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Environmental Mitigation Scenarios of GHGs Emissions: Analysis for Saudi Arabia

REEMA GHAZI ALAJMI
A PhD student at Swansea University, economic department.
Email: rajmi.2010@hotmail.com
Tel: 00447459762658

Abstract

This paper evaluates the efficiency of environmental reduction policies in terms of their impact on the Saudi economy and environmental quality. It explores the future trends of environmental pollution in Saudi Arabia, through analysis efficiency of the environmental mitigation policies. This is done by employing mitigation scenarios for two models: CO2 model and other GHG model. Firstly, the VECM approach is employed to estimate the relationship between economic growth and GHGs emissions from 1981-2010, and then the mitigation scenarios including business as usual scenario examine the future trends of this relationship over the period of 2011-2030 in Saudi Arabia. The results of the two models showed that cuts to CO2 emissions and other GHG emissions by 5% and 0.05% will decrease the GDP of Saudi Arabia. However, Saudi Arabian policymakers have to choose appropriate environmental reduction policies to avoid the impacts of these policies on GDP and focus on adopting smart growth to draw appropriate future plans that could support the country to reach sustainable development.

Key Words: *VECM, Environmental Policies, Mitigation Scenarios, CO2 Emissions; Other GHGS Emissions.*

Introduction

Scientists consider that the increase in the Earth's temperature will lead to lagged effects, such as changes in vegetation and in hydrological patterns and sea levels (Ansuategi and Escapa, 2002). Therefore, in the last few years the necessity of climate protection has been highlighted by the many environmental policies, environmental management and emission scenarios to protect the Earth and the life on this planet. These environmental policies are concerned with achieving sound environmental performance by controlling and identifying the effects of human activities and services on environment quality. Thus, policies of improving energy efficiency on both sides of demand and supply, if applied on a large scale, could reduce negative emissions and help the transition to a global economy which has low emissions of greenhouse gases (UNEP, 2012).

Environmental policies aim to reduce pollution through employing environmental instruments. Thus, to estimate these policy tools empirically, wide mitigation emissions scenarios have been developed, such as SRES[1] storyline families created by the Intergovernmental Panel on Climate Change (IPCC) in 1992 to

[1] Special Report on Emissions Scenarios describes the new scenarios, how they were developed and includes the main driving forces of future emissions, from demographic, technological and economic developments (Nakic´enovic et al., 2000).

develop emissions scenarios for global models. In addition to these scenarios, other econometric tests have explored the future of greenhouse gases emissions and environmental degradation. Forecasting GHG emissions and evaluating future environmental degradation is important for policymakers but this is not simple as predicting future scenarios is affected by social, policy and economic factors that change over time (Anderson, Fergusson and Valsecchi, 2008). However, scenarios and forecasting of environmental pollution have become more important in order to support policymakers to make a decision on the future of climate change. So, there are many researches and studies that have discussed and investigated these policies and scenarios.

This study aims to develop mitigation scenarios for Saudi Arabia in an attempt to explore the future trends of pollution and evaluate the efficiency of the reduction policies, which could support policymakers in Saudi Arabia to improve environmental quality and achieve sustainable development in the future.

The rest of this paper is organised as follows: Section (2) provides the literature review on environmental policy. Section (3) provides an overview of environmental policies in Saudi Arabia. Section (4) presents the methodology of this study. Finally, Sections (5) and (6) of this study provide the empirical findings estimation of environmental policies and the conclusion, respectively.

Related Literature

IPCC (2007) provided a view to reduce global emissions by holding the increase in global temperature below 2 degrees Celsius for the next two decades as projected by a range of SRES[2] emissions scenarios. Since 2010, UNEP has published a series of reports on the emissions gap to meet the two degrees Celsius climate target. Global emissions in 2030 must return to around their 1990s level and global emissions in 2050 have to be 40% below 1990 levels (UNEP, 2012). The Paris agreement entered into force on 4 November 2016 aiming to keep a global temperature rise this century below 2°C above pre-industrial levels by strengthening the universal reaction to the threat of climate change and pursuing efforts to limit the temperature increase even further to 1.5°C (UNFCCC, 2016).

The challenge that faces climate policy is to find an efficient mix between these two strategies in order to limit the general effects of climate change (Tubiello, 2012). This leads us to another question: how can the countries reduce the environmental pollution or how can the regions achieve the 2 degree Celsius climate target?

The two main forms of government intervention are command-and-control or conventional approach and market-based or economic incentive instruments to reduce GHGs emissions. This paper focuses on mitigation scenarios; there are myriad of mitigation scenarios developed to explore GHGs emissions future. Starting with a definition, a scenario is "a story, told in words and numbers, concerning the manner in which future events could unfold; analysis of a range of scenarios offers lessons on how to direct the flow of events towards sustainable pathways and away from unsustainable ones" (Raskin and Kemp-Benedict, 2004, p. 2).

In 1990 and 1992 the long-run emissions scenarios were developed by the Intergovernmental Panel on Climate Change (IPCC) to diminish climate change. These scenarios are an appropriate tool to unfold and analyse the future emission outcomes and to assess the associated uncertainties. The scenarios include four main storyline "families" namely; A1, A2, B1 and B2 which cover a wide range of economic and social developments, technological change, and demographic change driving forces of sulfur and GHG emissions.

