Energy Research and Development (R&D) Investment patterns in South Africa

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Abstract

This paper takes an analysis of energy research and development (R&D) investments in South Africa and their role towards achieving a vibrant energy sector through developing energy sector capabilities crucial for a sustainable energy system. The study shall address the question: How much is South Africa spending on energy R&D investments in relation to the BRICS countries; how much is directed towards the different forms of energy; and which forms of energy can South African R&D yield the greatest benefits? To do so, the paper uses a cross-country comparative analysis using the BRICS nations. We look into the historical trends in energy R&D expenditures along the development path of the BRICS nations using data on gross domestic product (GDP). This allows us to establish the kind of relationship that exists between energy R&D investments and economic growth in each country and draw comparisons between South Africa and its 'peer' nations. A comparative analysis helps in understanding how different countries have achieved higher economic growth through investments in energy R&D and on which forms of energy they have directed most of their R&D efforts. Such an analysis serves as a benchmark with regard to how much South Africa should spend on energy R&D investments and which energy projects government and private sector should channel most their R&D resources. However, comparisons across countries, although they serve as a benchmark to performance, need to take into account the inherent differences between countries.

Introduction

Literature on economic growth and development offers divergent views about the critical levers towards achieving economic growth in developing and emerging economies. In this context, a number of scholars propose inclusive institutions as a necessary factor towards achieving economic prosperity in less developed economies. Traditional mainstream models emphasise on human and physical capital endowments as key factors to achieving economic growth. This paper takes a departure from the traditional mainstream models of economic growth that treat labour and capital as the primary factors of production; towards energy-based models which take into account the role of energy in the growth process, capable of limiting economic growth Stern (2010). This is, especially, relevant in the South African context where energy sustainability challenges continue to impose strong constraints to economic growth; and hence traditional theories fail to fully explain SA's growth process. This paper takes an analysis of energy research and development (R&D) investments in South Africa and their role towards achieving a vibrant energy sector through developing energy sector capabilities crucial for a sustainable energy system. The study shall address the question: How much is South Africa spending on energy R&D investments in relation to the BRICS countries; how much is directed

towards the different forms of energy; which forms of energy can South African R&D yield the greatest benefits?

To do so, this paper uses a cross-country comparative analysis using the BRICS nations. We look into the historical trends in energy R&D expenditures along the development path of the BRICS nations using data on gross domestic product (GDP). This allows me to establish the kind of relationship that exists between energy R&D investments and economic growth in each country and draw comparisons between South Africa and its 'peer' nations. A comparative analysis helps in understanding how different countries have achieved higher economic growth through investments in energy R&D and on which forms of energy they have directed most of their R&D efforts. Such an analysis serves as a benchmark with regard to how much South Africa should spend on energy R&D investments and which energy projects government and private sector should channel most their R&D resources. However, comparisons across countries, although they serve as a benchmark to performance, need to take into account the inherent differences between countries. The paper's research findings will be useful to government departments such as South African National Energy Development Institute (SANEDI) and research institutes in South Africa as well as the government. This information will help government direct scarce resources to energy areas that yield the greatest impact on the economy and develop meaningful policy on energy R&D with a long term perspective.

The rest of the paper is structured as follows: Section 1 looks at the role of energy in the growth process. Section 2 looks into the importance of R&D investments in energy. Section 3 gives a background on energy R&D investments in South Africa. Section 4 concludes and gives the way forward.

