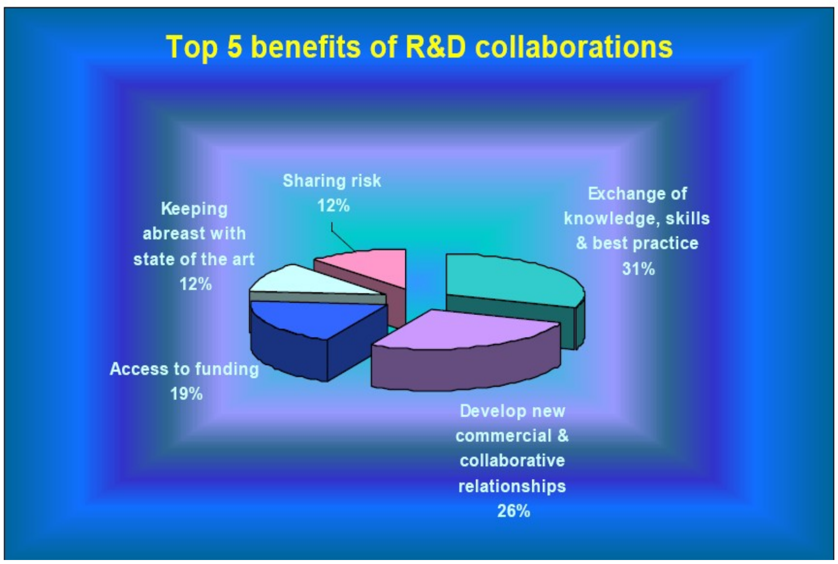
R&D collaborations

This involves pulling economic and financial resources together by organizations or countries to fund R&D activities (Schluga & Barber (2006). In Europe, the main examples are the European Framework Programmes (EFPs) on Research and Technological Development (RTD) as described in section 2.9b. R&D collaborations are specifically aimed at supporting transnational collaboration and coordination in research, and capital intensive projects (Schluga & Barber, 2006).

The main objective of these R&D collaborations activities has been to strengthen

Europe's science and technology capabilities and to promote European international competitiveness through coordinating national policies, integrating national research communities, improving the integration of marginal actors, and bringing together actors with the most advanced resources and capabilities. This has created a pan-European network of actors performing joint R&D (Schluga & Barber, 2006) and can be a good example for economies like Nigeria and Angola. The EU actively utilizes this strategy for high performance and to mitigate the costs of individual member nations. Erastos 1999 carried out a study to determine the benefits R&D collaborations and this can be observed in the illustration in (figure 20) below. Knowledge exchange and network expansion is top on the list. Keeping up to date is also a key point especially with today's global competition.

Figure 20: Benefits of R&D collaborations; source: Erastos Filos



Angola and Nigeria can adopt this R&D collaboration strategy, in their individual countries between companies or with other countries in Africa. This will provide a lot of economic growth benefits for the regions involved. Also it will significantly reduce the cost burden of individual nations and help facilitate cooperation between countries involved. The African Union could consider this as a strategic way of boosting economic growth in African economies. Barber & Schluga (2006) mentioned above

The importance of networks and alliances can never be underestimated. Even in the business sector, a lot of companies especially multinational companies have improved performance by forming strategic alliances and forming networks with other firms in the same industry. By doing so, they can share knowledge, pool resources and carry out projects together.

5. Summary & suggestions for future research

This paper has aimed to show the role that R&D plays in economic growth. The study used case studies, general management knowledge and business strategy considerations to buttress the main point as well as empirical data provided by other economists. Literature review provided a lot of insights into R&D in various economies in addition to the technology frontier: The USA. R&D in an economy is measured in various ways to form a total aggregate measurement. The study looked especially at the gross expenditure on R&D as a percentage of GDP. Furthermore, number of scientists working in a country was also taken as a way to show R&D intensity.

A closer look at some selected papers by: Grilliches (1979), Griffith (2000), Sveikauskas (1986), Hunt (1999), Lonmo & Anderson (2003), Audrestch (2006), Sjogren (1998) is presented to stress the main points of the paper and a model is presented to give a clear picture of the mechanisms used for effective R&D performance. Grilliches (1979) points out the issues involved in measuring R&D and sets the basis for this research to a large extent. He stresses that simple econometric analysis is not sufficient to show the relationship but that historical case studies could be a good approach as well. Sveikauskas (1986) and Griffith (2000) showed the contributions of R&D to economic growth with the latter paying attention to industry and country spillover contributions as well. Sjogren (1998) on the other hand considers R&D in combination with human capital accumulation as factors of economic growth and presents a model stressing human capital accumulation as the major contributor. The rest of the papers presented issues concerning R&D productivity.