[2] Special Report on Emissions Scenarios describes the new scenarios, how they were developed and include a range of the main driving forces of future emissions, from demographic, technological and economic developments (Nakic´enovic et al., 2000).

Each storyline has different models which have similar assumptions of driving forces, thus there are 40 Special Report on Emissions Scenarios (SRES) (see Nakićenović,et al., 2000, Figure: 1, p. 4). The A1 storyline and scenario family describe the technological change, the A2 storyline and scenario family reflect a more heterogeneous world, the B1 storyline and scenario family are convergent and oriented toward the environmental preservation world and the B2 storyline and scenario family are more ecologically-oriented but divided world (Anderson, Fergusson and Valsecchi, 2008). However, Girod, et al. (2009) evaluated the IPCC's emissions scenarios and stated that the IPCC's scenarios have changed over time. Thus, they propose future scenarios that review classification practices, scenario labelling and more formal qualitative construction paths.

In terms of employing these scenarios, some countries set out emissions reduction scenarios, for example, the new cumulative emissions scenarios for China to 2050 and 2100, which are partly based on the Tyndall Centre for Climate Change Research methods that have been developed. Also, four scenarios were developed by a number of organisations in China and the UK, setting their storylines to contain technologies change, industrial structure and economic development trends (Wang and Watson, 2008). Nordhaus (1993) investigated empirically two policies; the tax policy and GHG reduction policy in different scenarios. The study findings were that green taxes policy is more efficient than emissions cuts in terms of controlling emissions rate. Bühler and Jochem (2008) tested empirically two policy instruments to reduce CO_2 emissions in the transport sector in Germany. The first policy tool is to charge road users and the second policy is to improve the railway network to increase the speed of transport services. The results were that the impact of these two policies was small on decreasing CO_2 emissions from 1% to 4%. Also, Zhao (2010) studied empirically how CO_2 emissions cuts affect income for 23 OECD countries over the period 1980 to 2004. He forecasted the relationship between CO_2 emissions cuts and income for four years; 2020, 2030, 2040 and 2050. The findings showed that cuts of CO_2 emissions of 50% by 2050 reduced GDP around 0.3 % meaning economic growth slowdown by 15%.

In contrast, Tucker (1995) examined GDP per capita and CO_2 emissions for 137 countries over the period 1971 to 1991. He stated that proposals of emissions reduction will not affect income adversely, especially for less developed countries. Also, he discussed some global solutions for global warming, such as selling and buying GHG reductions by countries, an international market in emissions permits, knowledge to effectively control emissions through global environmental organisations. Also, Shukla (2006) discussed GHG emission IPCC SRES scenarios for India over the 21^{st} century. The findings showed that regime tools should enhance climate-friendly actions and then support climate-centric actions. However, Paltsev et al. (2009) analysed the cost of GHG emissions reduction policy of 80 percent by 2050 in the United States using the MIT Emissions Prediction and Policy Analysis (EPPA) model and investigated three policy scenarios described by the allowable emissions: 287, 203 and 167 billions of metric tons (bmt). By 2050, a reduction of 80% changes economic welfare cost between 2- 3% and CO_2 prices increase in the range $190 and $266 compared with the prices between $48 and $67 in 2015.

Cai, et al. (2007) employed three scenarios of CO_2 reduction in China's electricity sector for 2030 using the year 2000 as a base. The scenarios results were that CO_2 emissions under the business as usual scenario will increase but with mitigation the reduction range could be from 4.2% to 19.4%. Similarity, Taseska, et al. (2011) employed two scenarios besides the business as usual scenarios over the period 2008-2025 for the Former Yugoslav Republic of Macedonia to reduce GHGs emissions in the power system, which is based on lignite. The first reduction scenario replaces lignite in electricity generation with two gas power plants. In the second mitigation scenario in addition to gas plants there is assumed a decrease in electricity consumption and increase in renewable energy sharing. The study findings showed that emissions in 2025 increase 78% from the baseline; emissions decrease to 41% in the first reduction scenario and in the second mitigation scenario emissions decrease to 14%.

For literature that discussed environmental policies for Arab regions, Gulf countries and Saudi Arabia, respectively will be summarized below.

Babacar (2004) highlighted the environmental policies tools in Arab countries. (1) The raise people awareness policy is absent in some Arab countries and it is ineffective in countries that have applied. (2) Institutional and legislative policies, despite a presence in many Arab countries, suffer from a lack of clarity and lack of effectiveness. (3) Regional and international treaties at the regional level: Arab countries adopt ambitious programs and plans to reduce pollution and develop the environmental sector, in addition to participating in several international conventions, such as the Basel Convention, the United Nations Framework Convention on Climate Change conference (UNFCCC), the Kyoto agreement, the Montreal treaty to protect the ozone and the United Nations Conference on Biodiversity. (4) For mitigation GHG emissions policy: the United Nations Economic and Social Commissions for Western Asia (ESCWA) presented at the Sustainable Development Conference in 2002 a proposal for development of the electricity sector in Arab countries. The electricity generation sector and the transportation sector are largely responsible for greenhouse gas emissions. This proposal includes the mitigation tools, such as expanding the use of natural gas and improving the production of electricity.

