Abstract: Ambitious goals for climate change mitigation and energy security policies are driving deployment of renewable energy sources globally. However, the deployment of renewable energies at scale requires not only public but also private capital, such as foreign direct investment. Many countries with favourable conditions for renewables, such as the countries of the Middle East and North African region, are not attracting sufficient FDI. Risk perceptions of FDI stakeholders are one of the reasons. This paper discusses the de-risking approach as a possible tool to address subjective risk perceptions and assesses with a Computable General Equilibrium model macroeconomic feedback-effects of employing a de-risking strategy for FDI into a particular kind of RES-E, concentrated solar power, in the MENA region. Our results show that the application of de-risking approach reduces the costs for deployment of CSP, and therefore, also volumes of subsidies that would be needed to make CSP cost competitive with fossil fuel based electricity generation. This in turn leads to positive GDP and welfare effects in the MENA region. Our results allow us to recommend for energy policy the implementation of the de-risking approach as a potential consensual option with high political feasibility to reduce climate change mitigation costs.

Keywords: renewable energy sources, Middle East and North African region, de-risking approach, foreign direct investment

1. Introduction

Economic theory is dealing with such factors of human behaviour as risk aversion, which comes from the utility maximising behaviour of investors to reach expected profits. In case if investment is promising to be profitable, the volumes of investment usually increase. But in case when possibility of loosing money is too high investors will stay away from such business opportunity (Arrow, 1985). Such risk aversion is caused by risk perceptions, which are subjective judgments about characteristics and severity of risk. Risk perceptions are closely connected with the willingness of people to take risk and with their expectations of risk premiums as an incentive for taking the risk (Slovic, 2000). It is difficult to measure risk aversion in behaviour of investors as several factors are playing a role and reliable estimates to calibrate the level of risk aversion are lacking (Weber et al., 2002).

The decisions of private investors are influenced by perceived downside risk (Komendantova et al., 2012). To create attractive conditions for private investors, there is a need to decrease the downside risk of renewable energy investments by means of public policy instruments or to pursue so-called de-risking strategies (Schmidt, 2014). Schmidt (2014) identifies a de-risking approach as a set of measures to decrease downside risk of low-carbon investment and the policy de-risking as the process to reduce the likelihood of a negative event or risk for investment. Therefore, de-risking is a measure to decrease financial costs of low-carbon technologies. There are two kinds of de-risking measures, financial and policy. The financial de-risking, such as insurance or guarantees of public stakeholders, transfers financial impacts of negative events to other parties. The policy de-risking decreases the likelihood of the risk by improving investment climate and local institutions. One example is improvement of permitting procedures, which decreases the likelihood of the construction delays.

Following available evidence (del Rio and Gaul, 2007; Mendonca, 2007, Komendantova et al., 2012) this study is based on the assumption that risk aversion is playing an important role in energy markets, even though it is difficult to determine the extent of its influence. The second assumption is that de-risking strategy can address risk aversion of private investors. This study identifies the positive impacts of de-risking strategy in frames of a case study of concentrated solar power (CSP) in the Middle East and North African (MENA) region.

We select this region as despite favourable geographic conditions and available resources, development of solar projects in the region and especially private investment into these projects is hindered by several factors. We select CSP as a case study technology due to its potentials for climate change mitigation and due to high initial capital volumes, which are needed for deployment of this technology. CSP technology looks favourable from a central planner perspective, primary because of possibilities to generate large volumes of electricity and of capacity for storage. However, the targets settled by the MENA countries will require involvement of private capital, as CSP is a capital-intensive technology. While CSP may be attractive to policymakers, private investors are cautious in regards to CSP projects in the MENA region because of their perceptions of the associated investment risks, connected both with CSP technology and with the politico-economic environment in the MENA region. Currently most of the private investment in the MENA region goes to hydrocarbon sector, manufacturing, real estate or tourism. In cases when private investors do support CSP projects, their expectations on risk premiums are high. So far only Morocco, out of the MENA countries, has been able to attract significant private investment (RCREEE, 2013).

In the meantime several scientific works exist on impacts of subjective risks perceptions on foreign direct investment (FDI) into renewable energy sources (RES), however, scientific evidence about the impacts of de-risking strategy in macro-economic perspective is limited. In this paper we deal with high weighted average costs (WACC) for CSP projects. We argue that WACC plays an especially important role for energy projects like CSP, as due to large volumes of required capital for large-scale installations, typical for CSP, the capital for such investment should be leveraged with up to 70%-80% of total project being financed through debts. Therefore, high WACC driven by expected risk premiums is influencing the overall volumes of investment needed to make CSP technology cost competitive with fossil fuels. The novelty of this research lies in the identification of macroeconomic benefits of a de-risking strategy, which addresses subjective perceived risk for CSP investment. By applying a computable general equilibrium (CGE) modelling approach, we analyse economy-wide benefits of de-risking strategy in terms of macroeconomic spill-over effects due to a reduction of necessary volumes of RES-E subsidies, which would be needed to cover the downside investment risk into CSP with high risk premiums and high WACC. More specifically, we discuss economic benefits in terms of GDP, macroeconomic feedback effects and welfare effects of reduction in required subsidies for CSP.

2. Background

2.1. Deployment of CSP in the MENA region

The Middle East and North African (MENA) region has favourable conditions for deployment of solar power, and renewable energy more generally. The region has particularly good potentials for solar energy as it is situated in the Earth's Sunbelt with especially high direct normal irradiation ranging between 4,000 and 8,000 Wh/m2/day (Mason and Koumetat, 2011). For instance the level of solar irradiation in the region is three times higher then in Europe, where several solar development projects were currently deployed. The available solar resources in the MENA region would be sufficient to satisfy growing energy need of the region itself, as well as to generate electricity for export to Europe and to other African countries. One estimate of the economic potentials for concentrating solar power (CSP) is about 150,000 TWh/a, which is roughly equivalent to current global primary energy consumption (German Aerospace Center, 2006).

