Technology and Economics Opportunities in South Africa by Hosting SKA

Yu Lu, Ting Lei, and Yiming Guo

***Abstract*—In this paper, we describe briefly the Square Kilometer Array (SKA) which will be deployed in South Africa as the largest radio telescope ever being built in the world and analyze detailed the proportion relations between Research and Development Expenditure and Gross Domestic Product (GDP) which have occurred in England, Canada, South Africa, China and other countries being involved in SKA program respectively for recent 20 years. The Solo Model, a common model aiming to explain the relationship among labor (L), capital (K), technology (A) and production (Y), is used to theoretically expound those foreign investment effects on South Africa's economics and technology development in long-term and short-term periods, and the risks and opportunities of international trade with South Africa. Also, the roles of promoting South Africa's economic and technology development are discussed and oversee the positive effect by hosting SKA. Finally, several suggestions or comments are drawn for South Africa to introduce international investments to boost domestic economy and high technology while taking the opportunity of fulfilling the SKA project.**

***Index Terms*—SKA, technology and economics, investment in South Africa, Solow Model, risk and opportunity.**

I. Introduction

The Square Kilometer Array (SKA) will be the largest radio telescope ever built and will produce science that changes our understanding of the universe. The SKA will be built in South Africa and eight other African Countries, which has been selected through several round strict evaluation in the aspect of environment conditions, scientific goal, and infrastructure as well as the local sustainable economic development.

As the significant event of the signature of the international treaty establishing the intergovernmental organization (IGO) in Rome on March 12, 2019, it will oversee the delivery of the world largest radio telescope, primary site in Carnarvon, North Cape, South Africa.

Just as the speech of Ms. Mmamoloko Kubayi-Ngubane, Minister of Science and Technology of South Africa "This represents the start of a new era for global science governance. Already South Africa has delivered on the Meerkat, a pathfinder to the SKA, and our government looks forward to the next phase of this global initiative in building a platform for this extraordinary scientific achievement" [1].

Technology is powerful drive of the world toward a converging commonality. Some countries have better labor markets, some have advanced technologies which need to be commercialized. SKA is an excellent example that several countries cooperate with each other and investments circulating among the member countries. This paper focuses on the analysis of South Africa, one of the members as well as the host country in this organization. Why South Africa desired to be the main base of facilities? Why South Africa would like to participate such an organization with highly level technology investments? Some interesting results can be found in the rest of this paper.

About 40% to 50% of the population in South Africa lives in poverty and 25% of the population live in ultra-poor condition [2]. A lot of evidences confirm that there is a positive impact of foreign investments has on the growth of domestic economy [3]. For SKA, thousands of equipment will be built on the desert, which located far away from the living communities of North Cape. During the construction phase (even phase 1, 10% of the whole project) will be built over 5 years, and hundreds of engineers and scientist from all around world will gathered on SKA site. Much more local logistic, skilled workers and facilities will be provided by South Africa. This will obviously stimulate the economic growth and job opportunities. Furthermore, South Africa will obtain the high technology with less investments. More analysis can be found in the next part.

II. Research and Development Expenditure of Different Countries

Research and Development Expenditure (RDE) is a criterion evaluating the amount of money every country pays on their investment in technology. Only comparing the number of research and development expenditure is meaningless, because the developments of economy in each county are different. Gross domestic product (GDP) is a main standard to evaluate the condition of a country. The ratio of RDE to GDP is often used as a measurement of the allocation to innovation [4], which will be more meaningful than using the simple data of research and development to analyze the differences of the investments in technology. Comparing the RDE as the percentage of GDP will show the different degrees of attention that each country pays on the development of technology.

Comparing the Research and development expenditure as the percentage of GDP will show the different degrees of attention that each country pays on the development of technique. The Word Bank published the data of Research and Development expenditure (%GDP) from 1996 to 2016.

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The data of the period from 2001 to 2015 will be used in this paper because in these years, the data is more complete, and after 2000, technology is more important than before, and it brings more profits too.

Nowadays, technology becomes more and more important in economy, and it even becomes the most important productive force, so all countries over the world are trying to spend as much as possible in the field of technology. With the world speeding up the integration process, countries come together to promote scientific and technological development. So, the concept of SKA was drawn by the astronomy scientists, which has been agreed and continually developed in recent 20 years.

Obviously, the resources allocate to the Research and Development activities increased substantially from 1970s [5]. The Fig. 1 shows the total research and development expenditure of the whole world in recent 15 years. It is easily to find from the figure that from 2000, there is an increase in the spending on the research and development of technique. In other words, from 2001, people pay more attention on the development of technology and spend more on it as well. It verifies that from 2000, more and more countries found the importance of the development of the technique.

