Multiplier Effects on Socioeconomic Development from Investment in Renewable Energy Projects in Egypt: Desertec Versus Energy For Local Consumption Scenarios

Noran Farag*‡ and Nadejda Komendantova**,***

*Cabinet of the Minister of International Cooperation of Egypt, Senior Economist, 8 Adly Street, Downtown, Cairo, Egypt

**Risk, Policy and Vulnerability Program, International Institute for Applied Systems Analysis (IIASA), Schlossplatz 1, A-2361, Laxenburg, Austria

***Human-Environment Systems, Department of Environmental Systems Science, Institute for Environmental Decisions (ETH), Universitätstrasse 22, 8092 Zürich, Switzerland

‡ Corresponding Authors: Noran Farag, Tel: +2 0100 50 39245, Email: noran79@aucegypt.edu,

Nadejda Komendantova, Tel.: +43 676 83 807 285, Email: komendan@iiasa.ac.at

Received: 07.10.2014 Accepted: 07.11.2014

Abstract- Egypt is considering initiatives to deploy renewable energies, such as solar and wind; these would be financed through national and international public funds and private investment. Direct and induced impacts of investments could be significant drivers of socioeconomic development in Egypt, which currently has high level of poverty and unemployment plus volatile economic growth due to recent political upheaval. The initiatives would have two goals: i) export of electricity from renewable sources to Europe; and ii) generation of electricity to satisfy Egypt's growing energy needs. We thus posed two research questions: i) what are possible effects of investment in concentrating solar power (CSP), at a scale that would attract national and international policy incentives; and ii) what are effects of investment in CSP compared with the effects of a) the business-as-usual scenario, b) the DESERTEC investment plan, which foresees a large share of electricity being exported to Europe, and c) the national energy targets, under which CSP will be deployed to satisfy local energy demand. Our method is Social Accounting Matrix (SAM) of Egypt and the Leontief Input-Output model. Our results show that even though impacts from investments foreseen by the DESERTEC scenario will be highest in terms of GDP, output will be higher in the case of the scenario aiming to secure local demand of electricity from CSP. However, under this scenario, the income multiplier impacts will be the lowest, compared with the DESERTEC and business-as-usual scenarios.

Keywords—Renewable energy, solar energy, economic growth, economic development

1. Introduction

For decades development, mainly in the sense of economic growth, has been the strategic goal for many developing and transition economies. It still is. However, the pathways to achieving development goals vary significantly according to country, depending on the technologies and resources available. For instances, some countries, like those of Arab Middle East, are rich in natural resources such as oil and gas, while other countries, like China, are rich in human capital or, like Japan and South Korea, are reach in technological capability. The North African countries are rich in non-renewable energy sources, like solar and wind; however, this capacity has not, until now, been utilized to sustain economic growth and development.

Currently there are several national and international incentives to deploy renewable energies in the North African region, in general, and in Egypt, in particular. These incentives are demonstrating positive impacts on growth and income from investment in renewable energy sources in the region. Nonetheless, the government of Egypt has realized that securing a minimum economic income for its population is a major strategic goal if stability and growth in the region are to be guaranteed.

This paper investigates the impacts of both deployment of renewable energy sources, such as solar, and technology transfer for concentrating solar technology (CSP) as drivers of socioeconomic development. With the help of input-output modeling and data from the social accounting matrix of Egypt we analyze the impacts of investment in the deployment of CSP capacities in Egypt on gross domestic product (GDP), income and output. We also compare our results with existing estimates on impacts on growth and income from investment in CSP, as well as trying to understand how this investment can contribute to the government's strategic goal of sustaining income and guaranteeing an economic minimum for its population.

2. Background

2.1. Socioeconomic Situation

In 2011 Egypt witnessed revolution resulting from a number of socioeconomic problems encountered during the period of Hosni Mubarak's rule. About 45% of the Egyptian population was living beneath the poverty line of USD2 per day. Almost 5% of people held over 80% of Egypt's resources, and the other 95% shared the remaining 20% of resources, which indicates the high inequality among Egyptians [1]. The unemployment rate increased every year until it reached 13.2% in the first quarter of 2013; women made up 22% of the unemployed, and the percentage of unemployed young people (aged 15-29) was about 87.1% of the total unemployed [2]. Since the percent of poverty in Egypt is high, almost the entire income of poor people is spent on food. Food prices measured on the consumer price index (CPI) are increasing at a higher rate from one year to the next. Figure 1 shows the CPI for 2010, 2011, and 2012. Only in January 2012 did the CPI increase by 10% compared to January 2011. Consequently, Many Egyptians do not have the luxury to saving money for future needs. There were high expectations that the Arab Spring would solve socioeconomic problems. However, as Figure 1 shows that situation worsened after the revolution.

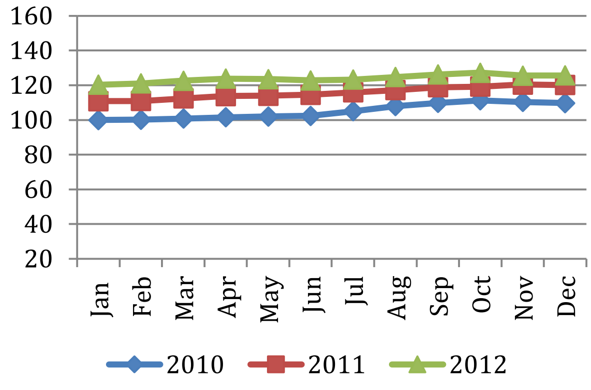

Figure 1. Consumer price index in Egypt (2010-2012). Source: CAPMAS statistics, 2012.