Wingqvist and Drakenberg (2010) briefed the environmental policy in their study about the Middle East and Northern Africa (MENA)[3] region that includes 18 countries. They stated that the implementation capacity of Multilateral Environmental Agreements and conventions remains insufficient, as is the coordination between authorities on the implementation of environmental laws. Also, they suggested raising people's awareness about environmental degradation, integrating between sectorial planning and climate change, and improving the regulation of preventing and reducing environmental pollution.

Moreover, the Arab countries are not prepared for climate change challenges and government policies are overdue in terms of support for low-carbon, coastal protection, promoting natural resources sustainable management and efficient goods and services (AFED, 2009)[4]. An empirical study by Khalid (2009) to estimate the effect of environmental pollution on economic welfare in Algeria was conducted through environmental policies. These policies were tax policy, subsidies policy, selection and prevention policy and state monopoly on the production of goods, which cause dangerous waste. The study findings showed that the pollution caused by industrial activity raises economic costs and the optimal policy is a combination of environmental policies.

A recent study that enhances technology as an environmental instrument by Farhani (2015) examined empirically the causal relationship in economic growth, renewable energy and CO_2 emissions in MENA countries. The results showed that renewable energy plays an important role in reducing CO_2 emissions in the short-run, and for long-run equilibrium, the error correction term (ECT) of renewable energy consumption was significant, which mean renewable energy may be a vital adjustment factor. Therefore, policymakers in MENA countries have to reinforce renewable energy and reduce CO_2 emissions.

An empirical study that examined the mitigation emissions scenarios for Saudi Arabia by Taher and Alhajjar (2014) employed abatement pollution policies for Saudi Arabia based on three different scenarios, over the period 2011-2030. The first scenario is the baseline scenario that assumes Saudi Arabia policymakers decrease CO_2 emissions by 1% in the future. The second scenario is the pessimistic scenario which supposes the policymaker undertakes lower pollution reduction by 0.65%. Then, the optimistic scenario which is ambitious abatement pollution with emissions cut by around 5%. Their findings showed that cutting emissions by 5% will reduce GDP by 0.075%, which is a better result compared with other

[3] Algeria, Bahrain, Egypt, Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Libya, Morocco, Oman, Qatar, Saudi Arabia, Syrian Arab Republic, Tunisia, United Arab Emirates, and Yemen.

[4] Arab Forum for Environment and Development.

scenarios. These results imply that the level of environmental pollution in Saudi Arabia is high because it is linked to rapid growth in the country, which means more pollution in the next decades. Then, they use their estimation of the three emissions reductions to forecast the real GDP in Saudi Arabia for the period 2011-2030. Thus, the results were that the under optimistic scenario for real GDP is forecast to increase from 904 billion SR in 2011 to 1.54 trillion SR in 2030, which is higher than real GDP in the baseline and pessimistic scenarios.

Overall, from the previous presentation of environmental policy in Arab regions, no studies discuss environmental mitigation scenarios for Saudi Arabia; in terms of other GHG emissions, only one study discussed mitigation emissions scenarios of Saudi Arabia. Thus, this paper will try to fill the gap in this area by employing mitigation scenarios for two types of GHGs emissions.

Environmental Policies in Saudi Arabia

This section will provide a brief introduction of environmental policy in Saudi Arabia. There are organizations and commissions in Saudi Arabia which are interested in protecting and maintaining the environment, such as the Saudi Arabian Presidency of Meteorology and Environment (PME). Also, the country has signed and ratified thirty-seven agreements, treaties and international protocols relating to regional and sustainable development, thirty one of them are international agreements and the rest are regional agreements (PME, 2011). Also, Saudi Arabia has a penalties system, when the Presidency of Metrology and Environment ensures that an environmental standard has been violated, it requires the violators to remove and address the environmental impact caused by their activities and report on how to prevent a recurrence of such violation in the future.

Moreover, Saudi Arabia has taken several initiatives to protect the environment: 1. the preservation of energy by reduction load of electrical power demand. 2. Established the Centre of Research Excellence in Renewable Energy. 3. Cogeneration projects. 4. Greening urban areas, building energy efficient infrastructures and waste management. 5. Campaigns of awareness. 6. Environmental inspectors. 7. Atomic and Renewable Energy center. 8. Build scientific and technical bases (Rahman and Khondaker, 2012). According to The Canadian Trade Commissioner Service (2012), Green Police and PME were created as Environmental Inspectors to improve the environmental performance in Saudi Arabia. King Abdullah City has a center for Atomic and Renewable Energy (KA-CARE) whilst another government initiative, in the environmental industry area, aims to build a scientific technical base in many fields: power generation, desalinated water production, industrial, agricultural, medical and mining.