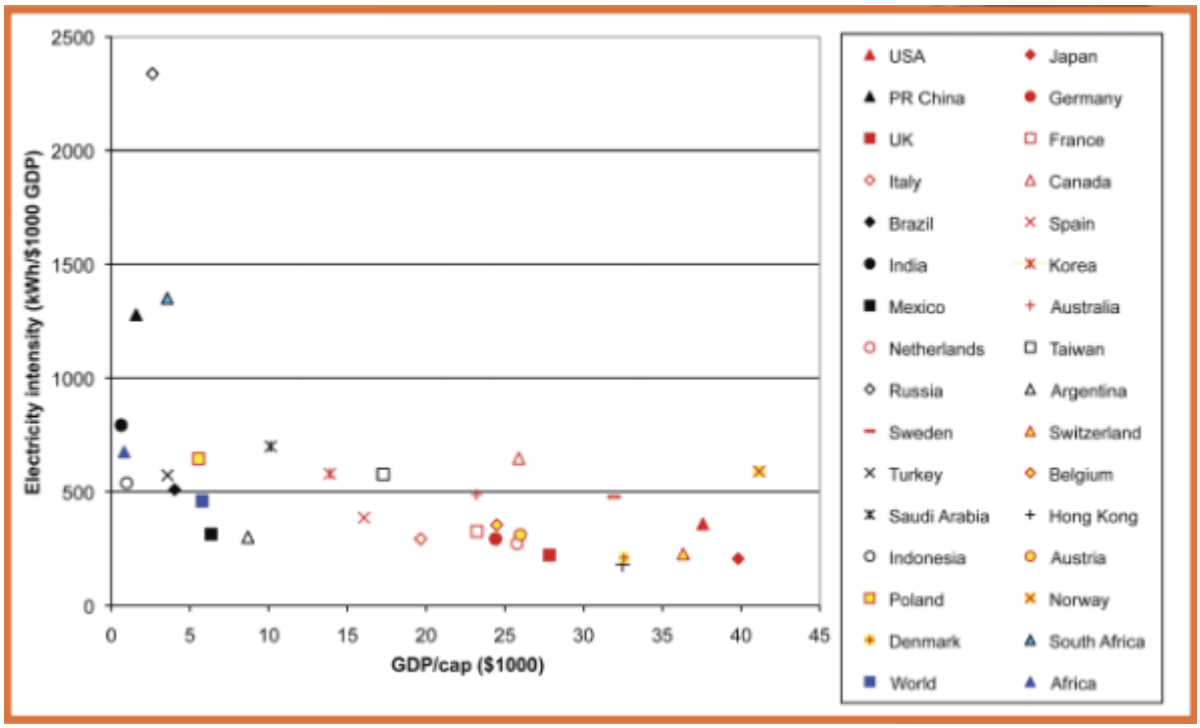
1. Energy and growth: Why energy matters

Energy is an essential input to production and economic activity and therefore affects economic growth (Stern, 2010). According to Stern (2010) synthesis model of energy-based models and mainstream models, he shows that when energy is scarce it has the effect of imposing substantial limitations on the growth of a country's economy. On the other hand, when energy is abundant in supply it has insignificant effects on economic growth. The paper shows that energy and GDP cointergrate and energy use granger causes GDP. Therefore it is important that South Africa addresses current and future energy challenges in order to ensure security of energy supply and release the constraints of energy on economic growth Stern (2010).

The rapid growing demand for energy in South Africa worsens energy sustainability challenges, bringing to the forefront issues of lack of security of energy supply, affordability, increased environmental adverse effects of using fossil fuels and high uncompetitive overall costs of producing

energy Vattenfall AB (2011). South Africa has a highly energy-intensive economy due to its specialization in the extraction of raw materials and primary processing of raw materials (Department of minerals and Energy, 1998). The country heavily depends on energy-intensive mining resource extraction sector and manufacturing industry. The high amounts of energy used in the industrial sector are compounded by the fact SA's electricity price for industry activities remain the cheapest in the world thereby acting as a deterrent for firms to save energy and encouraging the setting up of energy-intensive industries such as the aluminium smelters Roos (2009). South Africa's entire industry consumes roughly half of the total electricity produced in the country. This means that energy is an important driver of economic activity in South Africa given that its industrial sector is a key sector accounting for a significant share of local capital investment and GDP. (Department of minerals and Energy, 1998). According to a survey of the world's 30 largest economies which use the highest amount of electricity to produce US$1000 GDP, South Africa came out as the second largest consumer of energy, using approximately 1400kwh to produce US$1000 GDP, following Russia Roos (2009).