The case studies used in this study reveal the importance of productive R&D and the forces that facilitate productive R&D. The US patent system revealed the significance of patents and the BTO case showed avenues that can be used to achieve productive R&D in an economy. The country example case is used to show a picture of poor R&D in Nigeria and Angola; a case of low and unproductive R&D. This case study led to recommendations and suggestions for improvements based on the findings of the study in general. The model presented shows the mechanism through which R&D eventually translates to economic growth.

R&D is a very broad topic because apart from the types of R&D; basic, applied and experimental R&D, there is also process and product R&D, the forms of R&D: public or private and different fields of R&D: business R&D, medical R&D, agricultural R&D and etc. Also, different economists have different views and opinions about the subject; it will be interesting to distinguish between returns to basic and applied research especially at the aggregate level.

Basic R&D has a very large time lag (time from discovery to implementation of research effort) structure, this makes it difficult to estimate and to assess its independent effect on productivity (Grilliches, 1979). A suggestion for further research is to have a more detailed in depth study that observes the contribution of each of the aforementioned R&D forms to the economic growth of nations. They should be studied individually so that their links to economic growth will be more clearly seen.

5.1 Conclusion

From Literature review and the case studies discussed, I can safely say that productive R&D contributes to Economic growth. Although the contributions may not be able to be measured precisely for the reasons mentioned above, R&D definitely increases the gross domestic output of a nation directly through job creation, new products, processes, human capital accumulation as can be seen in the case of BTO in Norway and indirectly through spillover effects. Although I believe every sector of the economy requires R&D, however, empirical data shows that the economic sectors that receive R&D most are health and defense, followed by the business and manufacturing sector. The channels and mechanisms through which R&D leads to economic growth are seen in the knowledge/economic value filter and economic growth model; the role of patents, knowledge fliters (Technology transfer offices and etc) cannot be ignored.

The growth of the United States patent industry revealed the intensity of R&D activities in the country especially in the 90s and this same period represents the highest economic growth period in the US as shown by empirical data. Furthermore, the practical application and benefits of R&D in Norway is seen in the paper as providing employment and boosting productivity through the establishment of companies and the creation of proprietary innovation.

On the other hand, the effect of poor R&D investment is embodied in the study of Nigeria and Angola. Relatively low economic growth and under-utilization of huge economic potentials. Growth in these two economies is one-sided due to high dependence on commodity led growth. Oil shocks are sure to reduce GDP in these economies making them volatile economies. Overall, R&D contributes highly to economic growth and can be made to be more productive in these two economies by using knowledge filters, improving the patent industry and R&D collaborations. Apart from the challenges involved in knowledge management and capability transfer, this is always a success and it should be encouraged between and within countries to foster economic growth and high performance.

This research revealed that in general, a lot of scholars believe that R&D has contributed immensely to the economic growth of many nations, but however, there are lots of challenges in estimating R&D's role in economic growth to great certainty. This is due to the fact that output is measured poorly in R&D intensive industries like the health sector, service and defense sector. It is unlikely that a doctor will be interested in documenting how many patients got cured by a particular drug when he is busy trying to give care to other patients. Furthermore, R&D processes take time and may not have impact until after many years and past R&D depreciates and get obsolete especially in the global economy that we live in now, where there is huge competition among countries and multinational firms. Thus growth in R&D capital is not equal to the gross level of current or recent resources invested in expanding it. Also R&D results are often embedded in people, books, blueprints and tradition so it is difficult and presumptuous to aggregate all into one idea of R&D.

This research experienced limitations due to limited access to data (especially for R&D activities in Angola due to war history). Also, as said in the suggestions for future research, R&D is a very broad topic and many countries do not clearly map out data for the individual components like basic, applied etc. This makes it more difficult to show a clear link between R&D and economic growth.