Before the revolution in Egypt the unemployment rate was increasing steadily. The country was also experiencing severe governance problems: corruption prevailed and dictatorship was the main way of ruling; there were high inequalities in income distribution, which resulted in increasing rates of poverty and a decline in the middle class. These factors were the main triggers behind the Arab Spring revolution that occurred in 2011 in Egypt, Tunisia, Libya, and Syria. In January 2011 Egypt witnessed huge protests that led to President Hosni Mubarak stepping down. People taking part in these protests hoped for a better future in terms of greater job creation, greater equality, and increasing political freedom.

However, the conditions worsened in Egypt after the Arab Spring and then under the leadership of the Muslim Brotherhood party. The total budget deficit of Egypt reached 205 billion Egyptian pounds (EGP), equivalent to USD29.2 billion, representing 11.8% of GDP during the first 11 months of the 2012/13 fiscal year [3]. In comparison with the same period of the previous fiscal year, the deficit rose by approximately 50%. Moreover, the GDP growth rate slowed from 5.1% in 2010 to 1.5% in 2012 [4]. Simultaneously, the public debt, which is the general government gross debt as a percentage of GDP, increased from 73.2% to 76.4% to 79.2% in the years 2010, 2011, and 2012, respectively. People in Egypt attributed these problems to inefficiency on the part of the Islamic party. Therefore, on 30 June 2013, the first anniversary of the Muslim Brotherhood coming into power in Egypt, another revolution swept the country in protests against the incumbent president Mohamed Morsi.

Egypt is the biggest country in the region in terms of population size. The Egyptian population reached 84 million in 2012: an increase of 1.5 million compared to 2011. This is a burden on the government in terms of the need to provide more infrastructure and greater job opportunities, especially as Egypt is known as a youth society or, in other words, that youth, namely population below the age of 25, forms the majority of its society. The Egyptian census of 2006 revealed that about 25% of Egyptians are between the ages of 18 and 29. Although the Arab Spring addressed many problems of the Egyptian economy and society, it did not address the risk related to the non-creation of new sources of job creation. As mentioned, Egypt is a society of youth, and thus more jobs are required to employ those young people. The increase in population not only carries risks for socioeconomic development, given that the rate of unemployed is high and continuing to grow due to the growing number of young people entering working age; it also contains risks for energy security, as energy consumption is growing together with the growing population.

The demand for electricity has increased by more than 200%, from 6,902 MW in 1990 to 21,330 MW in 2009 [5]. By 2025 the level of electricity demand in Egypt is expected to be 50 GWh, which is almost twice the current level. The electrification rate of Egypt was approximately 99.4% in 2008 [6]. Indeed, with total access to electricity in urban areas and a 99% access rate in rural areas, Egypt's electrification rate is among the highest in North Africa. Nevertheless, approximately half a million people lack access to electricity. The electric energy consumption rate in Egypt has, on average, increased by 7% per year over the last three decades; it is projected to continue to grow by 6%, and the latest National Development Plan of 2007 called for the addition of 33,900 MW of capacity from 2012–2027 [7]. This will require a big expansion in supply and, to this end, Egypt has set out plans to attract USD110 billion in power investments by 2027. Hypothetically, the power supply capacity should grow by at least 2000 MW/year, which indicates the need for a sequential investment of around USD3-4 billion a year—which would include generation, transmission, and distribution [5].

Egypt is known as one of the Sunbelt countries, enjoying one of the largest potentials for solar energy application in the region. In terms of potentials for renewable energies in the North African region, it might seem logical to deploy renewable energy generation capacities, such as wind and solar, in Egypt. The Solar Radiation Atlas indicates that the average direct normal solar radiation ranges between 2,000 and 3,200 KWh/m^2 per year across Egypt. According to both the Solar Radiation Atlas and the German Aerospace Centre, Egypt's solar potential is estimated to be in the range of 74 billion MWh/year, from 9 to 11 hours of sun per day. Egypt has a remarkable potential in renewable energy resources from solar irradiation in the massive western desert, wind resources along the Gulf of Suez, and hydropower from the River Nile. In spite of the potential additional sources of energy, the collective share of these renewable resources in the energy mix is currently fairly limited. Despite high potentials of renewable energies, non-renewable sources dominate the energy mix with natural gas (56.2%) and oil (38.2%) accounting for the bulk of primary energy supply, and representing 94.4% of the total. The rest is mainly electricity, generated using hydropower (3.9%) and other primary sources (1.7%). The government of Egypt aims to generate 20% of the country's electricity through renewables by 2020, of which about three-fifths (i.e., 7,200 MW), would be from wind power, and the remainder from solar, hydroelectric, and other sources [6].

The renewable sector is a source of new job creation. Figure 2 shows that the wind sector has the highest potential in terms of the number of jobs, followed by the solar sector. These two sectors are becoming important employers in both developing and developed countries.