Electricity intensity of the world's 30 largest economies



Source: Adopted from Roos (2009)

Inglesi-Lotz and Blignaut (2012) paper carries out a comparative analysis of South Africa's electricity intensity to OECD countries. The results show that South Africa's electricity intensity- defined as the ratio of electricity consumption to total output has grown substantially to exceed all member countries in the OECD over the years 1990 to 2007. They attribute the high levels of energy

consumption to South Africa electricity intensive industrial sectors. Another key finding is that South Africa's greenhouse gas emissions are extremely high and continue to increase at a fast rate.

2. The importance of R&D investments in energy

The most interesting aspect of R&D lies essentially on the end results produced by the activity or the ability of the activity of R&D to create new knowledge and innovations, as well as economic and social impacts rather than on the pure or actual activity of research itself Frascati Manual (2002). According to the Frascati Manual (2002: pp 30), "Research and Experimental Development (R&D) comprise creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications."

R&D efforts are measured using indicators of R&D inputs and output. The measures of R&D inputs include R&D expenditures and R&D personnel, calculated on annual basis for example the amount of money spent during a year or the amount of person-years used during a year. The measures of R&D output include innovation, bibliometrics, and trade data. However, it is extremely difficult to measure R&D effort using R&D output because the indicators of R&D output are extremely difficult to define and produce (Frascati Manual (2002)). Grilliches (1979) also highlights the challenges of measuring the contribution of R&D towards economic growth. In this paper he reiterates the difficulty of measuring output in R&D intensive industries and the problem of defining and measuring the stock of R&D capital. R&D is a process that takes time and current R&D may not have an impact on measured current productivity until after several years hence R&D involves several lags.

The topic of R&D is relevant economically, socially and particularly in the field of policy and development. R&D is the key source of creating new knowledge. This raises the question of why new knowledge is important in the development of a nation. According to Ganguly (1999), knowledge is now termed the new currency for economic and social development which makes it a key factor contributing towards economic growth. The economic value of R&D can be defined as the increase in the value of output flow that the resources of a society can produce and when the results of research can be used to predict the implications of trying different solutions to a practical problem.

Studies on R&D and economic growth are not a new subject in the field of economics. Vast literature has shown empirical evidence of the positive contribution of R&D towards economic growth with great emphasis on developed economies. Early contributions in the literature looking at the role of R&D were made by Nelson (1959), Arrow (1962) and Grilliches (1979). The most relevant and recent

work in this area includes Stokey (1995), Goel and Ram (1994), Bayarcelik and Tasel (2012), and; Ping Ho, Kam Wong and Heng Toh (2009).

Bayarcelik and Tasel (2012) empirically explore the effects of R&D on economic growth in Turkey using the endogenous growth framework. The paper develops a panel regression model using data for listed chemical firms in Turkey to examine the relationship between economic growth as measured by GDP and innovation indicators as measured by the number of researchers employed in R&D departments, R&D expenditures, and patents. Their results show that investment in R&D and the number of employees in the R&D departments has a positive impact on economic growth.

Ping Ho, Kam Wong and Heng Toh (2009) paper based on Singaporean data draw empirical estimates of the effect of R&D on economic growth. Using the Cobb-Douglas production function approach, their results show that investment in R&D has a significant impact on total factor productivity. However their results show that the impact of R&D in Singapore is weaker in comparison with other developed economies indicating that the country should increase its R&D intensity and fully exploit local R&D activity.

However although many scholars have written on R&D-growth nexus, they tend to focus more on the developed economies rather than African countries. Literature that focuses on African developing and emerging countries is relatively scarce. This justifies my choice of South Africa as an emerging African economy. My paper will mainly build on Gyeke, Oseifuah and Vukor-Quarshie (2012); and Lederman and Maloney (2003) who echoe the same sentiments.