The Canadian Trade Commissioner Service (2012) stated that the environmental industry expected to develop quickly in Saudi Arabia for two reasons, the strength of political support, and political and economic stability, which attract development projects and investments in infrastructure. Furthermore, the Saudi Presidency of Meteorology & Environment (PME) has a new environmental policy ensuring implementation of new law standards. Also, it recruited Environmental Inspectors and created Green Police. The Saudi Government adopted another environmental policy which is moving to renewable energy by establishing the King Abdullah City for Atomic and Renewable Energy in 2010. In 2002, the Council of Ministers developed the Environmental Technology Program to face many important environmental issues, such as pollution and air quality (KACST, 2008). In accordance with guidance of the United Nations Framework Convention on Climate Change (UNFCCC), the UNDP is helping the country to undertake the Second National Greenhouse Gas Inventory and to prepare a report for the Second National Communication to the Conference of Parties. Also, Saudi Arabia has spared no efforts to address global environmental issues such as climate change (UNDP, 2017).

The challenges that face the environmental sector in Saudi Arabia are related to a lack of knowledge in special areas of pollution, such as monitoring of the environment, analytical services and management of hazardous waste (Canadian Trade Commissioner Service, 2012). The Gulf Cooperation Council countries

(GCC): Saudi Arabia, Kuwait, Qatar, United Arab Emirates (UAE), Bahrain and Oman face some issues. (1) The aims of reducing GHG emissions in the Gulf region are not clear. (2) Improving, establishing and maintaining the emission mitigation registry need much work. (3) Implementing new domestic policies, such as tax incentives for renewable energy and clean technology is needed. (4) Developing and integrating cross-sectorial policies to face climate change must be done, especially in agriculture, transportation and energy sectors. (5) There is a need to encourage environmental protection and enhance clean technology by employing economic instruments in environmental policy. Nevertheless, there is a shift in the GCC countries toward diversification in energy sources. In terms of emissions trading and CDM, the UAE and Qatar are ahead of the GCC region (Raouf 2008).

Comparing Saudi Arabia with other Gulf Cooperation Council countries (GCC)[5] with similar socioeconomics in terms of their commitments to environmental protection, at the international level, the GCC countries ratified the UNFCCC in 1994 and 1996. Also, in 2005 Saudi Arabia, Kuwait, United Arab Emirates (UAE), Qatar and Oman ratified the Kyoto Protocol. The country with least cooperation with agreements is Kuwait and the UAE is the best. The GCC countries are not in the list of Annex I parties[6], but the 2009 International Renewable Energy Agency (IRENA) is the first global agency— in the Middle East located in Masdar City in the UAE— to move toward a renewable future. At the regional level, the GCC countries in 1985 created the Environmental Coordination Unit to be responsible for environmental cooperation. For the environmental instruments, the GCC countries in 2009 discussed green tax but this tool is still in the preliminary stage. There are some projects in the GCC countries to support renewable energy: The King Abdullah University of Science and Technology (KAUST) has been built in Saudi Arabia, Masdar City in the UAE, Energy City is being built in Qatar and wind turbines have been installed in Bahrain. However, the GCC countries have adopted new policies toward ecological modernization (Reiche, 2010). Furthermore, in 2016 all the GCC countries signed the Paris agreement with three of them entering into force: UAE in November 2016, Saudi Arabia in December 2017 then Bahrain in January 2017 (UNFCCC, 2016).

In sum, from the previous overview of environmental policies in Saudi Arabia, it is obvious that the country only employed one market-based instrument, which is environmental charges by employing penalties for any environmental violations. Also, Saudi Arabia has applied an adaptation strategy, through its initiatives to improve environmental quality; this means there is no implementation of mitigation strategy at the current time.

Methodology

This study addresses the environmental policies and evaluates their efficiency, in terms of improving environmental quality and not affecting the country's economic growth, which leads Saudi Arabia to achieving sustainable development in the future. Therefore, this study will use scenarios framework, which aims to explore the effect of environmental reduction policy of three types of pollutants (municipal service, CO_2 emissions and other GHG emissions) on the economic growth of Saudi Arabia, through using VECM model results (see Table 1 and Table 2 in the appendix of this paper).

The CO_2 model and other GHG model of Saudi Arabia covered the period from 1981- 2010. The dependent variable under consideration is CO_2 emissions and was taken from Fossil-Fuel CO_2 Emissions by nation from the CDIAC (2015) online database and other GHG emissions (hydrofluorocarbons (HFC), perfluorocarbons (PFC) and sulfur hexafluoride (SF6)) taken from the World Bank database. Variables in these models are GDP and population growth taken from the World Bank database. Since the Saudi

[5] Saudi Arabia, Kuwait, United Arab Emirates (UAE), Qatar, Bahrain and Oman

[6] Group of countries including all the developed countries in the OECD and commit themselves to returning emissions of greenhouse gas levels to 1990 by the year 2000.

Arabian economic growth depends on other determinants such as oil prices, we will use oil prices as an independent variable in the model; oil prices are taken from SAMA database.

Before starting to apply the scenarios approach, we need to determine the scenarios assumption and mitigation scenarios percentage.

1. Scenario Assumptions

Under the absence of levels of pollution that Saudi's Government allocates to reduce and mitigate environmental policies, our mitigation analysis assumes that CO_2 emissions and other GHGs emissions will be cut by 5%; because the previous studies used a different percentage, we employ 5% as a target to reduce emissions as Taher and Alhajjar (2014). Also, Saudi Arabia is a developing country and aims to increase its economic growth, thus applying a reduction policy of more than 5% could affect its economic growth. In addition, this paper chooses years 2020 and 2030 to fit with the IPCC plan for mitigation of emissions scenarios.