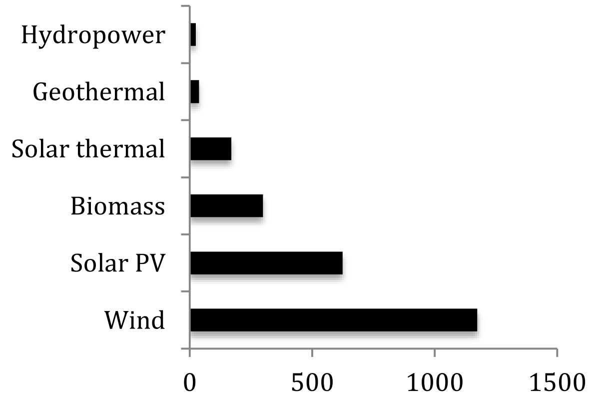

Figure 2. Jobs created according to renewable energy sector (in thousands of jobs)
Source: UNEP/ILO/IOE/ITUC, 2008

However, these jobs are distributed very unevenly across regions and, as shown by Figure 3, the most dynamic development has taken place in the Asian region. The North African region has attracted one of the lowest numbers of green jobs despite favorable geographic conditions and an abundance of renewable energy resources. Actually, the number of renewable jobs in North Africa is so limited that it is not even mentioned comparatively to other regions in the UNEP (2008) graph (Figure 3).

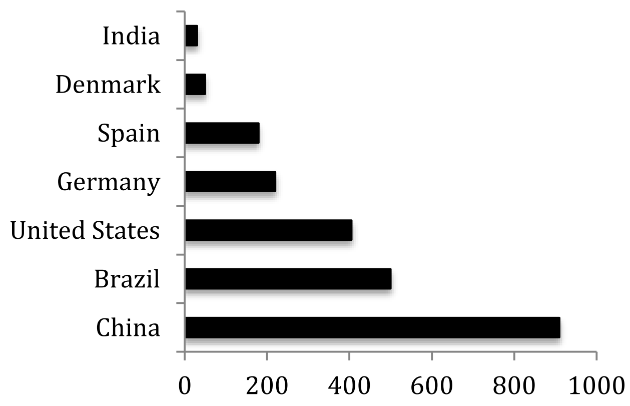

Figure 3. Employment in the renewable energy sector (wind power, solar photovoltaic and thermal, biomass, hydropower, and geothermal) in the year 2006 (in thousands of jobs). Source: UNEP, 2008

If we compare these numbers with the value of foreign direct investment (FDI) in the region (Figure 4) we can see the clear dependency between the regions attracting the largest FDI and experiencing the largest number of newly created jobs.

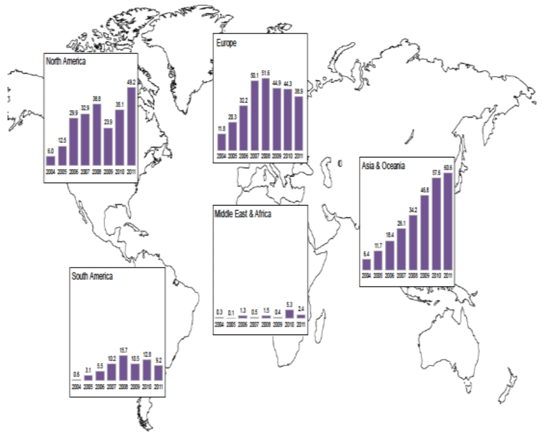

Figure 4. Private investment in renewable energy (million Euros). Source: Bloomberg New Energy Finance, 2013

Some scientific works point out that the North African region is not attracting FDI because of the risk perceptions by investors [8-9], which makes investment more expensive due to risk premiums on invested capital compared with other regions [10]. For that reason, we do not deal with the question on barriers to investment in the region, but look more at the results of that underinvestment, such as the low number of jobs created. Here, we address the question of what the impact of this investment would be, once it happens, on GDP and growth. And the question that interests us the most is what the impact of such investment would be on the socioeconomic development of the North African countries, represented in this research by Egypt, hosting the renewable energy projects, financed by, or with involvement of, private capital.

2.2. Technology

Concentrated solar power (CSP) is a technology that uses mirrors or lenses to concentrate the sun's rays to heat a fluid and produce steam. This steam drives a turbine and generates power in a way similar to that of a conventional power plant. However, other technologies are being studied such that not all CSP plants would necessarily use a steam cycle in the future [11]. CSP plants can be divided into two groups, based on whether the solar collectors concentrate the sun rays along a focal line or on to a single focal point (with much higher concentration factors). The line-focusing systems include parabolic trough as well as linear Fresnel plants and one-axis tracking systems, while point-focusing systems include solar dish systems in addition to solar tower plants; they also include two-axis tracking systems which are used to concentrate the sun's power.

The concentrated solar power (CSP) market—which is just beginning to develop in Egypt and worldwide — indicates that the technology is less mature than other solar technologies and requires higher capital costs. As CSP is still a new technology, the know-how has not been well developed in Europe, which could create opportunities for new market entrants to exploit the potential for technological innovation. The main raw materials required for CSP parts and components (steel, concrete, and cement) are available locally because these materials are used for construction and civil-engineering works carried out by engineering, procurement, and construction contractors. In this sector, Egypt has a comparative advantage over other North African countries because of the presence of construction companies with automated production, quality certification, and high-tech tools that could supply CSP plants with support structures. However, current Egyptian production does not meet the specifications required for the production of the glass used in CSP mirrors and the mirror coating, which is a major component of CSP technology and required for its implementation. Thus, joint ventures that offer extensive technical assistance and knowledge transfer are required if the capacities needed for such production are to be built in Egypt. Currently, two CSP projects have been launched; the first is in Kuraymat, providing 140 MW at a cost of USD340 million, and the second in Kom Ombo, providing 100 MW at a cost of USD750 million.