Gyeke et al. (2012) empirically investigate the contribution of research and innovation towards industrial and economic growth focusing on the developing economies of Sub-Saharan Africa (SSA). The paper estimates the impact of R&D on economic growth using the Cobb-Douglas production function on a panel data set of five SSA countries. Their results support a positive relationship between R&D expenditures and economic growth. This paper is similar to Lederman and Maloney (2003) paper which explores the relationship between R&D and development by generating patterns or trends of how R&D has evolved over the course of development using a panel data set of developing and developed countries. They find that R&D rises exponentially with a nation's level of development which explains why developing nations are lagging behind in terms of R&D investment.

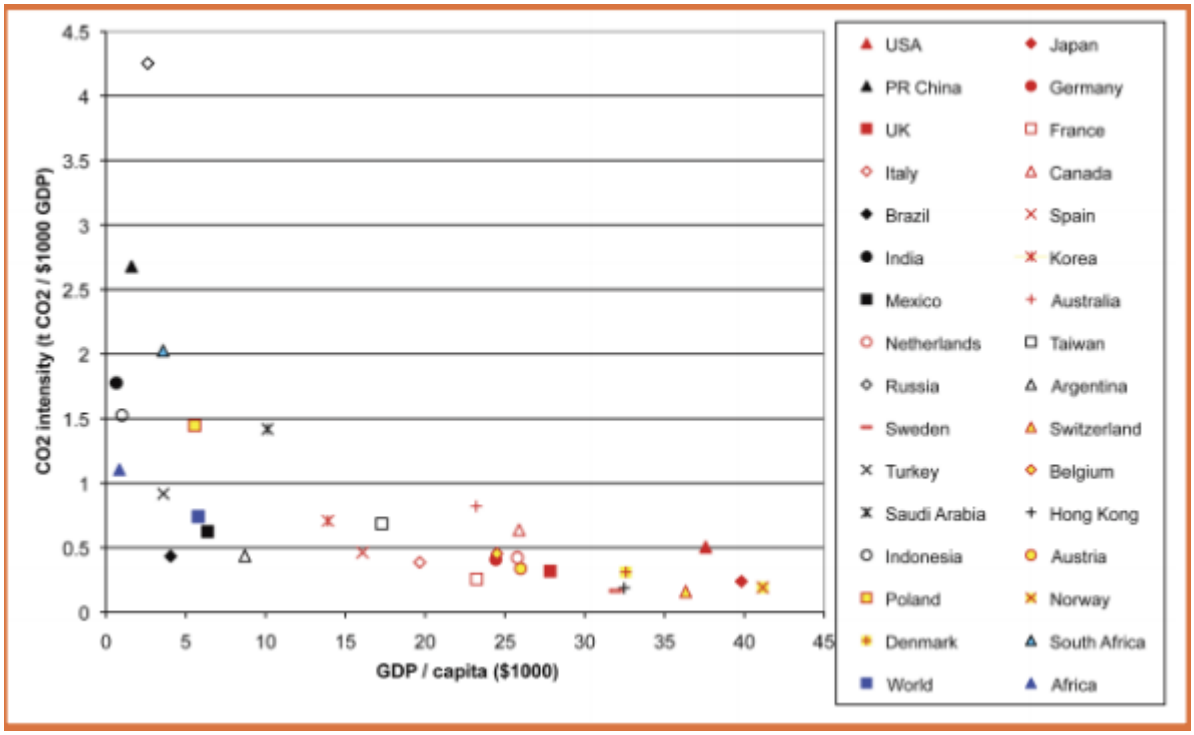
However, work that specifically focuses on economic impacts of energy R&D investments is still limited. Kempener, Anadon, Gallagher and Jiang (2012) are some of renowned scholars who have done a lot of work on energy research, development and demonstration (RD&D) investments focusing on emerging economies of Brazil, Russia, India, Mexico, China and South Africa (BRIMCS). Their case study paper provides an overview of energy RD&D investments in the BRIMCS nations using