2. Mitigation Scenarios

In this study, three types of scenarios will be employed to analyse environmental reduction policies. In other words, this study assumes that policymakers in Saudi Arabia reduce pollution in order to achieve sustainable development through improving environmental quality. There are three scenarios, namely: baseline scenario, optimistic scenario and pessimistic scenario that are employed to explore the future of environmental pollution pattern and economic growth manner.

2.1 Business as Usual Scenario

"Determining how these emissions will evolve in the future is the business of modelling, and an important aspect of every model is the baseline – what emissions would look like without explicit policies or targets" (Anderson, Fergusson and Valsecchi, 2008, P.i). In our case, this scenario, called business as usual or baseline scenario, assumes that Saudi Arabia will not apply any environmental instruments in the future to reduce pollution. Thus, this scenario uses a benchmark for comparing with other scenarios.

2.2 First Reduction Scenario

Scenario 1 supposes that government will apply environmental reduction policy to reduce pollution. This scenario examines the future reaction of GDP for example when environmental pollution variable is cut by a specific percentage.
This study assumes that Saudi Arabia's policymakers decide to achieve sustainable development through applying the optimistic scenario, which reduces pollution by 5%. This means reducing the three types of pollutants in this study by 5%.

2.3 Second Mitigation Scenario

Scenario 2 proposes another environmental reduction policy that the government will apply to improve the environmental quality. This scenario 2 will investigate if environmental pollution is cut by a specific percentage (which is different to the percentage in scenario 1) does this have a significant effect on the GDP in the future.

The second scenario is called pessimistic scenario, which assumes that policymakers in Saudi Arabia decide to undertake the mitigation policy of pollution by 0.05%.

3. Scenario Technique

This study has three scenarios namely; baseline scenario or business as usual, scenario 1 and scenario 2. To make mitigation scenarios we have to follow the steps that are listed below:

1- Run the VECM model for two models from 1981- 2010 for CO_2 model and the other GHG model for Saudi Arabia (see Tables 1 and 2 in the appendix). Then, make forecasting for our data for medium-term up to 2030, meaning from 2011 to 2030 for both CO_2 and other GHG models. To perform out-of-sample forecasts of all variables, moving average method will be used.

2- After obtaining the out-of-sample to 2030 our two VECM models will be solved separately. Each model will be solved using Eviews software to generate the scenarios for the prediction period. For example, CO_2 model from 2011- 2030 will be solved without any employment of reduction policy in the pollutant variable, so the result will be the baseline scenario. Then, we will solve the model again but employ reduction policy on the pollution variable (e.g. cuts CO_2 emissions by 5%), so the result will be called scenario 1 and so on. Finally, plotting the graph, which includes the previous period (from 1981- 2012) called actual time and the other scenarios (from 2013- 2030), will compare the baseline scenario with other scenarios to find out the feasibility of reduction policies and evaluate the effect on GDP.

Environmental Mitigation Scenarios Results

1. Mitigation scenario of CO_2 model

This section also uses the three different pollution reduction policy scenarios namely; baseline scenario, optimistic scenario and pessimistic scenario based on VECM models which are in logarithm (see Table 1 in the appendix of this study). Baseline scenario means the current situation of CO_2 emissions from 1981 – 2010 will continue as over the years 2011 to 2030 which means that Saudi Arabia policymakers will not apply any environmental policy to reduce CO_2 emissions. The optimistic scenario assumes Saudi Arabia's policymakers support environmental quality and introduce a 5% cut in CO_2 emissions. The third scenario is the pessimistic policy that assumes policymakers in Saudi Arabia follow a lower pollution reduction than the one in the optimistic scenario which is to cut CO_2 emissions by 0.05%. Table 13 presents environment mitigation policy and GDP under the three scenarios from 2011 – 2030 (after transforming numbers from logarithm to Riyal). The baseline scenario means no environmental policy action and Saudi Arabia's GDP forecast to decrease from SR 1,662,179 billion in 2011 to SR 179,196 million in 2030. The ambitious reduction for CO_2 emissions through cuts by 5% could decrease Saudi Arabia's GDP to SR 88,314 million in 2030. However, even with the pessimistic scenario, GDP could decrease to SR 166,956 million in 2030, which is higher than the optimistic reduction policy. In other words, the deeper the reduction in CO_2 the deeper the GDP for Saudi Arabia (see Figure 1).

Table 1 Environmental mitigation policy and GDP for the three scenarios

Indicator	Scenario	2011	2020	2030
Pollution reduction	Baseline	-	-	-
	Optimistic	5%	5%	5%
	Pessimistic	0.05%	0.05%	0.05%
GDP (Billion SR)	Baseline	1,662,179	875,543	179,196
	Optimistic	1,662,179	91,922	88,314
	Pessimistic	1,662,179	698,862	166,956

Note: GDP in 2020 and 2030 in million.