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7. Appendix

Appendix A : Data on R&D

Table 1: changes in R&D spending 1989-1999

	Gross Expenditures on R&D (GERD)			Gross Domestic Product (GDP)			GERD/GDP ratio		
Country	**1989**	**1999** (1995 PPP$)	**Change (%)**	**1989**	**1999** (1995 PPP$)	**Change (%)**	**1989**	**1999**	**Change (%)**
Austria	2,013	3,485	73	148,942	190,386	28	1.35	1.83	36
Denmark [a]	1,625	2,770	70	107,783	132,768	23	1.51	2.09	38
Finland	1,792	3,757	110	99,597	116,710	17	1.80	3.22	79
Iceland	58	167	188	5,737	7,162	25	1.01	2.33	131
Ireland	383	1,136	197	47,908	94,019	96	0.80	1.21	51
Korea [b]	7,565	14,797	96	393,891	599,189	52	1.92	2.47	29
Sweden	4,786	7,439	55	169,179	196,703	16	2.83	3.78	34
Canada	9,104	14,064	54	621,174	783,183	26	1.47	1.80	22
France	25,398	28,775	13	1,109,359	1,315,714	19	2.29	2.19	-4
Germany	38,895	45,264	16	1,357,875	1,854,397	37	2.86	2.44	-15
Italy	13,125	12,784	-3	1,061,339	1,229,681	16	1.24	1.04	-16
Japan	70,132	90,212	29	2,593,674	3,071,561	18	2.70	2.94	9
United Kingdom	21,532	23,066	7	1,000,163	1,228,025	23	2.15	1.88	-13
United States	167,593	229,280	37	6,408,700	8,626,701	35	2.62	2.66	2
OECD Total	**382,351**	**523,296**	**37**	**16,898,719**	**23,705,899**	**40**	**2.26**	**2.21**	**-2**