the most current data available in each country. The United States is used as a comparison. Kempener et al. (2012) differentiate RD&D expenditures according to a range of technologies and source of funding. Categories of technology include fossil fuel, nuclear, electricity, and renewables; whereas source of funding include government, state-owned enterprises, private industry and not-for-profit organisations. Their main findings reveal that BRIMCS countries carry out substantial energy RD&D investments approximately $14billion dollars which exceeds IEA countries total energy RD&D budget of $12.7 billion. Such findings challenge the traditional view that International Energy Agency (IEA) countries are primarily responsible for developing new energy technologies and calls for the active participation of BRIMCS countries in the development of strategies to speed up energy technology innovation. Lastly, their paper shows that the BRIMCS nations channel most of their RD&D efforts towards fossil fuel and nuclear energy. However the group is lagging in terms of RD&D investments towards renewable energy

Energy research is crucial to addressing the country's energy sustainability challenges. According to Vattenfall AB (2011) energy sustainability challenges comprise of three core issues around climate and environment, security of supply and competitiveness:

- Climate and environment- Every country is working to reduce the adverse climate and environmental effects caused by the use of fossil fuel by shifting towards environmentally friendly renewable sources of energy. This is particularly relevant to SA given that it is one of the largest emitters in the world. According to Ross (2009) South Africa is the third largest emitter behind Russia and China. Research and development is crucial in devising solutions to achieve lower carbon and energy intensity.

CO2 intensity of the world's 30 largest economies



Source: Adopted from Roos (2009)

- Security of supply- Lack of reliable energy supply is a big challenge for many developing countries including South Africa. Many countries lack a steady supply of fuel and energy all the time. Lack of access to electricity or unreliable electricity supply continues to pose threat to the economic development of nations, in addition to other concomitant social challenges. However, security of energy supply entirely rests upon investment in good infrastructure for electricity distribution and the adoption of an energy mix comprised of base load power and balancing power. Energy sources that are capable of producing enormous, uniform quantities of electricity over a considerable space of time make up base-load power, whereas balancing power is derived from quickly convertible energy sources to meet fluctuations in electricity demand. There is need to increase quantity and quality of energy. The fact that it is extremely difficult to store electricity directly implies that at any point in time, a constant amount of electricity must be produced that is directly consumed. The above problem becomes even worse, given that the renewable energy sources such as wind and solar in the energy mix poses difficulties following that these sources are not steady and produce electricity on a non-continuous basis.
- Competitiveness- High uncompetitive costs of producing energy in many developing nations, limits access to affordable and reliable energy. Energy research will devise ways of minimizing overall costs of producing energy and achieve a competitive energy mix given fixed resources.

In order to achieve a sustainable energy system and respond to the above challenges, energy research lays the basis for evaluating the technical and economic viability of technologies and the necessary conditions to ensure the desired performance or outcome (Department of minerals and Energy, 1998). Long-term R&D in the energy sector will help explore alternative competitive, large scale energy sources that will substitute fossil fuels, therefore reduce climate and environmental impact through the reduction of carbon dioxide emissions and greenhouse gases. Energy research explores various solutions with regards to converting fuels like coal and gas which can then be substituted as balancing power without compromising the overall productivity of the power stations Vattenfall AB (2011).

In addition, R&D helps devise new ways of making renewable energy resources more reliable and consistent and aids in evaluating the cost and viability of using renewable energy sources such as wind power, which are marked by high demand and lack of skills and resources. Research will facilitate aadoption of renewable energies. However, renewable energies require huge funding and with limited funds and scarce resources it is important that thorough research is carried out. This will guide public and private institutions in terms of priority subsectors in the energy sector that are in need of dire funding and thereby address/transform the country's energy crisis Vattenfall AB (2011).