2.3. Policy Targets and Incentives

There are currently several incentives for deploying renewable energies in North Africa, in general. These incentives are both North African and European, like the Mediterranean Solar Plan (MSP), the "Transgreen" incentive, and a number of national policy targets, as well as private-sector incentives, like the DESERTEC Industrial Initiative (DII).

The private DESERTEC Foundation was established on 20 January 2009 as a non-profit foundation with the aim of promoting the application of the worldwide universal DESERTEC concept "Clean Power from Deserts." The founding members of the DESERTEC Foundation are the German Association of the Club of Rome, members of the network of scientists TREC, as well as dedicated private supporters and long-time promoters of the DESERTEC idea. According to the DESERTEC concept, about 1% of the desert surface of the earth would be enough, in theory, to provide all of humanity with energy. As the region of North Africa has huge deserts and is geographically near to Europe, DESERTEC plans to source 15% of its Europe electricity needs from North African countries from renewable energy sources by 2050. Moreover, the aim of the Mediterranean Solar Plan is the development of renewable energy projects with a total of 20 GW by the year 2020.

With reference to the Egyptian national targets, in 2007 the National Democratic Party (NDP), which was the ruling party at the time, put in place major targets for the future of energy in Egypt to 2022. Among these targets are: i) keeping the volume of crude petroleum oil and extracts stable at its present level; ii) increasing natural gas production by an annual average of 5% during this period; iii) implementing policies to support energy, with a focus on allocating subsidies to those in need of them, namely the poor; iv) increasing the electricity generation capacity from renewable energy sources to produce about 20% of entire energy generation by 2020, with wind constituting 12% of this target, hydro 5.8 %, and solar 2.2%; v) initiating steps and implementing measures to promote the Egyptian nuclear program that includes building a number of nuclear power stations by 2022 and, most importantly, working to create a regional and international interconnection of electricity networks by the year 2022 [12]. To achieve these targets, a unified electricity network between North African countries, Arab countries, and the European Mediterranean countries should be established. Work on this has already started and significant progress has been made.

In 2008 the Egyptian Ministry of Electricity and Energy (MoEE) set the target of increasing the share of electricity from renewable energy sources by 20% by the year 2020. To reach this target, several technologies were considered, with a preference being shown for technologies associated with lower costs and more abundant resources.

In July 2012 the Egyptian Solar Plan was approved, and it has set a target for 2,800 MW of CSP and 700 MW of solar PV by 2027. For Egypt, the target is to have 20% of its local demand covered by renewable sources of energy by 2020. Although Egypt is not yet a net oil importer, it soon will be and is thus working hard toward generating electricity from renewable sources, especially solar and wind.

In June 2013 Egypt and Saudi Arabia signed a memorandum of understanding for USD1.6 billion to build an electricity grid that will enable the two countries to trade electricity, benefiting from different hours of demand peaks in the two neighboring Arab nations. This grid is planned to eventually link 14 Arab countries. Later in the project, it is planned to integrate the grid into the European network across the Mediterranean countries. It is also planned to implement projects aiming to interconnect countries of the Arab-Maghreb in terms of electricity and also to begin work at the African level, by investing in water sources in river-source countries in order to generate electric power. In fact, forecasting needs to take place with respect to the impact of this integrated approach [12].

2.4. Research Question

This background information leads us to the identification of our two research questions.

First: what will be the effects of FDI on the Egyptian economy with respect to deployment of CSP capacities at scales comparable to national targets and international incentives?

Second: how can the effects of FDI on CSP be compared with i) the business-as-usual situation, ii) the DESERTEC investment plan, which foresees a large share of electricity being exported to Europe, and iii) the national energy targets, under which CSP will be deployed to satisfy local energy demands?

3. Methodology

3.1. Methods

The model used in this research is calibrated on the Social Accounting Matrix (SAM) for Egypt for the fiscal year 2006/07. A SAM captures a statistical representation of the economic and social structure of a country, providing a static picture of its economy. The SAM is a square matrix, divided into equal columns and rows, where columns represent buyers (expenditures) and rows represent sellers (receipts). All institutional agents (firms, households, government, foreign sector) are both buyers and sellers. All the monetary flows from economic transactions and transfers occurring between the different institutional agents in that year are represented in the SAM. Each cell shows the payment from the account of its column to the account of its row. An account's incomes are thus shown along its row and its expenditures are shown along its column. For each account in the SAM, total revenue (row total) should be equal to total expenditure (column total).

The Egyptian SAM consists of six major accounts: production factors, economic agents, industries, composite products, capital, and taxes. It incorporates two production factors: labor and capital, and six economic agents: households (rural and urban), companies (private and public), government and the rest of the world (see Figure 5 for detailed parameters).

In Figure 5, activities are the sectors that carry out production. They buy intermediate consumption from commodities accounts; pay the value-added to the factor accounts, and pay production taxes and/or value-added tax, if any. Activities receive the value of sales of commodities. They are valued at producers' prices. Commodities are the final goods. They receive payments from activities, as a counterpart for intermediate consumption, from households (private consumption), from government (public spending), from the rest of world (export value), and from the savings-investment or capital accounts (investment demand). Thus, commodities pay the value of sales to activities, and they also pay the value of imports to the "rest of the world" accounts and, ultimately, taxes such as import tax. They are valued at market prices. However, factors represent the inputs needed for production, along with intermediate consumption, and thus consist of labor, capital, and sometimes land. This account receives payment from the activities under the form of value-added, either as wages or as interest payments or rents on capital or land. Factors use these receipts for payments to households and/or firms. All the private institutions in the economy are gathered under households. These receive the value of the payroll, profits from capital and land, and transfers from the other domestic and foreign institutions. Households use these earnings for private consumption, income taxes, and transfers to institutions and savings, which will be paid to the capital account.