[a] 1998, not 1999

[b] 1991, not 1989

Source OECD, Main Science and Technology Indicators (MSTI) database, July 2002

Table 2: GERD/GDP ratio. Source: OECD 2002

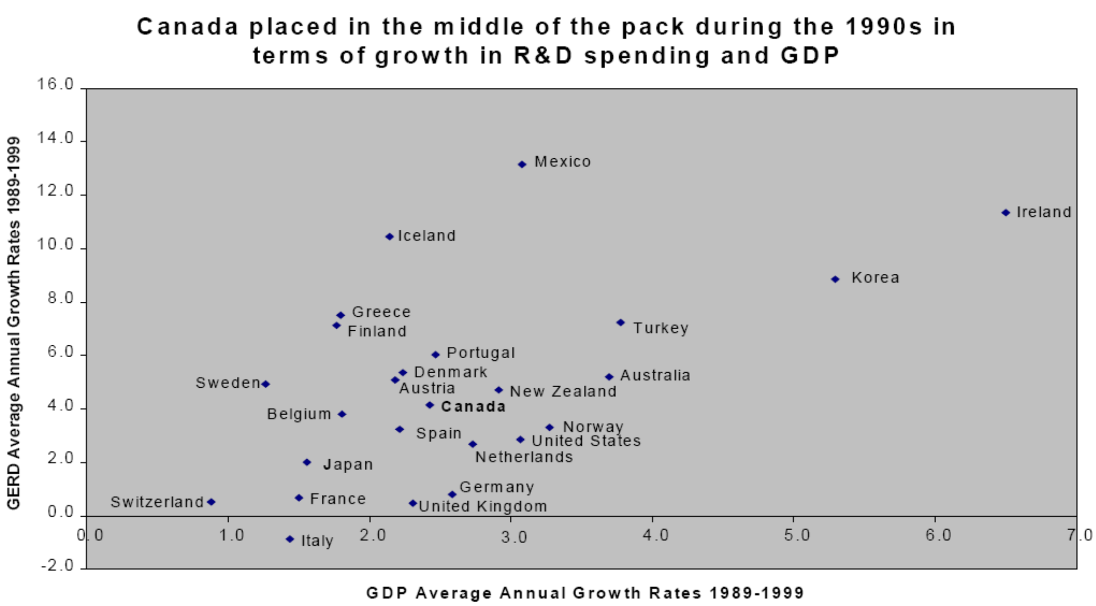

Table 3: Changes in R&D spending

	Gross Expenditures on R&D (GERD)			Gross Domestic Product (GDP)			GERD/GDP ratio		
Country	1989 (1995 PPP$)	1999 (1995 PPP$)	Change (%)	1989 (1995 PPP$)	1999 (1995 PPP$)	Change (%)	1989	1999	Change (%)
Austria	2,013	3,485	73	148,942	190,386	28	1.35	1.83	36
Denmark [a]	1,625	2,770	70	107,783	132,768	23	1.51	2.09	38
Finland	1,792	3,757	110	99,597	116,710	17	1.80	3.22	79
Iceland	58	167	188	5,737	7,162	25	1.01	2.33	131
Ireland	383	1,136	197	47,908	94,019	96	0.80	1.21	51
Korea [b]	7,565	14,797	96	393,891	599,189	52	1.92	2.47	29
Sweden	4,786	7,439	55	169,179	196,703	16	2.83	3.78	34
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Germany	38,895	45,264	16	1,357,875	1,854,397	37	2.86	2.44	-15
Italy	13,125	12,784	-3	1,061,339	1,229,681	16	1.24	1.04	-16
Japan	70,132	90,212	29	2,593,674	3,071,561	18	2.70	2.94	9
United Kingdom	21,532	23,066	7	1,000,163	1,228,025	23	2.15	1.88	-13
United States	167,593	229,280	37	6,408,700	8,626,701	35	2.62	2.66	2
OECD Total	**382,351**	**523,296**	**37**	**16,898,719**	**23,705,899**	**40**	**2.26**	**2.21**	**-2**

[a] 1998, not 1999
[b] 1991, not 1989
Source OECD, Main Science and Technology Indicators (MSTI) database, July 2002

Table 4: sources of funding of business R&D OECD countries

	1989				1999			
Country	Business	Government	Other National	Abroad	Business	Government	Other National	Abroad
Austria	89	6	0.0	5	64[a]	0	--	30[a]
Denmark	83	12	2.1	3	89	4	0.6	6[a]
Finland	96	3	0.0	1	94	4	0.0	1
Iceland	85	11	0.0	4	77	2	0.0	21[a]
Ireland	89	7	0.1	4	85	4	0.0	11
Korea [b]	--	--	--	--	94	6	0.2	0
Sweden	85	13	0.0	2	89	8	0.1	3
Canada	**73**	**10**	**0.0**	**17**	**69**	**4**	**0.0**	**27**
France	70	19	0.1	11	81	10	0.1	9
Germany	86	11	0.3	3	90	8	0.2	2
Italy	77	16	0.0	6	79	13	0.3	8
Japan	99	1	0.1	0	98	2	0.2	1
United Kingdom	69	17	0.0	13	67	10	0.0	23
United States	72	28	0.0	--	88	12	0.0	--
Total OECD	**80**	**18**	**0.0**	**--**	**88**	**9**	**0.0**	**--**

-- not available or applicable
[a] 1998
[b] 1995 most recent data available
Source: OECD, Main Science and Technology Indicators (MSTI) database, July 2002

Table 5: Leo Sveikauskas' findings on R&D and economic growth

Table 5: Central variables and results from analysis of the effects of research and development on productivity growth, private nonfarm business sector, 1948-82

(In billions of 1972 dollars unless otherwise indicated)

Year	R&D stock		Output of private nonfarm business[1]	Real R&D income[2]	R&D share of total output[3] (in percent)	R&D contribution to productivity growth[4] (in percent)
	Level	Annual growth rate in percent				
	(1)	(2)	(3)	(4)	(5)	(6)
1948..	$13.5	-	$364.5	$4.0	-	-
1949..	14.6	8.8	357.5	4.4	1.2	0.10
1950..	15.8	8.0	392.2	4.7	1.2	0.09
1951..	16.5	4.6	418.0	5.0	1.2	0.05
1952..	17.5	6.1	432.2	5.3	1.2	0.07
1953..	18.5	5.7	451.0	5.6	1.2	0.07
1954..	20.1	8.3	442.0	6.0	1.3	0.10
1955..	22.4	11.4	479.1	6.7	1.4	0.15
1956..	24.6	9.9	492.7	7.4	1.4	0.14
1957..	26.7	8.9	498.6	8.0	1.6	0.13
1958..	29.9	11.8	488.9	9.0	1.7	0.19
1959..	32.8	9.6	528.2	9.8	1.8	0.17
1960..	35.6	8.4	535.5	10.7	1.9	0.16
1961..	38.6	8.5	545.2	11.6	2.1	0.17