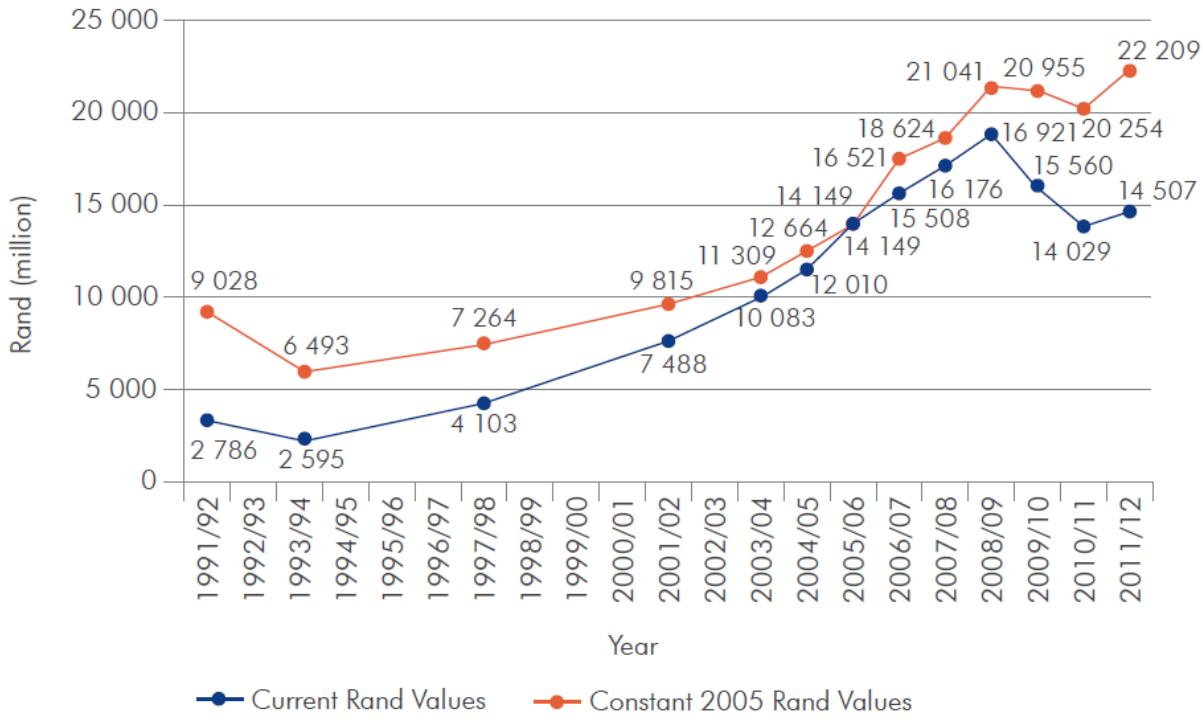
According to the Academy of Science of South Africa (ASSAF) (2014) there is need to increase the level of energy R&D investments in order to address the country's energy sustainability challenges around security of supply, reducing pollution and maintaining competitiveness. R&D investments in coal are inadequate. It is crucial to increase investments in coal research and development given that coal will continue to dominate South Africa's energy supply for many years to come. There is also insufficient R&D investments in clean coal technologies, carbon capture and storage research programmes Kolver (2014). This is compounded by the fact that most of R&D investments in SA are carried out by a few major firms in the industry. It is necessary that government mobilises public funds for energy R&D investment, as well as plan and coordinate energy research and development. Government departments focusing on energy need to coordinate their research and development activities, direct funds towards projects that have potential to yield the greatest yields, reduce gaps and duplication of resources. ASSAF (2014) agrees that there is need to substantially increase the R&D expenditures on energy to approximately 1.5% of GDP compared to the current expenditures. According to their research there is need to increase R&D investments in shale gas and renewable energy.