An economic multiplier measures an economic impact that plainly recognizes the interconnections between the networks of interdependent activities. When a change takes place in one part of such a network, its effects disseminate throughout the whole system. These effects typically result in a larger total impact than the original change would have caused had the other changes not been taken into consideration. SAM-based economic multiplier models belong to the class of general equilibrium models that use fixed prices for assessing the economic effects of exogenous change in income and demand. The multipliers are calculated for the business-as-usual scenario in order to compare the results with the multiplier effect achieved after CSP is introduced into the SAM.

Let Yi denotes the output of good i, that is used partly to fulfill intermediate supplies as an input for producing other commodities and partly to fulfill final demand. If Yij denotes the amount of commodity i used to produce a unit of good j and Xi denotes the final demand for commodity I, we will get the "input-output" equation:

$$Y_i = Y_{i1} + Y_{i2} + ... + Y_{in} + X_i \text{ for } (i = 1,..., n) \tag{1}$$

In other words, the production of each commodity is sufficient to meet the required amounts of inter-industry in addition to the final amounts demanded for that commodity. There must be n equations, one for each of the n commodities produced in the economy. The input-output method solves this system of equations for the n outputs Y_i, given the input-output coefficients a_{ij} and the final demand for each industry Y_i. However, prior to that, it is necessary to estimate the a_{ij}. The a_{ij} input-output coefficients are calculated as follows $a_{ij} = Y_j/Y_{ij}$.
Since SAM is a matrix, this system of equations might be expressed as:

$$Y = Z+X \tag{2}$$

If A = Z/Y, then Z = AY

$$\text{Then, } Y = AY + X \tag{3}$$

$$Y = (I-A)^{-1}X = MaX$$

where $(I-A)^{-1}$ captures the amplification of an exogenous injection X; Ma is the SAM multiplier; it is also called the Leontief inverse; X is a matrix of exogenous accounts; A is a matrix of average expenditure propensity; I is an identity matrix and Y is a matrix of endogenous income. Thus, the total quantities required of good i to produce a unit from good j, both direct and indirect, is denoted by the i, jth element of the $[I-A]^{-1}$ matrix.

In order to measure linkages between the CSP and the rest of the economy, the method of Rasmussen backward linkage is used. This index defines the relative degree to which a one-unit increase in final demand for the goods of a specified industry is dispersed all over the whole system of industries. The dispersion index is:

$$\sum_i^n \mathrm{Uij} = \frac{\frac{1}{n}\sum_i \mathrm{Bij}}{\frac{1}{n^2}\sum_{ij} \mathrm{Bij}} \tag{4}$$

where the number of industries is represented by n, and $\sum_i Bij$ refers to the sum of the elements in the columns of the Leontief inverse matrix $\boldsymbol{B} = (\boldsymbol{I}\text{-}\boldsymbol{A})^{-1}$. It can be interpreted as the required increase in output from the full system of industries needed to cope with an upsurge in the final demand for the products of industry j by one unit. This index has been commonly used to measure the backward linkages.

3.2. Data

The input parameters of the Egyptian SAM are displayed in details in Table 1. Figure 5 also illustrates the economic relationships among the whole economy reflected by SAM. The figure simply illustrates the relationship between the household, government, factors of production, activities, commodity market, and foreign trade sector. The household sector pays taxes to the government and buys products from the commodity market, which is fed domestically by activities and internationally by imports. Moreover, the commodity market feeds the export sector, which contributes tariffs that go directly to the government as revenues, forming government reserves. These reserves are then used for investment. The activities fed by the household purchases and that add value to the factor markets—labor, land and capital—form household incomes.

Table 1. The components of the Egyptian SAM, 2006

Activity/Commodity	**Factor**	**Institutions**	**Auxiliary institutional accounts**
Agriculture	Labor - less than completed secondary education	Household	Taxes
Crude oil, natural gas and other extraction industries	Labor - completed secondary education	Government	Subsidies
Labor Intensive industries	Labor - completed tertiary education	Rest of world	Savings
Capital Intensive industries	Capital for non-government activities		Investments
Construction	Capital for government education at primary level		
Electricity	Capital for government education at secondary level		
Transport and communication	Capital for government education at tertiary level		
Other productive services (hotels, trade and insurance)	Capital for government health		
Education in non-government schools & universities	Capital for water and sanitation		
Private sector health	Oil natural resource factor		
Other non-government services			
Education in government schools and universities			
Government Health sector			
Water and Sanitation			
Other infrastructure			
Other government services			

