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Economic-Environmental Consequences of Reforming Fossil Fuel Subsidies Using RICE Model in the MENA Region Countries by 2100 Horizon

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Abstract

The Earth's temperature has climbed by 0.7 degrees Celsius (°C) during the last 100 years, and the worldwide average temperature is expected to rise between 1.8 and 6.4 degrees °C by 2100. Climate change, particularly rising temperatures, according to IPCC, the Middle East and North Africa (MENA) area will face challenges throughout the twenty-first century. As a result, the study's aims are to evaluate the impact of policies which eliminate or targetize fossil fuel subsidies in order to reduce global warming, as well as the impact of these policies on economic variables (GDP, consumption, capital accumulation, employment, and environmental impact) in the MENA until 2100. For this purpose, a Dynamic Regional Integrated Climate-Economy Model (RICE) is utilized to do this. The findings suggest that in the long run, if no strategy to limit temperature rise is enacted and carbon subsidies persist, the average world temperature would rise by 4.74 degrees °C, while an optimal policy based on fossil fuel taxation will increase the average global temperature by 4.49 °C, and a policy reforming fossil fuel subsidies will increase the average global temperature by 4.24 °C. Generally, carbon tax measures in the MENA area will lower average world temperature increase by 0.5°C compared to other scenarios.

Highlights

- In this study, the impact of CO_2 emissions on the MENA region is examined in detail.
- The findings of this study are consistent with recent forecasts by the IPCC and NASAS (2021).
- In the long run, carbon tax in the MENA area will lower average world temperature increase by 0.5˚C.

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1. Introduction

Climate change, sometimes known as global warming, is one of the most important human problems in today's environmental debate. The use coal, oil, and natural gas are examples of carbon-based fossil fuels which is most scientifically important source of global warming, that produces greenhouse gases including CO2, NOx, CH4, and aerosols. Increasing CO2 levels in the atmosphere absorbs and re-emits radiant radiation, resulting in more heat being trapped in the atmosphere. According to estimates, CO2 created can stay for nearly a year in the atmosphere century (Nordhaus, 1992), causing a rise in global average temperature. Emissions of greenhouse gases, particularly CO2, are a key contributor to long-term global warming. As a result, much of the literature on global warming concentrates around this topic, and important economic policy suggestions are made to limit greenhouse gas emissions, notably CO2 (Nordhaus, 2007).

Many studies show that increasing greenhouse gas levels increases global temperature and climate instability since only a small portion of these gases, primarily CO2, is absorbed by oceans, while the remainder remains in the atmosphere permanently (IPCC, 2021). According to reports from the IPCC and the American Institute of Biological Sciences, if no effort is taken to limit CO2 emissions, the mean world temperature will rise by more than 2 degrees °C by 2030 compared to pre-industrial times (IPCC, 2021; Ripple et al., 2021).

Climate change has varied effects in different parts of the world. Underdeveloped nations and regions are more vulnerable than developed countries (Deke et al., 2001; Gbetibouo & Hassan, 2005; National Academies of Sciences, 2020). Due to arid environmental circumstances, the MENA Region is regarded as an important environmental center for future temperature swings. Despite having only 6% of the global population, the MENA region produced 3.2 billion tonnes of CO2, accounting for 8.7% of global greenhouse gas emissions in 2018.

The MENA region's greenhouse gas emissions have been more than quadrupled in the last three decades, surpassing the world average per capita. The Middle East is regularly included among the top ten nations with the highest per capita CO2 emissions. Iran and Saudi Arabia, the world's tenth and eighth greatest CO2 emitters, respectively, are responsible in 2018, greenhouse gas emissions accounted for 40% of total emissions. In 2018, Iran's per capita CO2 emissions surpassed 10.1 tCO2. (Global Carbon Atlas, 2020; National Intelligence Council, 2021).

As a result, the MENA region produces considerable CO2 emissions, which can be traced back to the region's vast oil and natural gas reserves, which are vital to the region's economy (Simone, 2019). Climate change is projected in the MENA region as a result of this high amount of CO2 emissions, particularly rising temperatures. If greenhouse gas emissions are not drastically decreased, a portion of the MENA region will become uninhabitable by 2100, according to the IPCC (Douglas, 2019; IPCC, 2021). According to the sixth IPCC report, Global temperatures would likely rise to 4.7 degrees °C by the end of the century if no action is taken to cut CO2 emissions (IPCC, 2021).