3. Background on energy R&D investments in South Africa

Figure 1 shows gross expenditure on research and development (GERD) over a twenty one year period (1991-2012) (expressed in constant 2005 rand values) in South Africa. This data is based on 2011/2012 National Survey of research and experimental development. As can be seen, R&D

expenditures have been on the rise since 1991. However, R&D expenditures have been declining since 2008/09, a time when the energy crisis challenges were heightening but shows signs of improvement from 2011-2012.

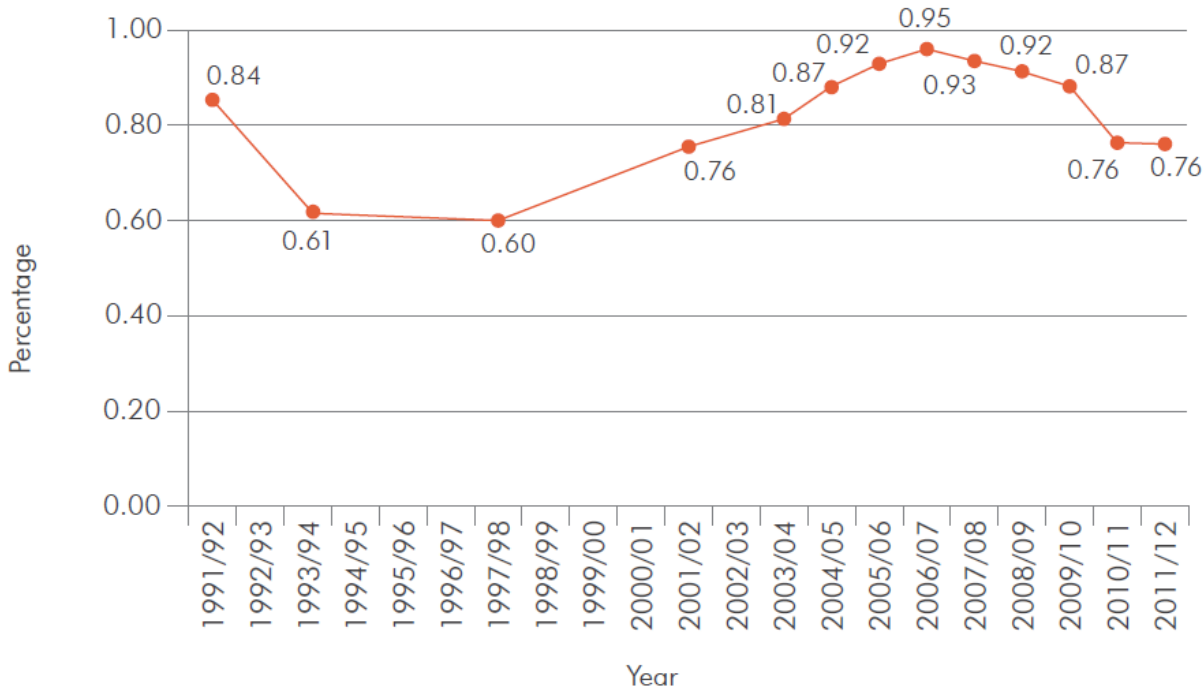
Fig 1. GERD in current and constant 2005 rand values, 1993/94–2011/12



Source: Adopted from HSRC, 2014

Figure 2 expresses gross expenditures on R&D as a percentage of GDP. The nine year period from 2001/02 to 2010/11 show that expenditures on R&D in the energy sector improved significantly with a Compound Annual Growth Rate (CAGR) of 11.7%. However, the most recent 2009/10 and 2010/11 National surveys of Research and Experimental Development show a 5.2% decline in South Africa's Gross Expenditure on Research and Development (GERD) in the energy sector SANEDI (2014).