Source: Egyptian Ministry of Planning, 2006

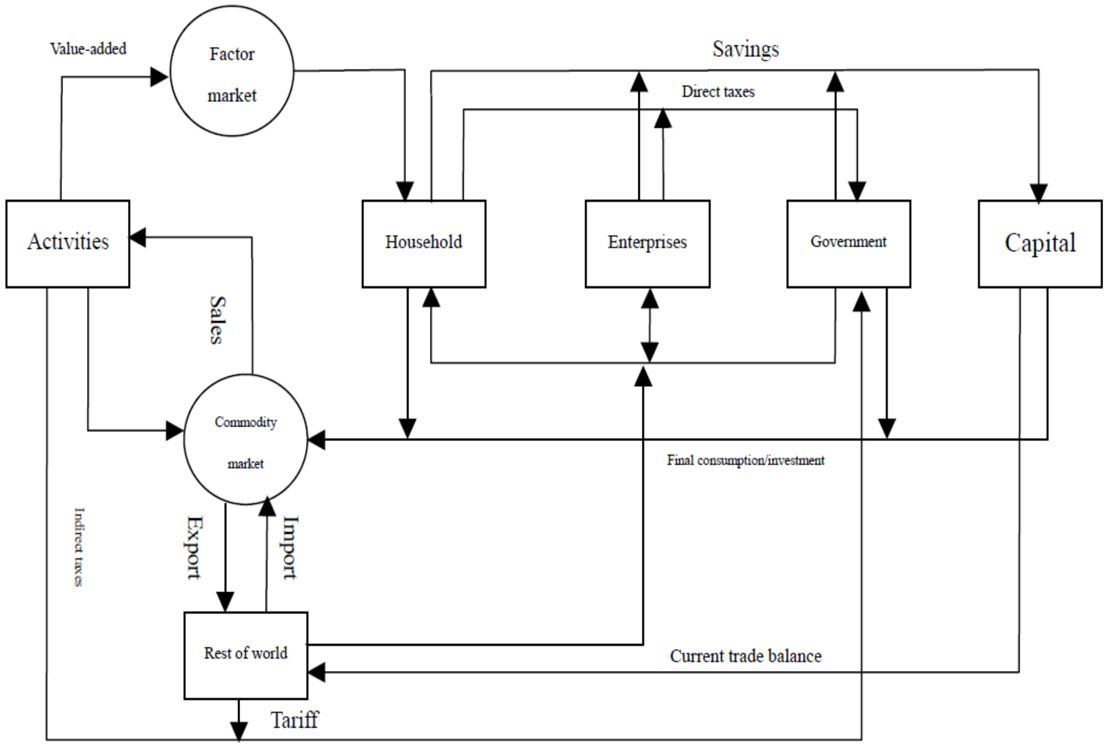

Figure 5. Economic representation of the flow of income in the Egyptian economy Source: Authors

4. Results

The aim of this research is to test the effects that changes in final demand or in one CSP industry would have on the rest of the Egyptian economy. SAM-based multipliers are often used in the analysis of the distribution of income across socioeconomic household categories caused by an external shock, which, in the case of this research, is investment in CSP technology. Comparing the multipliers of the original SAM, which does not include CSP, with the multipliers after adding CSP as a final product and as an intermediate good, the following results are depicted—the values indicate the increase in income in each of the endogenous accounts due to one unit of external injection through the exogenous accounts.

First, the output multiplier was calculated, which can be defined as the total value of the additional production in all sectors of the economy entailed by an additional unit of final demand for the sector's output. For instance, an additional demand for one unit in commodities will increase total input by 4.04 units, and thus the output multiplier is 4.04.

Second, the GDP multiplier is 1.62, which means that an exogenous increase of one unit in the demand for electricity generated from CSP will increase GDP by 1.62.

Third, the income multiplier, which relates the additional income created for each household type in response to the exogenous shock, namely, in this case, introducing CSP manufacturing, is 2.15. In other words, generating electricity from CSP entails an increase of 2.15 in household income.

After the initial impact of a shock, the effects spread to the rest of the sectors and are multiplied due to economic linkages, thus creating different impact rounds. For instance, during the first round, the increase in CSP demand will create an additional demand in the additives sector, which, in turn, in what may be called a "second round," will create an additional demand in the chemical sector, and so on. The impact of the exogenous shock reverberates through the economy, becoming weaker and weaker until it arrives at nil. These round-by-round effects can be clearly distinguished in the backward linkages, which identify additional intermediate demand generated by the expansion of a sector's production. The strength of the backward and forward linkages depends on the sector's level of integration in the economy. A sector having a significant importance for upstream industries and an input-intensive production technology will have at the same time stronger forward and backward production linkages and thus a larger multiplier.

If A is the input coefficient matrix, the coefficients of the direct backward effects can be obtained by summing the columns of the A matrix [13]. Nevertheless, these coefficients leave out the indirect effect and take into account only the first round effects. In order to observe the total backward linkages, the Rasmussen method is used which implies summing the columns of the inverse Leontief matrix. The analysis shows that an exogenous increase of 1 unit of demand for energy generated from CSP technology has a backward effect of 4.53, which means the additional intermediate demands from other inputs will increase by 4.53. By using these coefficients we can classify sectors according to their level of integration [14]. They distinguish three types of linkages: a) Strong: if coefficients are greater than 1; b) Intermediate: if coefficients are between 0.8 and 1;and c) Weak: if coefficients are below 0.8. As the coefficients in this case are greater than 1, we can say that the economic backward linkages are strong. However, on the sectorial level, the backward effect of CSP on labor-intensive industries will be 0.54, which shows a weak linkage. This is because none of the inputs required for manufacturing CSP energy are labor-intensive industries. On the other side, the backward effect on the capital-intensive industries is 0.95, which indicates a more or less strong linkage and, of course, this is easily explained by the fact that most inputs required for generating energy from CSP are manufactured by capital-intensive industries.