As a result, steps must be taken to limit greenhouse gas emissions and regulate the rise in temperature in MENA region. In this study, the carbon mark-up policy is employed mostly successful and joint intervention policy to reduce the region's excessive usage of fossil fuels. The effective output of greenhouse gases will decrease as the price of fossil fuels rises. This helps to decrease global temperatures by lowering CO2 levels in the atmosphere.

Fossil-fuel subsidies not only stymie global efforts to combat climate change, but they also worsen local pollution problems, putting human health and the environment at risk, according to the OECD-IEA (2020). They also place a significant burden on government budgets, depleting scarce economic resources that may be better utilized in the twenty-first century. Finally, subsidies to fossil fuels distort costs and pricing many producers, investors, and consumers use to make decisions, prolonging older technology and energy-intensive production methods.

For more than a decade, the IEA[1] (2018) has emphasized the positive impact of fossil-fuel subsidy removal on energy markets and climate change. Although there has been widespread support for reforming fossil-fuel subsidies (OECD, 2020) government support for fossil-fuel use and production in OECD nations according to the OECD (2018) study, with USD 151 billion in 2016.

Subsidies for fossil fuels are compensated in both rich as well as emerging nations, although the MENA area received the greatest proportion of fossil fuel subsidies in 2011, accounting for nearly US$ 237 trillion (48%) of the GDP in the area (Sdralevich et al., 2014). As a result, not only is the carbon price of fossil fuels not established in developing nations, particularly in the MENA region, but subsidies are also granted for their use (IMF, 2019). In the MENA region, fossil fuel subsidies much outnumber food subsidies. In 2011, energy subsidies to the following industries, for example, 50 % of petroleum goods, 26 % of electricity, and 23 % of natural gas accounted for 0.7 % of GDP (Ibid, 2014). These incentives appear to have the potential to cause substantial environmental issues by encouraging energy customers to employ inefficient end-of-life devices, which would result in higher carbon emissions.

Aside from energy subsidies, the MENA area has vast energy resources, with the exception of a few countries (Morocco, Tunisia, Egypt, Jordan, and Lebanon). In Egypt, energy subsidies accounted for about 20% of government spending in 2013-2014, while in Yemen, they accounted for 30%. (El-Katiri & Fattouh, 2014). Due to the failure of their subsidy reform plan in 2010, Iran remained the world's largest beneficiary of fossil fuel subsidies in 2018. The goal of this research is to determine carbon-based fossil fuel pricing that will minimize greenhouse gas emissions and postpone global warming through mitigation initiatives, because fossil fuel subsidies have a negative influence on carbon pricing.

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[1] International Energy Agency

In this article, the findings suggest that in the long run, if no strategy to limit temperature rise is enacted and carbon subsidies persist, the average world temperature would rise by 4.74 degrees °C, while an optimal policy based on fossil fuel taxation will increase the average global temperature by 4.49 °C, and a policy reforming fossil fuel subsidies will increase the average global temperature by 4.24 °C. Generally, Carbon tax measures in the MENA area will lower average world temperature increase by 0.5°C compared to other scenarios.

The relevant literature is discussed in the second and third sections, respectively, as is the mechanism of the Regional Integrated Climate and Economy (RICE) model and its equations. The empirical findings are presented in the fourth part. The fifth section contains the conclusion and policy recommendations.

2. Literature Review

Arrenhius (1896) initially raised the issue of climate change's influence on human life, and many subsequent references detailed this issue Nordhaus (1992), Fankhauser and Tol (1996). The concentration of greenhouse gases in the atmosphere, such as CO2, is the mechanism of climate change, water vapor, CO2, nitrous oxide (NOx), methane, and chlorofluorocarbon, allows the sun's ultra-violet and visible radiation to enter the atmosphere while retaining infrared radiation emitted by the earth's surface. The oceans will absorb CO2 to a certain extent, but the remainder, as well as other greenhouse gases, will remain in the earth's atmosphere, resulting in the greenhouse effect and a substantial rise in world temperatures (Barghouti, 2009). During the period 2018-2020, a tiny quantity of CO2 was absorbed by the land surface and oceans, as shown in fig 1.