Currently electricity consumption in the MENA region grows two times faster then the world average, and energy demand in the MENA region is projected to grow further by 7% per year over the next 10 years, out of a combination of population growth and economic development (OME, 2011). More specific drivers include air conditioning and seawater desalination, which will be increasingly necessary because of the impacts of climate change. A continuation of current growth and technological trends would imply a doubling of electric generating capacity by 2030 and a quadrupling by 2050 (WEC, 2013). Simultaneously, however, there is the need to decarbonise energy sector, and especially electricity generation, in the MENA region. By 2011 the electricity sector was the largest emitter of green house gas emissions in the region and accounted for 42% of the region's total carbon emissions in 2011 (World Bank, 2014).

Recognising the need to cover growing energy demand and to reduce the level of green house gas emissions from energy generation, the MENA countries have set ambitious targets for deployment of renewable energy sources, including solar. Algeria has set a target of installing 12 GW of renewable energy sources (RES) by 2030, which would cover 40% of its domestic electricity demand. Egypt set a target of 20% of RES in its energy mix by 2020, Tunisia targets 25% of RES in electricity production by 2030, and Morocco targets 6 GW of RES by 2020 (IEA, 2013). While it is still questionable whether any or all of these countries will reach their particular targets, it is clear that such ambitious targets would require massive involvement of private capital to facilitate deployment of RES at scale.

For the most part, MENA governments plan to achieve these targets mainly through large-scale projects, which would allow generation of electricity for large consumption centres as well as for industries. The plans for deployment of renewable energy sources in the MENA region include large-scale solar projects, comprising both photovoltaics (PV) and CSP, as well as large-scale wind (IRENA, 2016). While these technologies have some features in common, such as the large-scale size and therefore risk of sunk investment, the risk environment for individual technologies might be very different. For instance, among the large-scale renewable energy sources, wind has the longest history and most established track record and business models, which allows investors for calculating of possible return time and reducing uncertainty connected with investment. PV has been marked by significant cost reductions for components over last years, including a 50% reduction in investment costs over last four years alone (Rogelj et al., 2015). Together, PV and wind are already least cost renewable energy technologies, and can be competitive with fossil fuels in many countries (IRENA, 2015).

By contrast CSP is somewhat different. While it has also experienced robust learning (Lilliestam et al., 2017), the total global capacity for CSP is far less than for either PV or wind, at the same time as the technological complexity of new CSP is high, leading to questions of plant reliability. Arguably, CSP is being built despite its representing a riskier investment than either PV or wind, with the primary attraction being its potential to supply dispatchable electricity through the low-cost addition of thermal storage (NREL, 2016; Pfenninger et al. 2014). This inherent flexibility could justify investments despite both higher costs and higher levels of risk. Precisely because CSP has risks attached, and yet could be a crucial investment in order to help integrate high levels of RES in the MENA region, there is value in investigating the potential benefits of efforts to reduce risk levels associated with CSP investment. This is the subject of this article.

2.2. Previous works on de-risking

In the period 2008-2011 several research field missions were conducted in the MENA region. These missions included interviews with FDI stakeholders in the region as well as focus group discussions. The main research question was to understand the reasons why despite favourable geographical conditions the MENA region is attracting the lowest volumes of FDI into RES in the world and to identify barriers for FDI into RES in the region. This research showed that subjective risk perceptions or risk aversion play an important role. This risk aversion was connected with perceptions of likelihood of risk to happen and of seriousness of concern about a certain type of risk. Interviews with FDI stakeholders showed that complex and lengthy bureaucratic procedures are perceived as a major barrier and risk for investment, as their was a lot of uncertainty regarding the time horizon for these procedures (Komendantova et al., 2012).

In his paper published Schmidt (2014) discussed the importance of de-risking approach for developing economies where low-carbon investment suffer from high risks. Also in these countries the investment risks are typically higher then in other countries.

In parallel to this research and work with stakeholders, quantitative estimations were conducted on impacts of subjectively perceived risk on the levelized costs of electricity (LCOE) from concentrated solar power (CSP). For this research a standard LCOE model, which received name MARGE, was developed by Williges et al., 2011. The results showed that risk aversion increases the costs of LCOE from CSP. It also delays the time of cost parity of LCOE with fossil fuel technologies. Risk perceptions are leading to different internal rates of return (IRR), expected by stakeholders for invested capital. This research included scenarios for IRR between 5% and 20%. The development of scenarios was based on interviews with FDI investors about expected IRR. The modeling efforts showed that 5% scenario, which is potentially feasible for purely public investment, will make CSP competitive with privately developed coal power in about ten year period. At higher IRRs, the cost competitiveness of CSP will be pushed back by twenty years (Komendantova et al., 2011).

The same study also identified the volumes of subsidies, which will be needed to make CSP cost competitive with coal. The study is based on the following assumptions: the price of coal – fired power plants will remain constant at its current price of 4.5 Euro cents / kWh, the carbon price will drop to zero and the technology costs would fall by 15% with each doubling of capacity installed. Under this baseline scenario CSP will reach cost parity with coal by 2035 after 255 GW of capacity being installed in the MENA region. The total discounted investment will make 210 billion Euro and the volumes of required subsidies will be 65 billion Euro. Dependently on the internal rate of return (IRR) for CSP projects, the range of subsidies will vary between 3 billion Euro with IRR of 0% to almost 238 billion Euro with IRR of 20% (Williges et al., 2010; Komendantova et al., 2011).