1962..	41.9	8.5	577.3	12.6	2.1	0.17
1963..	45.1	7.7	602.8	13.5	2.2	0.16
1964..	48.4	7.3	641.2	14.5	2.3	0.16
1965..	51.9	7.1	685.8	15.6	2.3	0.16
1966..	55.5	6.9	726.5	16.6	2.3	0.15
1967..	59.5	7.3	741.9	17.9	2.3	0.17
1968..	63.9	7.4	782.2	19.2	2.4	0.17
1969..	68.7	7.4	805.0	20.6	2.5	0.18
1970..	73.6	7.1	796.6	22.1	2.7	0.18
1971..	78.7	7.0	819.9	23.6	2.8	0.19
1972..	83.3	5.8	877.7	25.0	2.9	0.16
1973..	87.4	4.9	938.1	26.2	2.8	0.13
1974..	91.5	4.7	917.9	27.5	2.9	0.13
1975..	96.2	5.0	896.3	28.8	3.1	0.15
1976..	100.6	4.6	957.9	30.2	3.2	0.14
1977..	104.1	3.5	1023.3	31.2	3.1	0.11
1978..	108.0	3.8	1081.7	32.4	3.0	0.11
1979..	112.1	3.8	1105.0	33.6	3.0	0.11
1980..	116.7	4.1	1088.7	35.0	3.1	0.12
1981..	121.8	4.4	1112.3	36.5	3.3	0.14
1982..	127.7	4.8	1083.4	38.3	3.4	0.16

1 Constant-dollar output of the sector. All calculations were conducted prior to the January 1985 GNP revisions

2 Column (1)*0.30, under the assumption of a 30 percent rate of return on the research stock

3 Column (4) divided by column (3)

4 To illustrate the methodology adopted to generate these estimates, the 1948-49 growth in the research stock, 0.088 (or 8.8 percent), is multiplied by the research share, 0.012 (1.2%), to determine the productivity contribution which is .0010 or 0.10 percentage points.

Appendix B: Data on Nigeria and Angola R&D

Table 6: Business investment in R&D and firm-level Technology absorption. Source: World economic forum 2005.

Business Investment in R&D, 2004 (1)			Firm-level Technology absorption, 2004 (2)	
Country	Ranking	Score	Ranking	Score
Tunisia	37	3.46	24	5.31
South Africa	24	4.03	28	5.22
Kenya	32	3.66	71	4.21
Uganda	38	3.42	66	4.27
Namibia	42	3.29	45	4.77
Botswana	44	3.21	70	4.22
Nigeria	47	3.15	75	4.05
Mauritius	50	3.12	55	4.47
Madagascar	55	3.03	48	4.70
Zimbabwe	62	2.97	90	3.57
Morocco	66	2.94	74	4.11
Ghana	67	2.92	60	4.40
Tanzania	69	2.90	69	4.22
Egypt	72	2.85	37	5.05
Gambia	73	2.85	86	3.81
Malawi	77	2.81	88	3.64
Zambia	80	2.73	64	4.29
Mozambique	81	2.72	97	3.16
Mali	82	2.68	72	4.17
Algeria	94	2.42	57	4.47
Angola	102	1.93	103	2.78
Chad	103	1.91	99	3.13
Ethiopia	104	1.85	96	3.26

Table 7: Subsidies for firm-level research and development and company spending on research and development.

Subsidies for firms-level research and development, 2004 (1)			Company spending on research and development (2)	
Country	Ranking	Score	Ranking	Score
Tunisia	13	4.62	37	3.5
Kenya	67	2.67	32	3.7
Gambia	61	2.75	73	2.8
Botswana	34	3.41	44	3.2
Morocco	42	3.30	66	2.9
Ghana	69	2.61	67	2.9
Mauritius	54	2.94	50	3.1
Namibia	47	3.17	42	3.3
Uganda	41	3.31	38	3.4
Zimbabwe	79	2.33	62	3.0
Nigeria	52	2.99	47	3.1
Zambia	72	2.61	80	2.7
South Africa	39	3.31	24	4.0
Malawi	81	2.29	77	2.8
Algeria	45	3.21	94	2.4
Egypt	35	3.38	72	2.8
Ethiopia	87	2.08	104	1.8
Tanzania	46	3.19	69	2.9
Mozambique	84	2.23	81	2.7
Mali	38	3.32	82	2.7
Madagascar	69	2.61	55	3.0
Chad	89	2.04	103	1.9
Angola	94	1.75	102	1.9