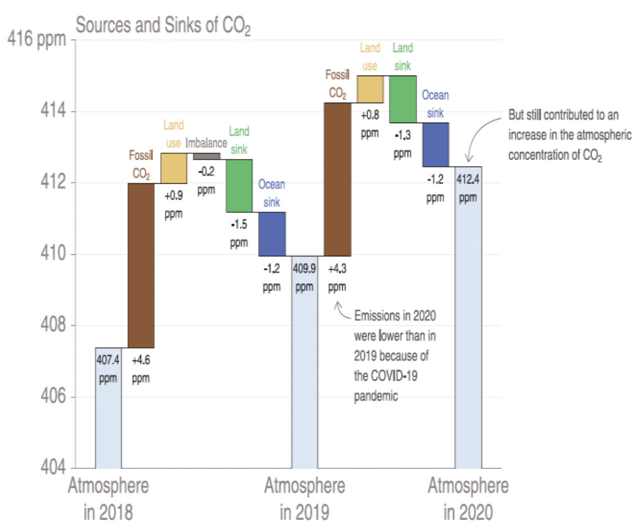

Figure 1. Sources and sinks of CO2

***Source**: united in science, 2021*

CO2 created, according to estimates, can stay in for almost century, the atmosphere has been warming and resulting in a rise in world average temperature. Scenarios for the environment, community, and economy have been produced due to global warming's long-term scope and degree of uncertainty. The capacity of land and oceans to absorb CO2 emissions caused by fossil fuels and land usage, show that greenhouse gases have a negative impact on the earth's temperature (Nordhaus, 1992a). Cap and trade policies, which allow agents to exchange emission allowances, and environmental taxes, which uses carbon markup pricing to reduce carbon emissions, are two common strategies used in response to global warming. However, these two initiatives are still unable to halt global warming. To mitigate the causes of global warming, an integrated economy-energy-environment framework will be required.

Mitigation programs, in their most basic form, aim to reduce greenhouse gas emissions in order to slow or prevent climate change. Climate change adaptation policies are techniques for limiting susceptibility to the effects of climate change (Mikhail, 2009).

Prior to 1990, traditional economic models were unable to research the implications of global warming and temperature rise agricultural yields and economic output. Since 1990, significant advances in climate change modeling have been achieved all around the globe, and integrated assessment models (IAM) have been developed by merging the two sectors of the economy and climate, allowing for an economic examination of the global warming problem (Nordhaus and Boyer, 2000).

Policy optimization and policy assessment are the two broad categories of IAM. A Dynamic Integrated model of Climate and the Economy (DICE) and other optimization models that are objective and well-defined and can decide the optimal policy assessment are more descriptive in character and examine numerous situations rather than seeking to determine the optimal policies. RICE regional models combine the two methodologies and may be used to evaluate policies. The following studies are relevant:

Eriksson (2020) has carried out research. A model is created to quantify the potential role of afforestation and avoided deforestation in climate policy, as well as their geographical allocation. The model builds on RICE-2010, a climate and economic multi-regional integrated assessment model. It is critical to include these forest initiatives into global climate policy. In view of the rigorous temperature requirements, this is extremely important under a 2°C target temperature, averted deforestation quickly reaches its full potential, but afforestation has the potential to significantly in the medium and long run, cut emissions. According to the study, concentrating policy efforts on tropical forests can result in the biggest reductions in emissions due to averted deforestation and afforestation.

Coady et al. (2019) showed that exclusion of fossil fuel subsidies and imposition of appropriate taxes could increase greenhouse gas emissions globally by 28%, 21%, and 23% in 2015, 2013, and 2010, respectively. The researchers got an idea from the two efficient policies of excluding fossil fuel subsidies and imposing appropriate taxes in order to control the increase in temperature and subsequently reduce greenhouse gas emissions for the present study and considered implementation of policies of exclusion and modification of fossil fuel subsidies as appropriate for MENA region as part of the world.