The work on impacts of risk aversion was conducted not only for CSP but also for other kinds of solar electricity, namely, photovoltaic (PV). Ondraczek et al., (2015) mapped the costs of solar PV globally using data for solar PV systems in 143 countries, also including the MENA region. The calculations were based on the standardized LCOE model and took into account the differences in solar resources and the differences in financing costs. The modeling allowed developing of two different sets of results. The first one showed the effects of solar irradiance on LCOE, namely, that in countries with solar irradiance above global average (1,862 kWh/m²/a) the LCOE was significantly lower then in countries with solar irradiance below global average. The second set of results showed impacts of weighted average costs of capital (WACC) on LCOE, namely, in countries where WACC was above the uniform rate of 6.4% LCOE was higher and in countries where it was lower the uniform rate LCOE was also lower.

To address further the topic of the need for de-risking approach, Schinko and Komendantova (2016) researched the impacts of different categories of risk investment on risk aversion of FDI investors and on financing costs for CSP in the MENA region. They applied the financing cost waterfall approach (UNDP, 2013) to quantify different categories of investment risk and to identify financing cost gap between developing region and a reference investment environment. The researchers also applied a standardized LCOE model and found out that the WACC for Algeria and Egypt is 8.3% and of Morocco and Tunisia is even higher of 9.2% comparatively to existing 4% in Europe. The results show that even though the solar resources in North Africa are significantly higher then in Europe, WACC impacts significantly LCOE in North African countries, which is almost equal to LCOE in Europe, where solar resources are not so high but the financing costs are significantly lower. Further sensitivity analysis showed that if WACC in North Africa was the same to Europe, the LCOE would be reduced by 32%.

From the point of view of governance, some studies looked at the governance approach needed to implement de-risking. For instance, UNDP (2014) report looked at the possibilities of de-risking in Tunisia and necessary governance interventions to create favourable investment environment for deployment of solar PV projects. Under de-risking approach the report understands financial and policy de-risking, with the latter addressing such governance risks as complex bureaucratic procedures and intransparency. Among measures of policy de-risking the report mentions streamlining of permitting procedures, improved operation and maintenance skills and long-term renewable energy targets. The authors find that public de-risking measures can catalyse 935 million Euro private sector investment and to create the overall savings for Tunisia of 359 million Euro over 20 years due to the application of the de-risking approach. The costs of the de-risking measures are estimated to be 145 million Euro until 2030 or 8.5 million Euro per year (UNDP, 2014).

Carafa et al., (2016) performed analysis of the de-risking aspects of policies in the MENA region and measured their impact on the costs of RES projects. They also explored the importance of domestic and regional multilateral governance structures to de-risk clean energy investment in Morocco. They find, on example of Morocco, that policy de-risking, which is intended at risk reduction, and financial de-risking, which is intended at risk transfer to other parties, depend on three interlinked factors, such as clear policy commitment from the government to develop solar capacities, available institutional capacities to transform political commitment into concrete projects and strong commitment of multilateral concessional finance.

Frisari and Stadelmann (2015) looked at the economic feasibility of CSP in India and Morocco and possibilities for de-risking measures implemented by international financial institutions. They highlight the leading role of public financial institutions in de-risking CSP by providing concessional loans in countries where public or private financing would be too expensive.

However, all these works looked at de-risking of one particular technology, in most cases CSP. These works also did not discuss over spillover effects from implementation of the de-risking approach neither the effects on welfare and GDP.

3. Methods

3.1. Modelling framework

For the macroeconomic assessment we employ a Computable General Equilibrium (CGE) model, which is based on Bednar-Friedl et al., (2012) and Schinko et al., (2014). The CGE model is programmed and implemented in MPSGE (mathematical programming system for general equilibrium analysis) (Rutherford, 1999), a subsystem of GAMS (general algebraic modelling system) (Rosenthal, 2013). Algebraically, the model is set up as MCP (mixed complementary problem), which is numerically solved by employing the PATH solver (Ferris and Munson, 2000).

Figure 1 illustrates the diagrammatic structure of the CGE model (for a detailed algebraic overview and information on the applied elasticities of substitution see Schinko, 2015). We assume perfect commodity and factor markets. The model comprises three classes of primary factors, which are assumed to be mobile within each region *r* but not internationally mobile:

- Labor L_r, which includes skilled and unskilled labour,
- Capital K_r and
- Resource-specific primary factors $R_{reu,r}$, each used exclusively in one of the five extraction sectors *reu*

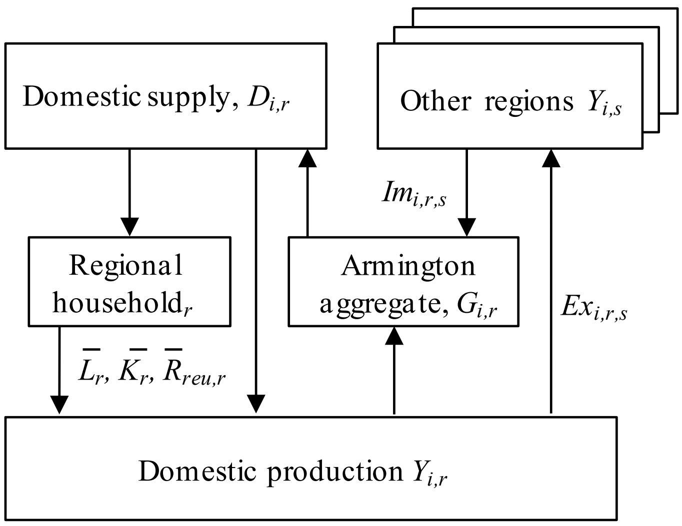

Figure 1: Diagrammatic model structure

Source: Schinko, 2014

Producer behaviour is characterised by profit maximization. For each domestic production sector *Yi,r*, the production technology of a representative producer is described by a multi-level nested constant elasticity of substitution (CES) production function. We implement different

CES nesting structures according to the respective production techniques and factor and input substitution possibilities of the different production sectors *i* (see Schinko, 2015 for the specifics of the employed nested CES functions).