Fig 2. GERD as a percentage of GDP



Source: Adopted from HSRC, 2014

Overall, expenditures on R&D in some subsectors of the energy sector have been rising since 2009/10 to 2012/13. These subsectors include clean energy and Nuclear Safety and Technology. In the clean energy program, funds were mainly devoted to carry out research on carbon reductions and storage. Increased R&D expenditures in the Nuclear Safety and Technology sub program contributed towards research on nuclear infrastructure and waste processing SANEDI (2014).

4. Conclusion

Search for data on R&D expenditures for the BRICS countries. In terms of future research, I intend to estimate the social rate of return on energy R&D investments in South Africa in order to determine which forms of energy can South African R&D yield the greatest benefits or where South African energy R&D investments are most excellent. I will then estimate the economic impact of energy R&D investments on South Africa's economic growth.

2 paragraphs on general conclusions. Preliminary analysis shows that South Africa's energy R&D investments are still lagging in the different forms of energy.

References

Academy of Science of South Africa (ASSAF). (2014). Increased Research and Development Crucial for South Africa's Energy Future. http://www.assaf.co.za/newsletter/?p=1023, accessed 24/08/2015.

Arrow, K. (1962). Economic welfare and the allocation of resources for invention. In *The rate and direction of inventive activity: Economic and social factors* (pp. 609-626). Nber.

Bayarçelik, E. B., & Taşel, F. (2012). Research and development: source of economic growth. *Procedia-Social and Behavioral Sciences*, *58*, 744-753.

Department of minerals and Energy (1998). White Paper on the Energy Policy of the Republic of South Africa. , Department of Minerals and Energy.

Frascati Manual. (2002). Proposed Standard Practice for Surveys on Research and Experimental Development. Organisation For Economic Co-operation and Development.

Ganguly, A. S. (1999). *Business-Driven Research and Development: Managing knowledge to create wealth*. Palgrave Macmillan.

Goel, R. K., & Ram, R. (1994). Research and development expenditures and economic growth: a cross-country study. *Economic Development and Cultural Change*, 403-411.

Griliches, Z. (1979). Issues in assessing the contribution of research and development to productivity growth. *The Bell Journal of Economics*, 92-116.

Gupta, K. L. (1994). *Research and Development in Public Entreprises*. Indus Publishing.

Gyekye, A. B., Oseifuah, E. K., & Vukor-Quarshie, G. N. K. (2012). The impact of research and development on socio-economic development: perspectives from selected developing economies. *Journal of Emerging Trends in Economics and Management Sciences*, *3*(6), 915-922.

Ho, Y. P., Wong, P. K., & Toh, M. H. (2009). The impact of R&D on the Singapore economy: an empirical evaluation. *The Singapore Economic Review*,*54*(01), 1-20.

Kempener, R., Anadon, L.D., Gallagher, K.S., & K. Jiang. (2012). Energy Rd&D Investments in the Major Emerging Economies and the United States. Historical Case Studies of Energy Technology Innovation in: Chapter 24, The Global Energy Assessment. Grubler A., Aguayo, F., Gallagher, K.S., Hekkert, M., Jiang, K., Mytelka, L., Neij, L.,Nemet, G. & C. Wilson. Cambridge University Press: Cambridge, UK.

Nelson, R. R. (1971). Simple Economics of Basic Scientific Research, The. *J. Reprints Antitrust L. & Econ.*, *3*, 725.

Roos, T. (2009). Overview: The race for electricity provision. South Africa's Council for Scientific and Industrial Research (CSIR). Quarterly Publication of the CSIR, Vol 4(1).

South African National Energy Development Institute (SANEDI). (2014).The State of Energy Research in South Africa. Academy of Science of South Africa (ASSAf).

Stern, .(2010).

Stokey, N. L. (1995). R&D and economic growth. *The Review of Economic Studies*, *62*(3), 469-489.

Vattenfall AB (2011). *Research and Development in the Energy Sector The energy system of the future*. Vattenfall AB.