Liu et al. (2018) used 2011 as the benchmark year to simulate and examine the effects of on the socio-economic system of the Canada, there are five distinct carbon pricing of Saskatchewan. They discovered that a carbon tax of $40 would cut greenhouse gas emissions by 7.3%. This carbon tax rate is compatible with the IPCC's results for preventing temperature rise in emitting countries by the end of the twenty-first century (IPCC, 2014).

Bretschger and Pattakou (2019) demonstrate the importance of damage function requirements in climate economics. They use higher-order polynomial functions up to cubic and quadratic forms to investigate the influence of climatic disasters on welfare and growth. According to their model, capital stock damage reduces both current income and economic growth.

According to the Statistical Review of World Energy (2016), the Gulf Cooperation Council (GCC) region with the most energy reserves has a massive amount of fossil fuel subsidies. The GCC possesses around 40% and 20% of the world's oil and gas reserves, respectively.

Wang et al. (2016) studied the impact of subsidy change in Abu Dhabi, United Arab Emirates, and discovered that it boosted GDP while lowering carbon emissions and private spending. With wage reduction as the only social cost of change, greater carbon mark-ups in Abu Dhabi have had no effect on the economy or employment, as earlier studies in Kuwait, Egypt, or China have demonstrated. As a result, eliminating subsidies is predicted to have a favorable impact on the economy while also preventing environmental damage in the MENA region.

Roson and Sartori (2016) & IPCC (2014b) provided climate impacts on different regions and ecosystems, Yet, for a global analysis of climate damages, the available data are not sufficiently complete and there is a big challenge for formulating a comprehensive climate damage function.

Moore and Diaz (2015) and Farmer et al. (2015) pointed out unclear which functional form for the damage function is suitable and where the limitations are to capture “everything by a simple function”. Damage functions are one of various elements of integrated assessment models which have recently been criticized.

Traeger (2015) introduce a version of the DICE-2007 model designed for uncertainty analysis. He is estimated damage coefficients by using the Belman equation estimates in conditions of uncertainty. Damage coefficients are used on a global scale and applicable to the whole world. In study are not estimated regional damage coefficients and specifically for Mena.

Revesz et al. (2014) and Stern (2013) admitted that the damage functions used in the most well-known models are empirically unsound. Furthermore, in most integrated assessment models, even under high-temperature scenarios, climatic damages have implausibly little effects on economic development.

According to Péridy & Brunetto (2012), in the MENA area, every 1°C increase in temperature leads in an average loss of 8% of GDP per capita. Damage ranges from around 5% in North Africa (excluding Egypt) to 15% in Egypt, Turkey, Tunisia, and a number of Middle Eastern nations. These findings are very similar to those obtained in international research (Dell et al., 2009), which revealed that global warming costs the MENA area 8.5 % of GDP per capita per unit increase in temperature.

RICE and DICE models were Nordhaus and Boyer (2000) came up with the idea to evaluate the impact of greenhouse emissions on the global economy. A regional climatic and economic integrated dynamic model was used in this comprehensive investigation. The globe is divided into eight regions (United States, other high-income countries, developed Europe, Russia and Eastern Europe, Middle-income countries, Lower-middle-income countries, China and Low-income countries). The results show that if no policy to reduce CO2 emissions by the end of the twenty-first century is implemented, global warming would increase by 2.53 degrees °C, and if the optimal carbon tax policy is implemented, global warming will increase by 2.44 degrees °C.

The RICE model (Nordhaus & Boyer, 2000; Nordhaus & Young, 1996) was used in this study to analyze the economic and environmental consequences of reforming fossil fuel subsidies in the MENA. According to several studies, global temperatures would climb by 3 to 4 degrees °C by 2100 if no legislation is passed to reduce them. As a consequence, in this study, an attempt was made to identify the necessary effective parameters, such as temperature in the base year (2015), which conforms to IPCC.