Following the Armington trade assumption (Armington 1969), goods of the same variety but produced in different regions are not perfectly substitutable. As visualized in Figure 1, the Armington aggregation activity $G_{i,r}$ corresponds to a CES composite of domestic output and imported goods $IM_{i,r}$ as imperfect substitutes. The resulting Armington supply $G_{i,r}$ enters the domestic supply $D_{i,r}$ satisfying final demand and intermediate demand in production activities. The domestic output is exported to satisfy the import demand of other regions $X_{i,r}$. Further, the imports of any particular model region consist of imports from all other model regions, traded off at a constant but sectorally differentiated elasticity of substitution.

The “Regional Household” is an aggregate of private households and the public sector and thus represents total final demand in each region *r*. It provides the primary factors capital K_r, labour L_r, and natural resources R_r to the domestic production sectors, and receives total income including various tax revenues. The regional household redistributes this stream of income between the private household and the government for private consumption and public goods provision, respectively.

3.2. Data

The data for electricity costs are derived from the LCOE model, developed by Schinko and Komendantova (2016) for the North African countries of Algeria, Egypt, Morocco and Tunisia (see the Supplementary Material for an algebraic formulation of the LCOE model). The shares of specific cost components in LCOE from CSP are employed to derive the unit of cost production function for CSP power generation. Further on, we add a mark-up to the capital input cost of the CSP technology to account for the differences in the current region specific electricity price for conventional electricity sources and for results of calculated electricity costs for CSP.

By changing the WACC, which is a part of CSP investment costs, we can integrate risk perceptions of investors (see the Supplementary Material for an algebraic formulation of the WACC). WACC integrates the internal rate of return (IRR), which is closely connected with subjective perceptions of risks by investors. Namely, the higher is perceived likelihood and seriousness of concern about a particular type of risk or a number of risks for a particular project, technology or region, the higher will be expected IRR, which is perceived as a compensation for a higher risk. The lower perceived risk translates into lower WACC and the higher perceived risk translates into a higher WACC. The investment costs, calculation of LCOE and WACC are derived from Schinko and Komendantova (2016).

Economic data are derived from the GTAP8.1 database (Narayanan et al., 2012), which includes detailed national accounts on production and consumption together with bilateral trade flows for the base year 2004 and 2007. The data on international energy markets are derived from the database of the International Energy Agency energy volume balances and converted into monetary values as well as on energy related CO_2 emissions (Lee, 2008). The data on the real GDP growth rates and fossil fuel prices for the year 2020 are derived from the World Energy Outlook 2009 reference scenario (OECD / IEA, 2009).

On the regional level, the model differentiates between four North African countries (Algeria, Egypt, Morocco and Tunisia) and five other world regions (Rest of Africa and Middle East, Europe, North America and South America, Asia, Rest of the world) that are linked through bilateral trade flows. On the sectoral level data are collected for 15 economic sectors such as:

- Primary energy sectors (crude oil, coal and natural gas)

- Secondary (refined oil products, electricity comprising of conventional electricity and CSP)
- Energy intensive and trade exposed sectors (iron and steel, non-metallic mineral products, paper and pulp, chemical products)
- Other industries and services (extraction and mining, transport (air, water and other transport), agriculture, non-energy intensive sectors, food and textile industries, services and utilities, capital goods)

3.3. Scenario assumptions

We consider a scenario with a uniform CSP target for the four North African countries amounting to 5% of total electricity production by 2020[1]. Furthermore we assume that these countries, as well as all other model regions, do not implement any other climate change mitigation policies such as carbon taxes or a cap and trade scheme. We assume technological improvements for solar tower CSP plants by 2020 in terms of capital costs being reduced by 28% (Hinkley et al., 2011), and O&M costs by 23% (Turchy et al., 2010).

By applying the CGE model presented above we analyze (1) the required subsidies for CSP power generation to achieve cost competitiveness with conventional technologies in the year 2020, given the respective level of financial de-risking and (2) the implications of de-risking CSP investments on GDP and welfare after taking into account macroeconomic feedback effects. We conduct a comparative static CGE analysis of hypothetical CSP goals in the MENA region. The results would not change qualitatively if we modeled e.g. 2030, since we only upscale the economy using GDP growth rates from the literature.

The targets for the implementation of CSP projects in the North African region are very different across the four case study countries. However, to make macroeconomic effects of a de-risking approach to CSP investments across specific North African countries comparable, we use a uniform CSP target in the CGE simulation amounting to 5% of total electricity production by 2020.

We are aware that this modelling exercise has two limitations, which are important to be highlighted at this point. The first one is that we assume the implementation of a de-risking strategy is cost neutral. The second one is that we assess the macroeconomic effects of the implementation of the de-risking approach as such, without identification of impacts and benefits from separate de-risking measures. These both questions were beyond the scope of this research and it will be certainly worth to address these questions in future research works.

5. Results

Our results results allow for an identification of impacts of different levels of de-risking on subsidies required for CSP electricity. Figure 2 shows cost competitiveness trajectories for a 5% CSP target in total electricity production by 2020 in four MENA countries. These trajectories indicate the required level of CSP subsidy (in USD2007/tCO_2) for the price of electricity from CSP to brake-even with the price of conventional electricity, given the level of financial de-risking. The level of financial de-risking (X axis in Figure 2) indicates the percentage reduction in the financing cost gap between the MENA countries and European reference financing costs. A level of 100% would imply that a mix of de-risking policy instruments has been set in place by the governments that would eventually lead to a convergence of financing costs in the MENA countries and the European Union as our reference case. As mentioned before, in our modelling exercise we do not consider explicit policy instruments but rather assume that policy makers put instruments in place that can later be determined to have led to a de-risking of a certain level.