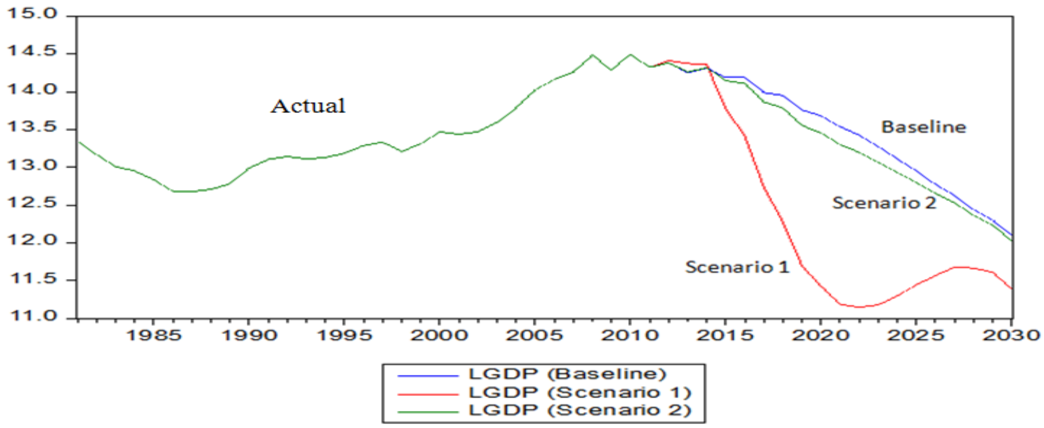

Figure 2 GDP forecast under the CO_2 three scenarios from 1981-2030

Note: This figure is based on VECM model results in Table 1 in the appendix, which is the actual line. Moving average method was used to perform out-of-sample forecasts over the period of 2011 - 2030 for this model. Baseline scenario is the business as usual, scenario 1 cuts CO_2 emissions by 5% and scenario 2 cuts CO_2 emissions by 0.05%. GDP numbers are in logarithm.

In the view of CO_2 scenarios, under the optimistic scenario, GDP will sharply drop from 2014 to 2022. In other words, Saudi Arabia's economy relies on the fossil fuel sector, which is responsible for CO_2 emissions. Thus, if Saudi Arabia's government decide to cut CO_2 emissions that in turn affects GDP.

2 Mitigation scenario of other GHG model scenarios

Based on VECM models which are in logarithm (see Table 2 in the appendix of this paper) this part also used the same method as in previous parts, which is that: (1) Baseline scenario means the current situation of other GHG emissions (HFC, PFC and SF6) from 1981 – 2010 will continue over the years 2011 to 2030 without any employment of environmental reduction policy to reduce other GHG emissions. (2) The optimistic scenario assumes Saudi Arabia's policymakers introduce a 5% cut in other GHG emissions to enhance environmental quality. (3) The third scenario is the pessimistic policy that supposes policymakers in Saudi Arabia follow a lower pollution reduction than the one in the optimistic scenario which is to cut other GHG emissions by 0.05%. Table 2 shows environment reduction policy and GDP under the three scenarios from 2011 to 2030 (after transforming numbers from logarithm to Riyal). The baseline scenario means no environmental policy action and Saudi Arabia's GDP forecast to increase from SR 2,238 billion in 2011 to SR 10,210 billion in 2030. The ambitious reduction for other GHG emissions through cutting emissions by 5% could decrease Saudi Arabia's GDP to SR 4,601 billion in 2030. However, even with the pessimistic scenario, the GDP could decrease to SR 9,428 billion in 2030, which is higher than GDP in the optimistic reduction policy. Essentially, the reduction policy of other GHG emissions will decrease the GDP in Saudi Arabia comparing with GDP under baseline scenario, (see Figure 2).

Table 2 Environmental mitigation policy and GDP for the three scenarios

Indicator	Scenario	2011	2020	2030
Pollution reduction	Baseline	-	-	-
	Optimistic	5%	5%	5%
	Pessimistic	0.05%	0.05%	0.05%
GDP (Billion SR)	Baseline	2,238,351	4,750,260	10,210,733
	Optimistic	2,238,351	2,618,520	4,601,532
	Pessimistic	2,238,351	4,475,595	9,428,428

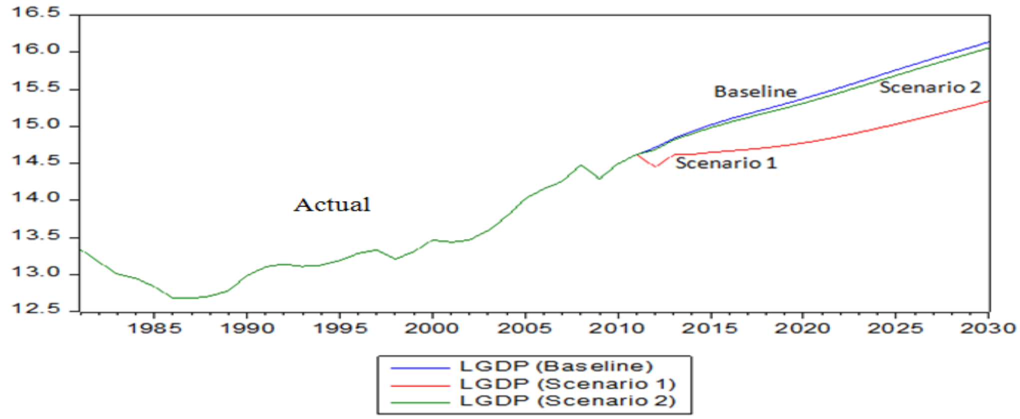

Figure 2 GDP forecast under the GHG three scenarios from 1981-2030

Note: This figure is based on VECM model result in Table 2 in the appendix, which is the actual line. Moving average method was used to perform out-of-sample forecasts over the period of 2011 - 2030 for this model. Baseline scenario is the business as usual, scenario 1 cuts GHG emissions by 5% and scenario 2 cuts GHG emissions by 0.05%. GDP numbers are in logarithm.