Many studies predict that global temperature will increase in the range of 3 to 4 °C by 2100 if no policy is implemented to reduce the temperature. Therefore, in the present study, an attempt has been made to calculate the required effective parameters such as temperature in the base year (2015) corresponding to IPCC. Other studies have looked into the implications of reforming and by the end of the twenty-first century; consumer fossil fuel subsidies will be gone. Emissions will range from 1 to 10% by 2030, and from 6.4 and 8.2% by 2050, according to these studies. Carbon markup pricing was also mentioned as an important strategy for changing fossil fuel subsidies (Delpiazzo et al., 2015; Jewell et al., 2018; IEA, 2018).

The purpose of this study is to compare the effects of adopting mitigation measures in the MENA region to eliminate fossil fuel subsidies (zero carbon mark-up) and reform fossil fuel subsidies (US$ 40 carbon mark-up) with the current situation or fundamental policy (allocation of carbon subsidies).

The idea of income categorization of MENA countries is based on the most recent World Bank income classification in this study (World Bank, 2019). The MENA region is classified into three income levels (high income, high middle income and low middle income). The impact of global warming on MENA GDP (in the basic scenario) is analyzed first, followed by the impact of mitigating alternatives. It's also worth mentioning that a research by Nordhaus and Boyer (2000) concluded that the threat presented by global warming portrays climate change in a less worrisome light, although the current analysis employed updated IPCC information. The environmental and economic ramifications of enacting mitigation strategies to reduce temperature rise, as well as the effects of these policies on GDP, investment, and damage costs, are assessed in the Middle East and North Africa. Other decision variables are such as those that contribute to economic growth (GDP).

Based on the outcomes of the two studies, the researchers concluded that rising temperatures in the MENA area are likely to harm GDP. As a result, the current study aims to prevent the environmental and economic consequences that are expected to occur in the MENA region by the end of the twenty-first century by implementing mitigation policies that exclude and reform fossil fuel subsidies, taking into account the current situation in the region (carbon subsidy allocation).

Contribution of this study is as follows: (a) The impact of CO2 emissions on the MENA region is examined in detail. The countries of the MENA are split into three income groups (high income, high middle income and low middle income). (b) When compared to previous early 1990s studies, the image of climate change appears to be far less worrisome, as demonstrated by the values of the parameters calibrated in the base year (1995), which differ from IPCC data.

3. Model: The Structure of RICE

The RICE model (Nordhaus & Young, 1996; Nordhaus and Boyer, 2000) was used to examine the economic-environmental repercussions of global warming in the MENA area. The RICE model is a variation of the Ramsey model that includes investments in environmental climate change. Emissions decrease are equivalent to make a Ramsey model investment, in the developed model, which means that GHG concentrations are treated as a negative capital stock and emissions reductions as an investment. Consumption sacrifice that decreases emissions and so prevents economically damaging climate change while also increases future consumption possibilities.

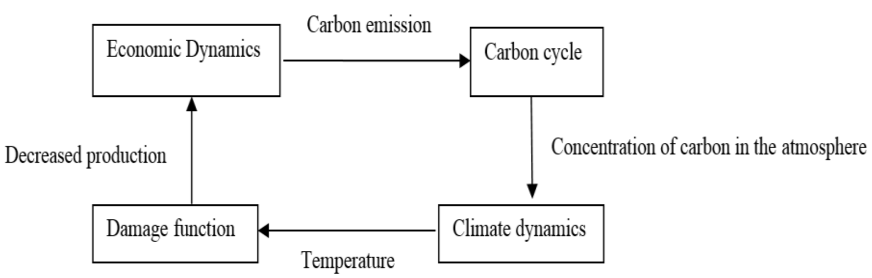

Figure 2. Interactions between the economy and the environment

***Source**: Kendrick et al., 2007*

The essential links and processes of the RICE model are depicted in Figure 2. CO2 is released by industry as a result of world output (as a result of the use of fossil fuels). When the concentration of CO2 in the atmosphere grows, the greenhouse effect occurs, causing the earth's temperature to rise. The negative effects of rising temperatures, such as environmental deterioration, lower the global economy's productivity in MENA. The most well-known and widely used policy intervention, according to Kendrick (2007), is carbon pricing, which raises the price of fossil fuels and thereby lowers greenhouse gas emissions. This lowers CO2 levels in the atmosphere and aids in the reduction of global temperatures. As a result, decreasing global warming's harmful consequences will enhance economic productivity.