We find that for each of the four countries (Algeria, Egypt, Morocco and Tunisia) the required subsidy for CSP to make it cost competitive with conventional electricity will be the highest for the case of pre-de-risking financing costs, namely, with a 0% level of financial de-risking (see Figure 3). Subsidies will also have to cover increased volumes of risk premiums, which will be required in case of pre-derisking by private investors to cover the risk for privately financed CSP power stations.

Several factors are playing a role in the reduction of the costs of CSP. Based on the learning rate for CSP technology deployment, we assume that capital costs can be reduced by 28% due to technological improvements (Hinkley et al., 2011). The costs of operation and maintenance could be reduced by 23% (Turchy et al., 2010). As previous research, conducted by Schinko and Komendantova (2016), showed with a de-risking strategy it would be possible to reduce the LCOE of electricity from CSP by 32%. This will be mainly possible through reduction of risk premiums and further reduction of costs of capital. However, even then subsidies will still be needed to make CSP cost competitive with fossil fuels in some MENA countries.

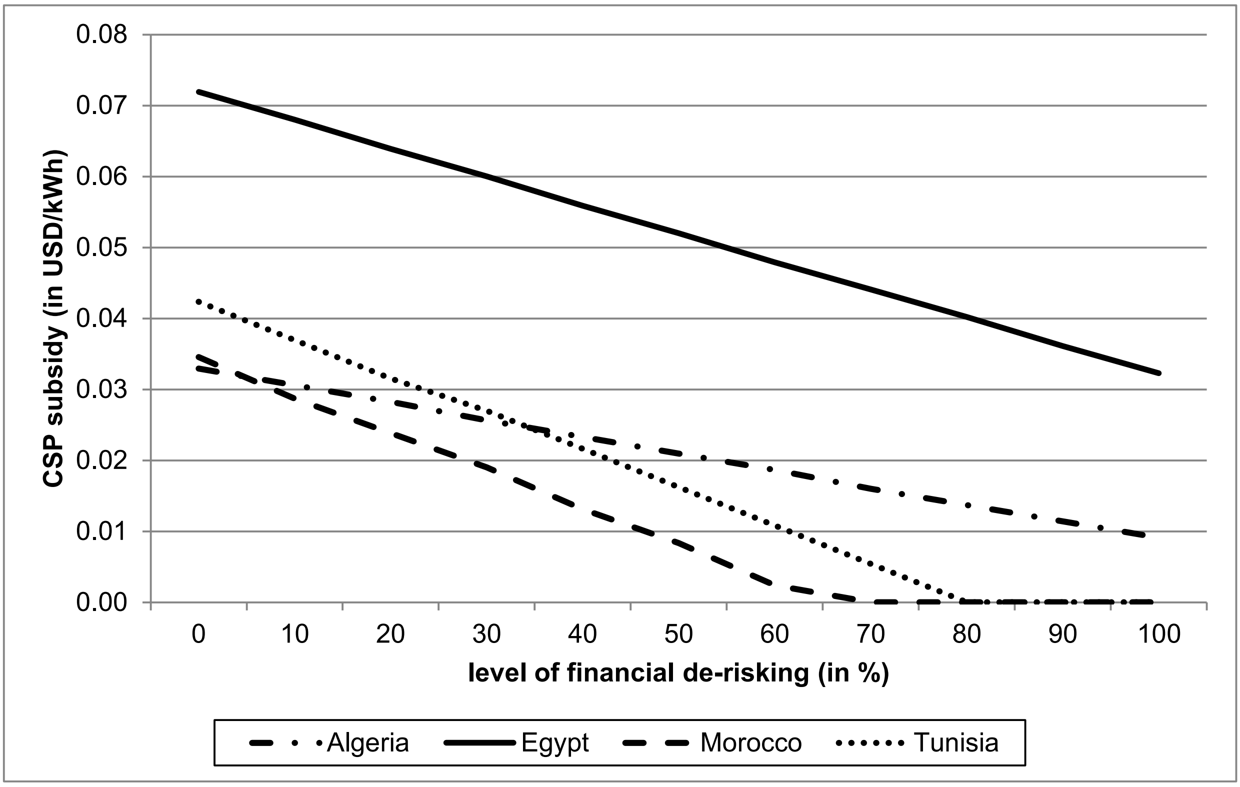

Figure 2: Impacts of de-risking on required CSP subsidies

While the required subsidy for CSP in Egypt decreases from $ 0.072 /kWh to $ 0.032 /kWh along the cost competitiveness trajectory depicted in Figure 2, CSP production in Morocco does not require subsidies to reach a break-even as soon as an 70% level of financial de-risking can be achieved. The same holds true for 80% financial de-risking of CSP investments in Tunisia, i.e. fully closing the financing cost gap between the MENA region and a European reference financing cost environment. Algeria, whose cost competitiveness trajectory starts below the ones from Morocco and Tunisia, still has to pay a subsidy of 0.009 USD/kWh to their CSP electricity producers in order to level the playing field. The slope of the trajectory as well as the absolute level of the required subsidies depends on the initial price differential of CSP and conventional electricity, which is reflected in the unit cost functions of the CSP technology in four countries. The two countries with relatively higher cost gaps, Egypt and Algeria, require a positive subsidy throughout the cost competitiveness trajectory. The two countries with the relatively lower initial cost gaps, Morocco and Tunisia, do not only require lower subsidy rates throughout the cost competitiveness trajectory but can even achieve cost competitiveness of CSP without having to pay subsidies, if the perceived risks of investment and in turn financing costs can be sufficiently reduced (by 70% in Morocco and by 80% in Tunisia).