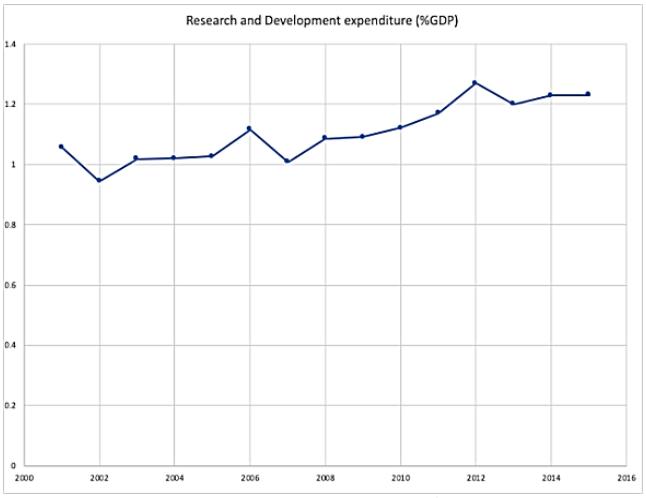

Fig. 1. Research and development expenditure of the whole world [14].

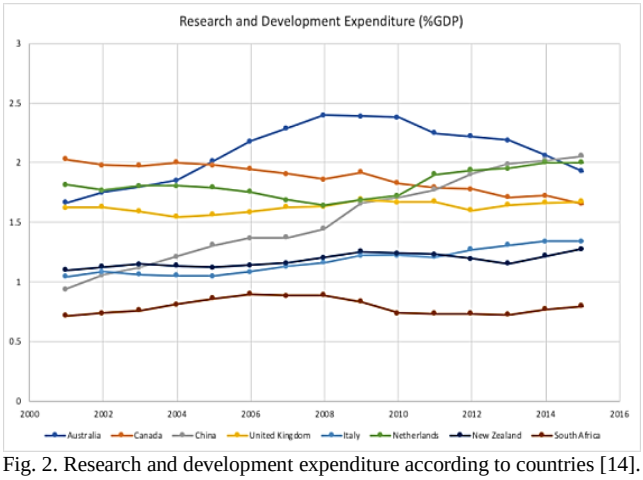

Fig. 2. Research and development expenditure according to countries [14].

As the member of SKA, which is a program pay much attention to the development of high technique, the member should spend a lot on the research. But the spending of different countries is different. The tendency of the RDE about some of the SKA`s member countries (Australia, Canada, China, United Kingdom, Italy, Netherlands, New Zealand, and South Africa are the representatives) can show the difference of investment in the technology each member country did during the fifteen years (from 2000 to 2015). The Fig. 2 shows the tendency in research and development expenditure of each member country of SKA.

In general, the majority of the countries have the tendency that they paid more on Investments in technology, but there are some exceptions. From 2008, the investments in technology Australia paid began to decrease, in 2008 the research and development expenditure was about 2.4% of GDP, but in 2015, the research and development expenditure was only about 1.9% of GDP. Another exception is Canada, from 2001 to 2015, the ratio of research and development expenditure to GDP decreased from 2.1% to 1.6%. For South Africa, the ratio of research and development expenditure to GDP is stable. The ratio of research and development expenditure to GDP is greater than 1% for all countries except South Africa. From 2001 to 2015, the increases in the ratio of South Africa was about 0.1%, but the ratio is still lower than 1%. What`s more the ratio of Research and Development expenditure to GDP of South Africa is about one third of the ratio of research and development expenditure to GDP of Australia.

Overall, most of the countries paid more on investments in technology, but there are some exceptions. The economic condition determines the resources devote to the Research and Development activities [6]. The differences in the economy of different countries can also explain the big gap between the ratio of RDE to the GDP of different countries. South Africa is not a developed country, and with such a high poverty, the economic condition of South Africa must be much worse than other countries and the spending on the investments in the technology must be lower than other countries.

III. The Oretical Analysis of the Investment in South Africa

In Economics, the production function is a mathematical description of how inputs of the production turn into the output, and it states the technological relationship between the quantities of inputs and the quantities of the outputs. It is also the foundation of the Solow model. The commonly used model aiming to explaining the relationship among labor (L), capital (K), technology (A) and production (Y):

$$Y_t = F(K_t, A_t L_t)$$

The production function has some properties: productive and diminishing returns. Productive means the increase in every input (labor, capital, or technology) will lead to the increase in output. In other words, the increase in labor or capital will result in the increase in the production, and the development in technique will also increase the quantities of products. For the relationship between the output and the increase in the capital, the "productive" can be mathematically written as:

$$\frac{\partial Y_t}{\partial K_t} > 0$$

In the short run, the production function is a simple way to explain the increase the output when other countries make investment to South Africa. In the short run, the SKA input to South Africa can only change the quantities of the capital, and the investments will not affect the level of the technology and the number of the labor in the South Africa. Without the developments in technology, the output can increase in proportion to labor and capital inputs [7]. When other countries make some investments into South Africa, the capital of South Africa in the production can be divided into two part: the domestic investments and the foreign investments, and the production function can be rewritten as:

$$Y_t = F(K_{td} + K_{tf}, A_t L_t)$$

When there is an increase in the foreign investment, the total capital will increase if the domestic capital does not change. Adding every one of the inputs will lead to the increase the output, so the increase in the foreign capital will result the increase in the output. Mathematically the relationship between the foreign investment and the output can be written as:

$$\frac{\partial Y_t}{\partial K_{tf}} > 0$$

In the short run, when other countries increase the investments in South Africa, the production in the South Africa must increase, and the increase in the production also means there will be an economic growth in the South Africa.

The second property of production function diminishing returns means that holding other inputs constant, the increases in production will become smaller and smaller as adding more and more of the input. In other words, if the technology and the labor force does not change in the short run, with the increase in the capital, the return on the increase in the capital decreases:

$$\frac{\partial^2 Y_t}{\partial K_t^2} < 0$$

The diminishing gives the limitation of using production function to analyze how foreign investments affect the economy of South Africa in the long-run. In the long-run, with other inputs constant, as the increase in the capital, the affect that the increase in the capital can has on the output will approach to zero. In other word, with the foreign investments become more and more, the changes in the output will become less and less and even near to zero, if there is nothing change about other inputs.

Actually, in the long run, the foreign investments in South Africa will be useful, because it does not only affect the quantities of capital, but also leads to the changes in the labor and technology. Some econometrists did researches on how the foreign investments affect the economic growth. Balasubramanayam et al found that higher foreign investments inflow leads to higher economics in most of countries, and Ramirze also found that for Mexico, the foreign investments inflow has a positive effect on the labor productivity growth. [8].

SKA shall be constantly built over fifteen years and operated more than fifty years. This will no doubt bring more cutting-edge technology, scientific observatory, construction facilities and working opportunities in South Africa as well as other African co-host countries. It is foreseen that for the SKA program, billions of euro send hundreds of scientists to South Africa to do the researches on the radio telescopes.

In fact, things become more complicate in the long run. The foreign investments will bring more working chances for people in the South Africa, and at some time, the investments will also lead to the development in the technique. For the SKA program, for example, other member countries of the program investment billions of ponds to South Africa and send hundreds of scientists to South Africa to do the researches on the radio telescopes. The program makes more people in South Africa have the chance to work because the program not only need scientists, but also need some worker to do some simple work. The local people become labor, and they have the chance to earn money for the daily life. At the same time, the SKA program is high technique research program, and there is no doubt that it will bring some new technique to South Africa to make some produce progress become more efficient.

The Solow model gives the thought about analyzing the long run economic growth using the three important economic factors: capital, labor, and technique. In the long-run the Solow model is suitable to be used to analyze how the foreign investments affect the economy of South Africa, because it explains the relationship among the output, capital, labor and technique. The general Solow model combine the capital accumulation, labor and technique growth to explain the growth of output. There are some assumptions of Solow model. First, the technique and labor will increase as a constant rate n and g respectively. Second, the capital depreciates at a rate δ, which is greater than 0, but smaller than one. The third assumption is there is a constant rate saving (s) of output in each period. Forth, the investments-saving market is in equilibrium, so the investment in one period is equal to the saving of the output in each period. Combing these assumptions and the production function, mathematically, the Solow model can be written as a set of equations:

$$Y_t = F(K_t, A_t L_t)$$
$$K_{t+1} = sY_t + (1-\delta)K_t$$
$$A_{t+1} = (1+g)A_t$$
$$L_{t+1} = (1+n)L_t$$

With the constant rate of saving (s) and depreciation (δ), in general, the capital of the following year will increase, because at the first period, the production function shows an increase in the output, in other word, the saving in the next period after foreign countries make investments in South Africa increases. At the same time, because the labor will increase, and there will also be an increase in the level of the technique, in the long-run, the output will increase.

In the long-run, there is a "steady state" level of the economy, the "steady state" level means the capital per efficiency unit of labor is steady, and it will not change in the following periods holding other factors constant. In the Solow, in order to find the "steady state", the model is detrended all of the variables in the model, as the variables A and L grow at a constant rate, in other words, every variable in the model is divided by AtLt. Then the model can

be written as:

$$\frac{K_{t+1}}{A_t L_t} = \frac{sY_t}{A_t L_t} + (1-\delta)\cdot\frac{K_t}{A_t L_t}$$

$$k_{t+1} = \frac{sy_t + (1-\delta)k_t}{(1+g)(1+n)}$$

The kt is the capital per efficiency unit of labor at current period, kt+1 is the capital per efficiency unit of labor at next period, the yt is the output per efficiency unit of labor at current period. For each period the growth rate of capital per efficiency labor can be written as:

$$k_t' = sf(k_t) - (n+g+\delta)k_t$$

At the "steady state" level the capital per efficiency unit of labor k* will be:

$$sf(k^*) = k^*[(1+g)(1+n)(1-\delta)]$$

The SKA program makes more local people "become" labor, the number of labors in the economy of South Africa will increase at the time when SKA program begins, and it also makes development in technique when the program begins or ends. The program will not affect the growth rate of labor and technique, but the increase in labor and the developments in technique only happen when the program begins, and they are short-term events, so the long-run effect on the labor and technique can be ignored, and the growth rate of labor and technique can be assumed as constant, in other words, even there are some foreign investments changes the number of labors and the level of technique, the growth rate of labor and technique are still n and g. Without any changes in the growth rate of labor, technique and the rate of depreciation, the "steady state" level of k will not change. With the increase in the technique and the number of labors, the total capital needed at the "steady state" level will increase, even the capital per efficiency labor at "steady state" level does not change. The increase in the capital still will be needed in the long-run, and because of the increase in the labor and the development of technique, the diminishing returns' decrease rate will be mild.

IV. Opportunity of Trading with South Africa

For the past decades, there is a large increase in foreign direct investments (FDI), and the FDI increases from 24 billion dollars in 1990 to 178 billion dollars in 2000 [9]. South Africa, as a developing country, attracts more and more foreign direct investments in these years. Figure 3 shows the trends of the foreign direct investments in South Africa.

In Fig. 3, we can find that the ratio of foreign direct investments inflows to GDP of South Africa increases from 0.2% in 1991 to 0.4% in 2015. Although the inflation of the ratio is great, the general trend of the ratio is increasing. The economic elements and policy in South Africa had little effect on the decrease in the ratio.

The large labor market is an advantage of investing to development of high technology. The price of human capital in South Africa is lower. Doing the research on high technology in South can lower the cost of the researches. The cost for facilities and material will be lower than which in other countries. Besides, South Africa has the advantages in the geographical condition, which is essential for some scientific research. Furthermore, the basic industry and system standard in South Africa had established before the era of Mandra [10]-[12]. As the world integration process, the countries of which the level of technology is lower will import the high technology products from other countries [13]. The data, World bank has published, shows the import of South Africa increased from 31 billion of dollars in 2001 to 123.4 billion of dollars in 2011, the ratio of imports of goods and services to GDP increases from 25.4% in 2001 to 29.7% in 2011. The increasing of the ratio makes us believe that the economic growth in South Africa will lead to the increase of economics in South Africa.

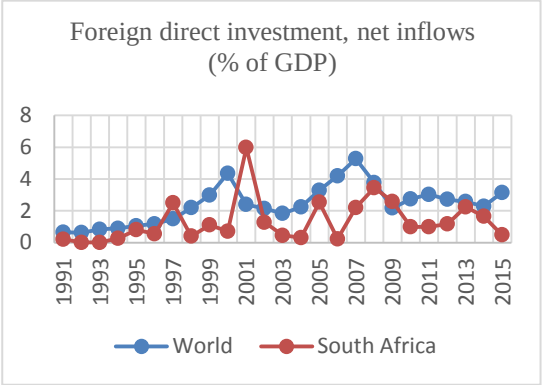

Fig. 3. Foreign direct investment, net inflows of the world and South Africa.

V. Conclusions

South Africa as the host country of SKA, enjoys a golden opportunity for the economics, science and technology, etc. At the meanwhile, it is also a challenge for jointly executing the big science project with many member countries, which will be strongly subject to each country's efforts. So the delay or postpone will be foreseen happened. South Africa government and relative department shall have an emergency plan to handle with these issues upon happened.

Nevertheless, there are many steps and arrangements that the South Africa government need to be thinking as follows,

How to keep the constantly investment/contribution to SKA Organization promised in the IGO (the intergovernmental organization) treaty?

How to use this opportunity to encourage local company, people involve in the business?

How to manage the local resources coping with SKA construction and operation?

How to jointly work with other member countries as the host country?

The speech by former South Africa President Jacob Zuma is the best ending of this lecture.

"In doing so, we are building on a platform of extraordinary scientific achievement. The successful construction in the Northern Cape of the MeerKAT telescope, the world's largest and most sensitive radio telescope, and the development of the Square Kilometre Array has enabled South Africa to develop capabilities in areas such as space observation, advanced engineering and supercomputing. This is not merely about advancing human

understanding of the origins of the universe – it is about responding to the challenges that face South Africans now and into the future. It is about developing the technology and the capabilities that will build a dynamic and competitive economy that creates decent, sustainable jobs. It is about enhanced food security, better disease management, and cheaper, cleaner and more efficient energy.

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