Manufacturing energy from CSP depends significantly on a number of other products and services, as the multiplier of CSP-generated energy on other services including hotels, trade, and insurance is 0.38. This is because currently 50% of the inputs required to produce CSP-energy are imported. Concurrently, the multiplier effect of the energy from CSP on the exports sector is 0.68, which offers a promising future for Egyptian exports. The global tendency toward switching to renewable energy, in addition to the normal increasing demand for energy, provides a good market for the CSP industry in Egypt.

4.1. Scenarios

Three scenarios are analyzed in this research. The first one is used to test the effect of the DESERTEC scenario, which would imply securing 15% of Europe's electricity needs from the Middle East and North African (MENA) countries using renewable energy sources. An investment of about €400 billion is planned to be injected into the MENA region to 2050 to produce electricity from renewable energy. The assumptions in this scenario are that each country will take an equal share of the investment, that all of it will go into deployment of CSP technology, and that the installations will be constructed over an equal period of time.

Under these assumptions, we are talking about FDI of around USD27 billion. If we assume equal distribution of investment to be injected annually till 2050, then the yearly investment will be USD806 million which is equivalent to EGP 5.4 billion. This investment shock is introduced into the Egyptian SAM to calculate multipliers and test its effect on the Egyptian economy.

According to this scenario, the output multiplier is 4.32, which is higher than before the investment shock was introduced, while the income multiplier and the GDP multiplier are 2.19 and 2.12, respectively. Comparing the base scenario with the DESERTEC plan scenario, it is shown that the GDP and output will be much higher when the DESERTEC investments are injected into the Egyptian economy, while the income multiplier, which represents household incomes, will also increase, but at a lower rate. It is good to have higher GDP, but why would household income increase slightly compared to output and GDP? Although this result needs more investigation, we assume that it could be due to some losses incurred from the decrease in incomes of people working in the manufacturing of substitute goods or services such as coal, oil, and natural gas. Additionally, CSP technology is not a labor-intensive industry, especially if vertical technology transfer is envisaged which foresees turnkey power plants. On the other hand, horizontal technology transfer, which also anticipates deployment of manufacturing industries for CSP components, would generate three times more job-years then vertical technology transfer, when all components are imported [15].

The second scenario is to secure the electricity needs of the local market from renewable energy, specifically CSP. In this scenario, we assume the costs currently associated with generation of the required amount of electricity from oil and natural gas to be the costs of generating the same output from CSP technology. Oil contributes to 41% of Egyptian energy consumption, which equals 3.6 quadrillion BTU (British thermal unit). Natural gas contributes to 46% of final energy consumption, while the remaining 13% is met by renewable energy sources (traditional biomass, hydro, wind, and solar) and coal. The total net generation of electricity in Egypt was approximately138.7 billion KWh in 2010, of which 90%, that is 124.3 billion KWh, was from fossil-fueled electric, 12.9 billion KWh from hydro, and 1.5 billion KWh from wind. Although Egypt is abundant in solar energy, this is not yet a main source of electricity, one reason being the high costs of generating electricity from thermal energy. The vast increase in Egyptian electricity consumption which is much faster than capacity expansions has persuaded the Egyptian government to allocate more investments to the power sector over the next few years, in addition to seeking financing from foreign sources.

Solar tower systems are estimated to have a levelized cost of electricity (LCOE) of between USD 0.16 and USD 0.27/KWh at present, depending on their location, the size of their thermal energy storage, and the particulars of the project [11]. In Egypt the cost of producing energy from CSP is estimated to be USD0.20 for every KWh. Since Egypt consumes about 124 billion KWh of electricity annually, the total cost required to produce the same amount of energy is USD25 billion. From the SAM, the cost to produce the required electricity from oil and natural gas is about USD15 billion. It appears that producing the same amount of electricity to secure local demand costs USD10 billion less when using fossil fuel than when using CSP technology. In Figure 7 it is shown that the GDP multiplier is slightly higher than in the base scenario, while it is significantly lower than that of DESERTEC. As the costs of generating electricity from CSP technology are higher than generating the same capacity from oil, totally securing local demand through CSP is not an efficient option. The income multiplier according to the local scenario is lower than both the base and DESERTEC scenarios. Household incomes will decrease if the government switches 100% to CSP; this may be due to the high prices paid for obtaining high-cost electricity. However, the output multiplier is higher in the second scenario than in the other two. This is because a lot of other inputs are required to transform solar heat into energy. The third scenario is to test the current plan of the Egyptian government, which implies increasing the electricity generation capacity from renewable energy sources to reach 20% of the total generation by 2020, with wind constituting 12% of this target, hydro 5.8 %, and solar energy 2.2%.

The average cost of generating one unit of electricity (KWh) from wind in an offshore installation is USD 0.15 while with an onshore installation the average cost is USD0.10. Moreover, the cost of generating one unit of electricity from hydropower whether grid-based or off-grid is on average USD0.1. As Egypt consumes from electricity of about 124 billion KWh annually, as mentioned above, according to the plan, the amount of electricity needed from wind will be 14.9 billion KWh, from hydropower 0.712 billion KWh, and from solar 0.27 billion KWh (Table 2).

Table 2. Costs of different energy sources

Source	Costs (in million USD)	Share in total final energy consumption (%)
Oil and natural gas	12000	80
Wind (onshore)	1490	12
Hydropower	71	5.8
Solar (CSP)	54	2.2
Total	13615	100

Source: Authors' calculations

The total costs according to this scenario are the lowest compared to the other scenarios. If these figures are input into the SAM of Egypt taking into account the specified percentages that the government has set, the results reveal that the GDP multiplier and the income multipliers are better than both the base scenario and the second scenario that implies securing the total demand of electricity from CSP. However, it is less than the DESERTEC scenario. Nevertheless the output multiplier is just better than the base scenario but lower than the other two scenarios (Table 3).