Taxation or any other kind of emissions regulation, on the other hand, reduces the economy's efficiency and, as a result, the global (regional) economy's output. As a result, carbon pricing (or any other scheme that reduces emissions) has two conflicting effects on economic activity. When the emission control strategy is taken into consideration, figure 3 illustrates the model's rotation diagram.

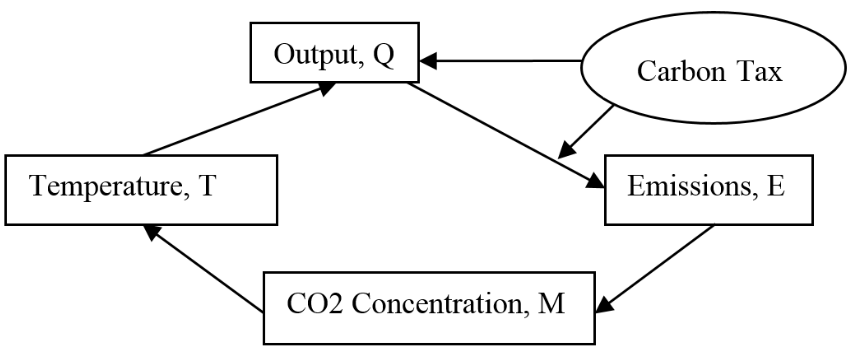

Figure 3. Emissions are taken into account in the RICE model's circulation diagram
Source: *Kendrick, 2007*

The RICE model is a general equilibrium model that can be computed. The objective function as well as economic and climatic (thermodynamic) restrictions, are given independently in the following model equations.

3.1 Objective Function

The areas are expected to optimize a social welfare function, which is the discounted sum of population-weighted per capita consumption utility.

$$W_J = \sum_t U\,[c_J(t), L_J(t)]R(t) \qquad (1)$$

Where W_J is the objective function of region J, U[$c_J(t)$cJ(t), $L_J(t)$]LJ(t)] is the utility of consumption for region J, $c_J(t)$cJ(t) is the flow of consumption per capita during period t, $L_J(t)$ is the population at time t, and R(t) is the pure time preference discount factor.

Constant elasticity of substitution (CES) is the explicit version of the utility function, and the parameter indicates the constant amount elasticity of marginal utility of per capita consumption:

$$U[c_J(t), L_J(t)] = \frac{L_J(t)\{[c_J(t)]^{1-\alpha} - 1\}}{(1-\alpha)} \quad (2)$$

We take (the limit of) $\alpha = 1$ in the RICE model; the logarithmic or Bernoullian utility function is obtained (3) equation:

$$U[c_J(t), L_J(t)] = L_J(t)\{\log[c_J(t)]\} \quad (3)$$

3.2 Production Function

A variation of a basic neoclassical production function is used to depict production. The production or GDP $[Q_J\ (t)]$ of region J is determined by a constant-returns-to-scale model. In capital $[K_J(t)]$, labor $[L_J(t)]$, and energy (fossil fuel), the Cobb-Douglas production function, $ES_J(t)$, is used (t). In the model, total fossil fuel consumption is equivalent to all fossil fuel use's carbon content. As a result, coal, oil, and natural gas are grouped together in a single aggregate, with carbon weights used to group the various fuels. The production function as well as all of the other functions utilized in this work; were modified from Nordhaus and Yang (1996), Nordhaus and Boyer (2000), and Yang (2020). The (4) *equation* is the production function in area J during period t:

$$Q_J(t) = \Omega_J(t)\{A_J(t)K_J^{\gamma}(t)L_J^{1-\beta_J-\gamma}(t)ES_J(t)^{\beta_J} - C_J^E(t)ES_J(t)\} \quad (4)$$

$$ES_J(t) = \varsigma_J(t).E_J(t) \quad (5)$$

In (3) equation, γ is the elasticity of output with respect to capital and MENA β_J is the elasticity of output with respect to energy services (discussed below), and the term $(1 - \beta_J - \gamma)$ is the output elasticity with respect to labor. $A_J(t)$ represents the level of Hicks-neutral technological change. The term $\Omega_J(t)$ is a damage coefficient that relates to the impact of climate change on output. Labor inputs are equal to population. The term $[C_J^E(t)ES_J(t)]$ in (4) equation subtracts from gross output the costs of producing fossil fuel.