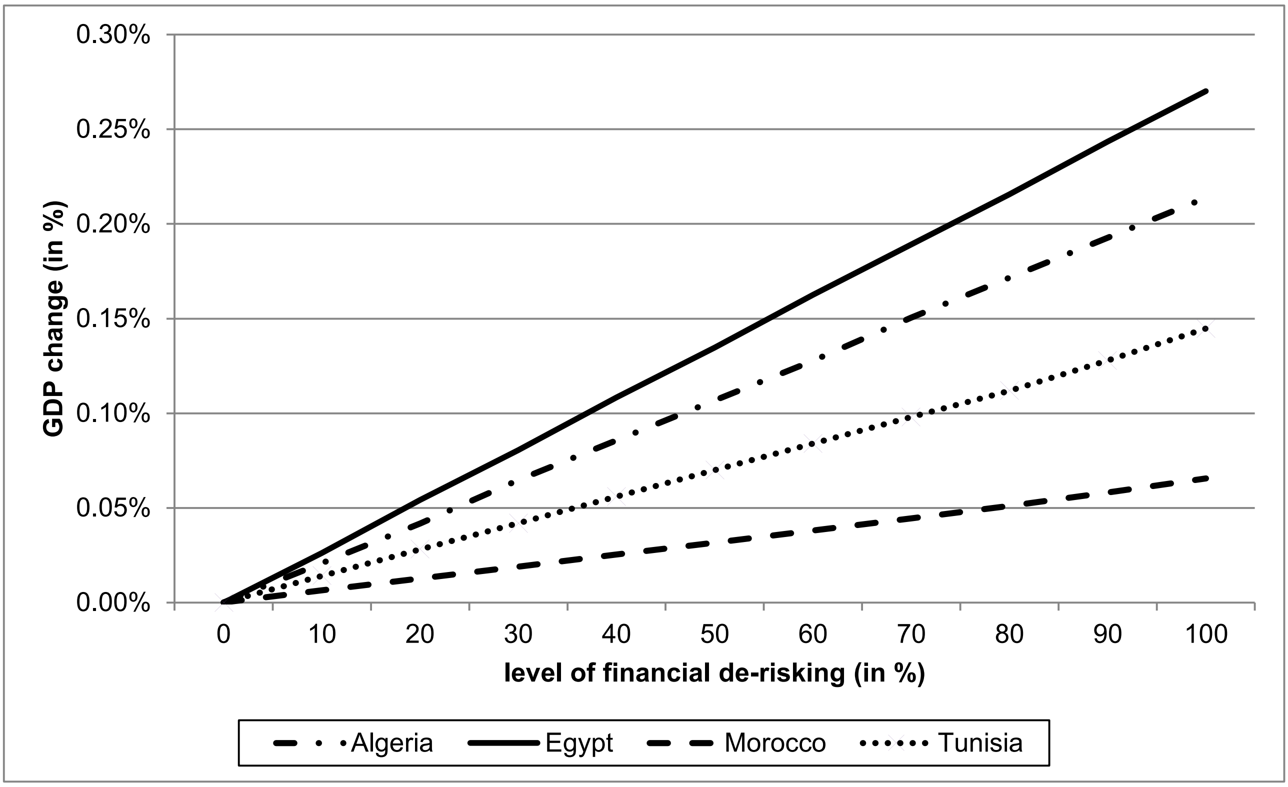

Figure 3: GDP gains along the cost competitiveness trajectories for a 5% CSP target in total electricity production by 2020 across North African countries

Figure 3 shows the net economy wide gains in terms of GDP increases that go hand in hand with increasing levels of de-risking (i.e. a reduction in financing costs). The economics rationale behind this trajectory is twofold. First, de-risking will directly lead to a reduced level of subsidies needed for CSP to become cost competitive with fossil fuel based electricity generation. The freed up amount of public budget can now be used for productive investments or the increased provision of public goods, both driving up GDP. Second, de-risking will also lead to a decrease in the overall costs of electricity. This cost reduction in one of the key input factors for production sectors as well as final demand indirectly leads to higher output in other economic sectors, translating into further overall economic benefits in terms of GDP gains for countries hosting CSP projects.