However, the SAM multiplier method is just the first step and there is further work required to develop a Computable General Equilibrium (CGE) model, which is providing ways for data validation, which SAM multipliers method does not provide.

Table 3. Summary of multipliers from one unit injection into CSP

Type of Multiplier	Multiplier of base scenario (current level of investment)	Multipliers of 1st scenario (DESERTEC plan)	Multipliers of 2nd scenario (secure local demand of electricity from CSP)	Multipliers of 3rd scenario (government plan till 2020)
GDP multiplier	1.62	2.12	1.67	1.72
Income multiplier	2.15	2.19	2.04	2.16
Output Multiplier	4.04	4.32	4.46	4.21

Source: Authors' calculation

5. Conclusion

The results show that the DESERTEC plan will have the largest impacts if measured by GDP and by income multipliers. This scenario can achieve the highest possible growth for the Egyptian economy. Applying the GDP multiplier to the real figures of the 2012 Egyptian economy, the GDP will be USD500 billion instead of USD236 billion. However, comparison of the DESERTEC scenario with the business-as-usual scenario shows that this investment will have the greatest impacts on GDP, while at the same time having less significant impacts on income and output. The DESERTEC scenario will also have more significant impacts on GDP in comparison to the scenario that foresees deployment of renewable energies to secure local energy demands. The "local" scenario will also have the lowest impacts in terms of income. However, the "local" scenario will have higher impacts on output than the DESERTEC scenario. There are also currently doubts if energy cooperation, including all kinds of energy sources, such as gas or alternative energies, between the European Union and countries, marked by high political risks, could be useful in terms of security of energy supply.

The average annual income per household in Egypt is USD1,750. By applying the income multiplier of the DESERTEC scenario, the average annual income per household will be USD3,832. The current government is targeting the enactment of a law that sets a minimum annual wage of approximately USD2,060. Thus, the DESERTEC investment could have significant impacts on socioeconomic development. However, these assumptions are made for the ideal situation where the induced effects of foreseen investment are distributed equally across the population. Taking into account i) the socioeconomic divide in the country between different groups of population and different regions, ii) the institutional structures and the risk of resource curse, and iii) the risk that the majority of components needed for deployment of CSP capacities will be manufactured outside the country, and given iv) the induced effects of investment abroad, further research is needed on how the induced impacts of investment will be distributed among different Egyptian and international stakeholders.

Acknowledgments

The work described in this paper was supported by the Egypt National Member Organization to IIASA and by the European Research Council in frames of its “ERC StG2012 - 313553 – Desertection” grant. The paper reflects the authors’ views and not those of the Egyptian NMO or the European Research Council. We wish to thank all the colleagues and persons who provided us with professional advice and collaboration. We are especially grateful to Yuri Ermoliev and Tatiana Ermolieva, who helped with the development of methodology.

References

[1] D. Abdou, Z. and Zeinab, “The Egyptian Revolution and Post Socio-Economic Impact”, Topics in Middle Eastern and African Economies, vol. 15, no. 1, pp. 588-595, 2013

[2] CAPMAS, Bulletin of Labor Force, Central Agency for Public Mobilization and Statistics, 2013.

[3] Financial Statistics and Fiscal Data. The Egyptian Ministry of Finance Statistics, 2013.

[4] IMF, Growth Resuming, Dangers Remain, World Economic and Financial Surveys, World Economic Outlook, 2012.

[5] UNEP, Global Trends in Renewable Energy Investments, United Nations Environment Program, 2013.

[6] IEA/OECD, World Energy Outlook 2012. International Energy Agency, 2013.

[7] REEEP, Annual Report 2013, Renewable Energy and Energy Efficiency Partnership, 2013.

[8] N, Komendantova, A. Patt, and K. Williges,. “Solar power investment in North Africa: Reducing Perceived risks”, Renewable and Sustainable Energy Reviews, 15 (9), pp. 4829-4835, 2011

[9] N. Komendantova, A. Patt, L. Barra, and A. Battaglini, “Perception of risks in renewable energy projects: The case of concentrated solar power in North Africa”, Energy Policy, 40, pp.103-109, 2012

[10] J. Ondraczek, N. Komendantova, A. Patt. “WACC the Dog: The effect of financing costs on the levelized cost of solar PV power”. Renewable Energy, Volume 75, March 2015, Pages 888-898.

[11] IRENA, Renewable Power Generation Costs in 2012: An Overview. IRENA Report. International Renewable Energy Agency, 2013.

[12] P.,H. Sudin, “Struggling between resources-based and sustainable development schemes—an analysis”, vol. 39, Issue 8, pp. 4431–4444, 2011.

[13] H.Chenery, and T. Watanabe, T., “International Comparisons of the Structure of Production”, Econometrica, 26 (4), October, pp.487-521, 2011

[14] P. Dasgupta, P. and D. Chakraborty. “ The Structure of the Indian Economy”, 15th International Input-Output Conference, Beijing, China, P.R., session I.1.6, June 27-July 1, 2005

[15] N. Komendantova and A. Patt, “Employment under vertical and horizontal transfer of concentrated solar power technology to North African countries”. Renewable and Sustainable Energy Reviews (2014), pp. 1192-1201, 2014