Table 8: Protection of intellectual property on different countries of the world

Countries	Protection of intellectual property	
	Ranking	Score
Sweden	1	6.3
Denmark	2	6.3
United States	3	6.2
Germany	4	6.2
Finland	5	6.1
United Kingdom	6	6.1
Netherlands	10	6.0
Singapore	13	5.7
France	14	5.7
Austria	15	5.7
Canada	16	5.7
Luxembourg	17	5.6
Belgium	18	5.5
Ireland	21	5.2
South Africa	22	5.0
Malaysia	25	4.8
Tunisia	26	4.8
Estonia	29	4.7
Portugal	30	4.6
Spain	31	4.5
Slovenia	32	4.5
Namibia	33	4.5
Hungary	37	4.2
Egypt	38	4.1
Thailand	39	4.0
Czech Republic	43	3.9
Ghana	44	3.9
Italy	45	3.9
Indonesia	47	3.9

Countries	Protection of Intellectual Property	
	Ranking	Score
Malta	50	3.7
Brazil	51	3.7
Uruguai	53	3.6
Mauritius	55	3.5
Malawi	57	3.5
Botswana	58	3.5
Lithuanian	61	3.4
Mexico	62	3.3
Mali	66	3.3
Gambia	67	3.2
Madagascar	69	3.1
Zimbabwe	70	3.1
Kenya	71	3.1
Latvia	72	3.1
Nigeria	73	3.0
Tanzania	74	3.0
Zambia	75	3.0
Algeria	77	2.9
Poland	79	2.8
Philipines	82	2.7
Uganda	85	2.7
Argentina	88	2.5
Mozambique	89	2.5
Peru	90	2.4
Vietnam	93	2.4
Equador	95	2.3
Paraguai	97	2.2
Ethiopia	99	2.2
Chad	102	2.0
Angola	104	1.8

Table 9: Research results from study of Nigerian universities Source: Field analysis, 1991.Note: SAP, Structural Adjustment Programme. Constraint	Yes	%	No	%
Poor funding of research	118	91.5	11	8.5
Lack of clear-cut enabling policies	63	48.8	66	51.2
Poor or indifferent attitude of industrialists to results of university	83	64.3	46	35.7
Poor or indifferent attitude of university scientists	16	12.5	113	87.6
Bureaucracy	41	31.8	88	68.2
Poor communication between universities and the productive sector	83	64.3	46	35.7
Paucity of university-based research results	7	5.4	122	94.6
Inadequate research personnel	22	17.1	107	82.9
Economic reasons (e.g., SAP)	47	36.4	82	63.6
Political reasons	29	22.5	100	77.5
Security reasons	6	4.7	123	95.3
Other	7	5.4	122	94.6

Table 10. Use of university expertise or research results by the productive sector Source: Field analysis, 1991. Note: SAP, Structural Adjustment Programme.				
	Yes	%	No	%
Was your research commissioned by industry?	25	19.4	104	80.6
Is your research expertise in demand in the productive sector?	39	30.2	90	69.8
Has your research result been applied in the industry?	28	21.7	101	78.3
Has your research result been commercialized?	13	10.1	116	89.9
Source: Field analysis, 1991.				

Appendix C: Interview with BTO

1. How long does the patent filing process last?
2. Can you give a list of the companies established/spin offs from BTO
3. Do you think that BTO contributes in anyway to Economic growth in Norway
4. How do you think BTO achieves this contribution
5. In what way does BTO encourage investors and entrepreneurs
6. What are the factors specifically considered before commercialization is undertaken by BTO
7. In what area especially do the scientists working behind the scenes research on
8. What area produces the highest number of innovations: Medicine, IT etc
9. What are the challenges facing R&D by the scientists
10. What are the challenges facing BTO as a technology transfer company today.

Spin-offs from Bergen transfer office

1. iSentio
2. Fleunse Syntesis
3. NoWires
4. Nettervakten
5. Tendo Tech
6. Pattern Solution
7. CareNor
8. BioProtein
9. TextUrgy
10. BerGen Bio
11. UniGeo
12. Zeg Power
13. Erac
14. LTL NOR AS
15. 12 Touch AS
16. Metas AS