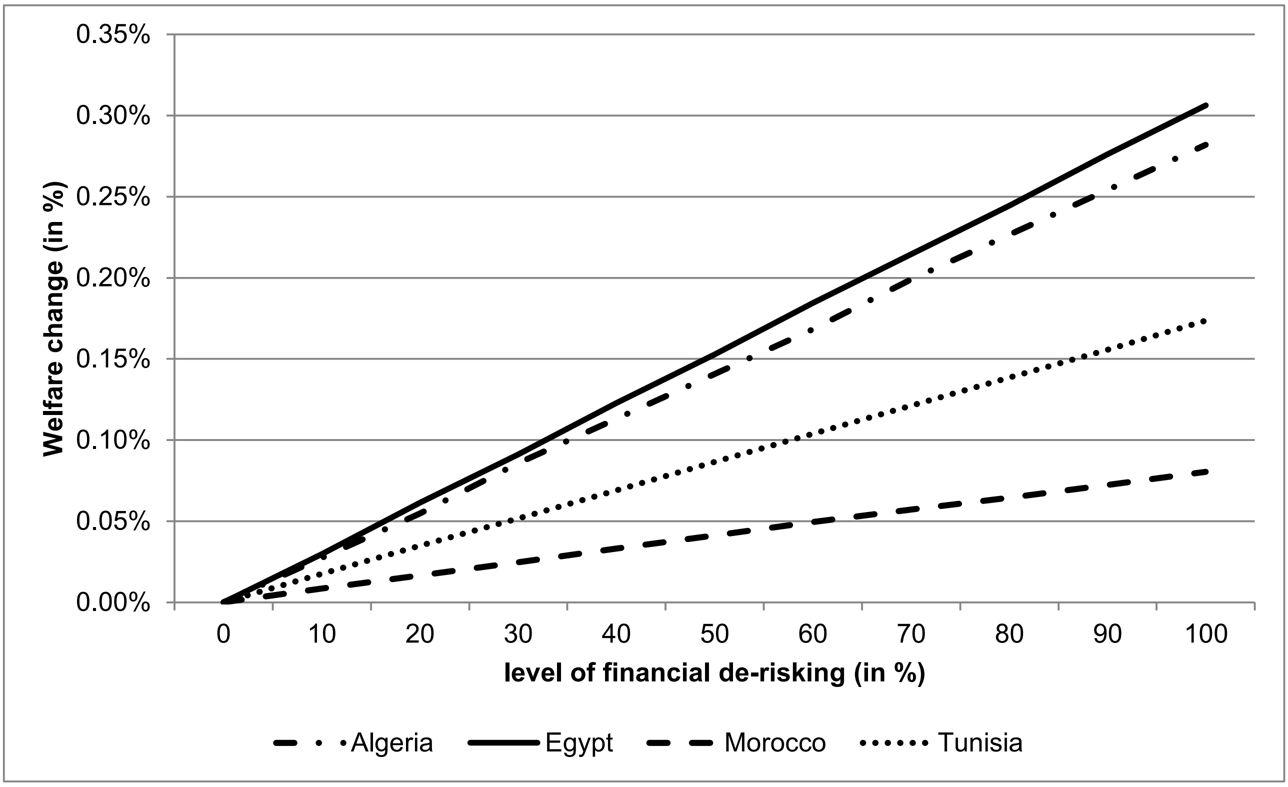

Figure 4: Welfare gains (expressed in terms of Hicksian equivalent variation) along the cost competitiveness trajectories for a 5% CSP target in total electricity production by 2020 across North African countries.

In addition to overall GDP effects, Figure 4 shows welfare gains expressed in terms of consumption possibilities by private households (i.e. the Hicksian equivalent variation), which are again presented relative to the pre de-risking financing cost situation along the cost competitiveness trajectories for a 5% CSP target in total electricity production by 2020 across the four North African countries. We find a linear trend for GDP and welfare increases along the pathway to a 100% financial de-risking scenario, i.e. a situation in which North African countries are assumed to be subject to the same financing costs as in Europe. The linearity of results is determined by the underlying linear de-risking function; future research could delve into more sophisticated parameterizations for those. At the point of full financial de-risking, welfare increases by 0.08% (Morocco), 0.17% (Tunisia), 0.28% (Algeria), and 0.31% (Egypt) while GDP increases slightly less, namely by 0.07% (Morocco), 0.14% (Tunisia), 0.21% (Algeria), and 0.27% (Egypt). Again, the country differences depend on the initial price differential of CSP and conventional electricity, which is driven partly by the respective investment risks and partly by the respective level of (subsidized) conventional electricity prices.

In a comprehensive sensitivity analysis we identified the CSP target and the assumed technological progress by 2020, more specifically progress in terms of reduced investment costs, as the most influential parameters on our results. While a change (halving or doubling) in the CSP target mainly influences the potential welfare and GDP gains along the cost competitive trajectories, a similar halving or doubling of the potential investment cost reduction due to technological improvements may have considerable implications on the trajectory of required CSP subsidies in addition to financial de-risking (see Figures SM1-SM9 in the Supplementary Material for detailed sensitivity analysis results). Even though variations in these critical parameters may change our model results in quantitative terms (e.g. the levels of financial de-risking at which CSP becomes cost competitive with conventional electricity generation the four MENA countries), this does not change our results in qualitative terms (e.g. the relationship between the level of financial de-risking and welfare and GDP gains, or the relative performances of the four MENA countries).

6. Conclusion and Policy Implications

Evidence shows that currently high initial costs of investment are the major barrier for further deployment of RES, even despite favourable geographic conditions in several regions like the Middle East and North African region. These initial costs of investment are driven by both existing objective risks but also by subjective risks, namely, risk perceptions, which are often influenced by cognitive or behavioural biases. Several existing studies in energy policy research are addressing objective risks and are evaluating different measures how these risks could be mitigated. However, research on subjective risks is less prominent. Currently it was mainly conducted in frames of discussions about the de-risking approach.

Under de-risking approach we understand a portfolio of measures to address different kinds of risks, such as regulatory, political, revenue and market, technical, force majeure, financial, construction, operating and environmental risks. As the nature of these risks is different, so the de-risking measures needed to address them will vary also and will include long-term energy policies and support schemes, as well as the establishment of harmonized, unbundled and well-regulated energy market. The de-risking approach also includes the reduction of bureaucratic complexity, streamlining of permitting and licensing procedures, establishment of contract enforcement and recourse mechanisms or establishment of long term offtake agreements with municipalities or local companies to reduce revenue risks, full service of long-term operation and management contracts with prime contractors or manufacturers of equipment to transfer technical risk.

In this paper we evaluate potentials of a de-risking approach in a case study of large-scale CSP projects in the MENA region. We select this particular case mainly because CSP is a relatively new technology and because it is connected with especially high costs of initial investment. Also, previous research identified that perceived risk, connected with complex bureaucratic procedures and regulatory barriers, was a crucial determinant of economic feasibility for CSP projects when investors required higher risk premiums due to uncertainties in the administrative processes.

In order to be attractive for people in the MENA countries, CSP has to become cost competitive with other available electricity generation options and eventually with the current market prices for electricity, which both are currently highly subsidised in the region. Our earlier results showed that implementation of a de-risking approach will lead to significant reductions of LCOE for electricity generated from CSP. However, even the most comprehensive de-risking measures will only lead to a 32% reduction in LCOE on average across the region. This does increase price competitiveness of CSP in comparison to fossil fuel based electricity generation technologies but still does not make it fully competitive as long as subsidies for fossil fuels in the region continue to exist (Schinko and Komendantova, 2016).