In view of other GHG scenarios, under the optimistic scenario, GDP will decrease, because Saudi Arabia's economy relies on the fossil fuel sector, which in turn causes GHGs emissions. Our findings that mitigation scenarios to cut CO_2 emissions and other GHG emissions affect the GDP of Saudi Arabia are in line with other studies that estimated reduction policies of other pollutants on GDP (see Zhao, 2010). Meanwhile, Taher and Alhajjar (2014) and Tucker (1995) found the opposite.

This study's key findings are platforms for the future of pollution trends in Saudi Arabia. Thus, environmental policies will be useful if the policymakers choose the appropriate environmental instruments and take into account the economic growth when employing an environmental reduction policy. Even though Saudi Arabia embarked to diversify income, has initiatives to improve environmental quality, signed environmental agreements and ETP, the country still needs to focus on raising the efficiency of the current sources, accelerate her efforts in mitigating environmental pollution, as well as try to adopt another strategy, such as smart growth principles in order to achieve sustainable development. In sum, Saudi Arabia has to reduce its dependence on oil for reasons of environmental pollution as the Saudi Arabian economy, by 2022, may face an intractable deficit in the absence of discovering new oil reserves, new technology and new policies (Lahn and Stevens, 2011); in sum, combinations of technologies with scenarios can lead to reducing CO_2 emissions (Anderson, Fergusson and Valsecchi, 2008).

Conclusion

In this paper, a mitigation scenarios technique was used to explore the manner of environmental pollution in the medium-term up to 2030. This study used the estimation of two VECM models namely; CO_2 model and other GHG models to apply the environmental reduction policies through employing mitigation scenarios.

This paper started by summarizing the literature review on the environmental policy including mitigation scenarios and the previous studies about Saudi Arabia. Then, a brief background of the Saudi Arabian environmental policies was presented. This background illustrated Saudi Arabia's approach towards environmental protection, through highlighting three important channels: it presented the fines and penalties system in Saudi Arabia to prevent excess harm to the environment for ensuring that environmental standards have not been violated. Saudi's initiatives to improve environmental quality are displayed by the Environmental Technology Program (ETP). Also, the challenges that face the country have been highlighted. This paper investigated three scenarios (baseline, optimistic and pessimistic scenarios).

The findings of the CO_2 model were that: (1) Saudi's GDP under baseline scenarios decreased and GDP under pessimistic will decrease too, even though Saudi Arabia applies a 0.05% reduction policy. Also, there is no difference in this decline in both scenarios but GDP under the optimistic scenario will decrease more than GDP in other scenarios after applying mitigation pollution policy by cutting CO_2 emissions by 5%. Also, other GHG model findings were that: (1) Saudi's GDP under baseline scenario will increase in the future and higher than GDP under the optimistic and pessimistic scenarios. The pessimistic scenario GDP will decrease but GDP under the optimistic scenario after applying mitigation pollution policy by cutting other GHG emissions by 0.05% will decrease more than GDP under the pessimistic scenario.

In sum, based on this paper's findings, the mitigation policies of CO_2 and other GHG were not efficient because they will affect GDP. Thus, Saudi Arabian policymakers should take into account the impact of reduction pollution policies on GDP and reconcile them to achieve sustainable development. Also, the country can focus on adopting smart growth to improve environmental quality, as well as focus on raising efficiency of current sources, responsible for GHGs emissions. However, the findings of this study may change in the future when Saudi Arabia starts to implement the Paris agreement or apply the ETP because new data and variables may appear in the environmental policies models. Thus, a full environmental reduction policy evaluation is left for future studies.

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Appendix

Table 1: VECM Estimation for Variables (Long-Run) model

Vector Error Correction Estimates
Sample (adjusted): 1985 2010
Included observations: 26 after adjustments
Standard errors in ( ) & t-statistics in [ ]

Cointegrating Eq:	CointEq1		
LCO2(-1)	1.000000		
LGDP(-1)	-0.598885		
	(0.10803)		
	[-5.54361]		
LOP(-1)	0.105550		
	(0.08433)		
	[1.25169]		
C	-4.988305		
Error Correction:	**D(LCO2)**	**D(LGDP)**	**D(LOP)**
CointEq1	-0.584981	0.777748	1.112943
	(0.23377)	(0.35024)	(0.93309)
	[-2.50242]	[2.22060]	[1.19274]
D(LCO2(-1))	-0.218448	-0.822591	-1.198230
	(0.23998)	(0.35956)	(0.95791)
	[-0.91027]	[-2.28780]	[-1.25088]
D(LCO2(-2))	-0.085554	-0.945231	-1.507535
	(0.27333)	(0.40951)	(1.09100)
	[-0.31301]	[-2.30818]	[-1.38179]
D(LCO2(-3))	-0.169639	-0.692551	-1.242475
	(0.23421)	(0.35091)	(0.93488)
	[-0.72429]	[-1.97356]	[-1.32901]
D(LGDP(-1))	-0.112565	-0.112307	0.492993
	(0.29901)	(0.44800)	(1.19354)
	[-0.37646]	[-0.25068]	[0.41305]
D(LGDP(-2))	1.190982	0.977840	0.598726
	(0.37950)	(0.56859)	(1.51481)
	[3.13827]	[1.71976]	[0.39525]
D(LGDP(-3))	0.994635	0.841533	2.056979
	(0.34624)	(0.51876)	(1.38206)
	[2.87263]	[1.62219]	[1.48834]
D(LOP(-1))	0.029059	0.012012	-0.425631
	(0.12101)	(0.18130)	(0.48301)

	[0.24014]	[0.06625]	[-0.88121]
D(LOP(-2))	-0.420483	-0.269437	-0.330997
	(0.13459)	(0.20165)	(0.53723)
	[-3.12413]	[-1.33614]	[-0.61611]
D(LOP(-3))	-0.478206	-0.262701	-0.472507
	(0.12454)	(0.18659)	(0.49711)
	[-3.83978]	[-1.40788]	[-0.95051]
C	-0.352591	-0.244500	-0.462949
	(0.09165)	(0.13732)	(0.36584)
	[-3.84699]	[-1.78051]	[-1.26544]
POP	0.119959	0.114449	0.189694
	(0.03254)	(0.04875)	(0.12988)
	[3.68661]	[2.34758]	[1.46051]
R-squared	0.748747	0.457892	0.291038
Adj. R-squared	0.551334	0.031950	-0.266004
Sum sq. resids	0.082788	0.185840	1.319023
S.E. equation	0.076899	0.115214	0.306946
F-statistic	3.792791	1.075009	0.522471
Log likelihood	37.85207	27.34019	1.863267
Akaike AIC	-1.988620	-1.180014	0.779749
Schwarz SC	-1.407961	-0.599354	1.360409
Mean dependent	0.042034	0.059409	0.041413
S.D. dependent	0.114804	0.117100	0.272800
Determinant resid covariance (dof adj.)		1.71E-06	
Determinant resid covariance		2.67E-07	
Log likelihood		86.10808	
Akaike information criterion		-3.623699	
Schwarz criterion		-1.736554	

Table 2: VECM Estimation for Variables (Long-Run) model

Vector Error Correction Estimates
Sample (adjusted): 1984 2010
Included observations: 27 after adjustments
Standard errors in ( ) & t-statistics in [ ]

Cointegrating Eq:	CointEq1
LGHG(-1)	1.000000
LGDP(-1)	-0.358797
	(0.11282)
	[-3.18024]
POP(-1)	-0.278014
	(0.06209)
	[-4.47771]
C	-1.829277

Error Correction:	D(LGHG)	D(LGDP)	D(POP)
CointEq1	-0.227863	0.234841	-0.037405
	(0.06638)	(0.12450)	(0.16717)
	[-3.43285]	[1.88629]	[-0.22375]
D(LGHG(-1))	0.431083	0.426811	0.237335
	(0.18495)	(0.34690)	(0.46580)
	[2.33077]	[1.23035]	[0.50952]
D(LGHG(-2))	0.092238	-0.209249	-0.231186
	(0.17834)	(0.33451)	(0.44916)
	[0.51719]	[-0.62555]	[-0.51471]
D(LGDP(-1))	0.042672	-0.023421	0.079456
	(0.11831)	(0.22191)	(0.29796)
	[0.36067]	[-0.10555]	[0.26666]
D(LGDP(-2))	0.179228	0.033335	0.141537
	(0.13658)	(0.25618)	(0.34399)
	[1.31221]	[0.13012]	[0.41146]
D(POP(-1))	0.140200	-0.179129	1.573580
	(0.06247)	(0.11717)	(0.15732)
	[2.24437]	[-1.52885]	[10.0022]
D(POP(-2))	-0.180745	0.271350	-0.868482
	(0.07551)	(0.14163)	(0.19018)
	[-2.39355]	[1.91584]	[-4.56665]
C	-0.001135	0.063755	-0.045058
	(0.01537)	(0.02883)	(0.03871)
	[-0.07388]	[2.21168]	[-1.16409]
R-squared	0.677482	0.277601	0.921707
Adj. R-squared	0.558660	0.011454	0.892863
Sum sq. resids	0.073074	0.257073	0.463492
S.E. equation	0.062016	0.116319	0.156187
F-statistic	5.701643	1.043036	31.95420
Log likelihood	41.50228	24.52080	16.56349
Akaike AIC	-2.481651	-1.223763	-0.634333
Schwarz SC	-2.097699	-0.839812	-0.250381
Mean dependent	0.024799	0.055098	-0.166667
S.D. dependent	0.093351	0.116991	0.477171
Determinant resid covariance (dof adj.)		1.03E-06	
Determinant resid covariance		3.59E-07	
Log likelihood		85.38988	
Akaike information criterion		-4.325177	
Schwarz criterion		-3.029340	