This means that subsidies will be needed to make CSP fully cost competitive with fossil fuels. The results of this paper show that de-risking of CSP investment in combination with technological progress and RES-E subsidies as well as energy policy measures to address objective risks can lead to cost parity between CSP electricity generation and conventional fossil fuel based technologies.

Further on, we add to the current state of the literature by moving beyond a partial equilibrium or single sector LCOE assessment (such as e.g. conducted by Schinko and Komendantova, 2016). By employing a macroeconomic Computable General Equilibrium (CGE) model we were able to assess the follow-on economy-wide effects of a de-risking approach to RES-E investments in the MENA region. The costs connected with the implementation of energy policy measures to address risks for investment and to make CSP cost competitive with fossil fuels, such as subsidies, can be compensated with overall positive macroeconomic spillover effects and GDP gains. For instance, the implementation of de-risking approach will reduce the required volumes of financial support, which otherwise would be needed to cover high-risk premiums, expected by risk averse investors. This reduction in required financial support for CSP electricity in turn translates into economic benefits across the four North African countries of on average up to 0.15%, or 327 million USD, GDP increase in 2020. Therefore, our research shows that addressing perceived risks by investors will eventually have overall positive economic effects and potential macro-economic benefits.

These results are, of course, dependent on existing subsidies structure in a country as well as the legal and political systems. The higher the volumes of existing fossil fuels subsidies, the more intensive should then de-risking measures be. For instance, in fossil fuel poor countries like Morocco and Tunisia even 80% de-risking measures will be sufficient. At the same time as in fossil fuel producing countries, which are also heavily subsidising fossil fuel production, like Egypt and Algeria, a 100% de-risking will be required. Given the difference in legal and political systems of each of North African countries, it is crucial to evaluate effectiveness of each de-risking measure under conditions of each concrete country. If one de-risking policy is put in place e.g. in Morocco, and the same policy in place in Egypt, would it achieve the same level of de-risking in both countries? Questions like these require further research, especially case studies would be recommendable.

These results are also dependent on the costs associated with a financial de-risking approach and the costs of implementation of necessary public policy and private risk mitigation measures. Hence, the GDP and welfare gains along the cost competitive trajectories can be regarded as the upper limit for policy implementation costs. If this limit is not exceeded, a financial de-risking strategy can be achieved without net economic costs. However, in addition to the direct effects of a financial de-risking strategy on CSP investments, which we explicitly analyze in this study, there will be de-risking spillover effects for other renewable energy and infrastructure investments in the MENA region, leading to further economic benefits in these sectors and to even higher net economic benefits than obtained in our macroeconomic analysis. Therefore, our results represent conservative estimates for potential macroeconomic benefits of a financial de-risking strategy. Because of these indirect effects and since we have shown that reducing perceived risks and hence the cost of capital will have a substantial impact on LCOE for CSP plants in the North African region, we argue that the costs of achieving this goal will likely stay below the economic benefits.

Taken into consideration that high initial investment costs are one of the major barriers for deployment of RES-E technologies, such as CSP, and that these costs are driven by investment risks pushing up the costs of capital, a de-risking strategy can become a powerful policy option. High investment risks are also decreasing competitiveness of RES vis-à-vis fossil fuels (Schmidt, 2014). Our results allow developing two recommendations for energy policy targeting deployment of renewable energy sources.

The first one is that implementation of the de-risking approach can address subjective risk perceptions of private investors. This, in turn, will allow a reduction of required subsidies for RES, and especially so capital-intensive technologies as CSP, to achieve cost competitiveness with fossil fuels. This will happen because less subsidies will be needed to cover high risk premiums. In some countries, mainly dependent on energy imports, implementation of de-risking approach can even make RES-E cost competitive with fossil fuel based electricity generation without further support for RES-E.

The second recommendation is that funds, which would have been spent for subsidies to support deployment of RES, could then be spent for other welfare generating economic activities and create additional spillover and multiplier effects on local and national economies. De-risking approach can also become an energy policy instrument to stimulate climate change mitigation as it can potentially reduce investment costs for low carbon electricity generation and hence of climate change mitigation measures. If we consider that the goals of energy policy on necessary infrastructure investment to reach the rising global energy demand would require US$37 trillion by 2035 (IEA, 2014), a part of this investment can be compensated with the economy-wide benefits from the implementation of a de-risking approach. The de-risking approach can also be regarded a low hanging fruit for energy policy, as it does not require substantial behavioural change from the side of energy consumers. It rather targets energy producers and through its long term, mainly policy related measures (such as streamlining of permitting procedures) it allows investors to gain trust.

Further research, as in line with recommendations of Carafa et al., (2016) is needed to understand how policy de-risking could be implemented in developing countries, namely, through policy commitments to development of RES, or through improvement of domestic institutional capacities for realisation of these commitments, or how international concessional financing institutions can contribute to implementation of de-risking approach. Moreover, we suggest that further research is needed on how energy policy measures and improvement of institutions can be facilitated at the local governance level, as the actions of stakeholders at this level are frequently shaping the details of RES projects and their implementation.

The two recommendations presented above are following the line of recommendations to energy and climate policy on creation of attractive conditions for private low-carbon investments in developing countries. If we consider that there are two levers of climate policy where the first one is focused on an increase of returns of low-carbon investment and the second one is focused on a decrease of downside risk of low-carbon investments, or de-risking, the majority of the past and current climate policy instruments are focusing on an increase of returns of low-carbon investment (Schmidt, 2014). Our results also show the need for future energy and climate policies to focus on decrease of downside risks in low-carbon investment. Therefore, the implementation of the de-risking approach in the energy policy can become a powerful policy tool to redirect investment from high to low-carbon technologies. This implementation would require the removal of barriers in investment environment and an improvement of local institutions, which will allow reduction of the likelihood of risk for investment into low-carbon technologies.

7. References

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