The link between fossil fuel inputs and energy services is therefore shown in Equation (5). Carbon-augmenting technology is a type of technological advancement in the energy industry, where $\varsigma_J(t)$ denotes the degree of carbon-enhancement technology. Thanks to carbon-enhancing technical innovation, society can squeeze more energy services per unit of fossil fuel. Based on the varied spectrums of the analyzed nations and their more or less unique economic systems, this study investigates the production function with continuous returns to scale.

Economic and climatic restrictions are included after the objective and production functions are presented in the RICE model. The RICE model has a number of advantages, including a full explanation of the climatic equations as well as the influence of CO2 concentration on the atmosphere and the repercussions of global warming.

3.3 Economic Constraints

For most regions, the growth of population is assumed to follow an exponential path. The growth rate is anticipated to decrease at a geometrically decreasing rate over time. Let $g_j^{POP}(\mathrm{t})$ be the population growth rate in area J during period t, and $\delta_j^{POP}t$ denote the population decrease rate. The population growth rate at time t is thus:

$$g_j^{pop}(t) = g_j^{pop}(0)exp(-\delta_j^{pop}t) \tag{6}$$

This demonstrates that the population rate will eventually decrease. Total factor productivity (TFP) is also calculated exponentially and at a decreasing rate, as population expansion slows with time, lowering productivity growth (Nordhaus and Boyer, 2000). Let $g_j^A(t)$ be the constant rate of decline in period t, and $\delta_j^A t$ signify the TFP growth rate in period t. The (7) *equation* is the total factor productivity increase at time t:

$$g_j^A(t) = g_j^A(0)exp(-\delta_j^A t) \tag{7}$$

The concept of per capita consumption is (8) *equation*:

$$c_J(t) = \frac{C_J(t)}{L_J(t)} \tag{8}$$

The capital stock's development is provided by:

$$K_J(t) = K_J(t-1)(1-\delta_K)^{10} + 10 \times I_J(t-1) \tag{9}$$

Where δ_K denotes the capital stock's value yearly rate of depreciation. Capital is expected to depreciate at a rate of 10% each year. Despite the model's ten-year lifetime, because most growth models are based on a two-part economy comprising families and companies (consumers and investors), the model used in this study does as well. The (10) equation is added to the list of economic restrictions based on this assumption:

$$Q_j(t) = C_j(t) + I_j(t) \tag{10}$$

3.4 Climate Constraints

The links between concentration, climate change, and damage equations will be discussed in this section. The first link is between economic activity and greenhouse-gas emissions. The radiative forcing of greenhouse gases affects climate in the RICE model. Among the GHGs, only industrial CO2 is endogenous and the other GHGs are exogenous in the model.

In the RICE model, industrial CO2 emissions account for nearly 90% of total CO2 emissions so industrial CO2 gets the most attention. The RICE model takes a structural approach, relying on a three-reservoir model that has been calibrated against previous carbon-cycle models. The key idea is that, in the long run, the deep seas serve as a small but significant carbon sink. The three carbon reservoirs are believed to be the atmosphere, a swiftly mixing reservoir in the upper seas and the biosphere, and the deep oceans. Each of the three reservoirs is forecast to be well-mixed in the short term, but mixing between the upper reservoirs and the deep seas is expected to be gradual. CO2 accumulation and transport are thought to be described by the following linear three-reservoir model.

$$M_{AT}(t) = 10 \times ET(t-1) + \varphi_{11}M_{AT}(t-1) + \varphi_{21}M_{UP}(t-1) \quad (11)$$

$$M_{UP}(t) = \varphi_{12}M_{AT}(t-1) + \varphi_{22}M_{UP}(t-1) + \varphi_{32}M_{LO}(t-1) \quad (12)$$

$$M_{LO}(t) = \varphi_{23}M_{UP}(t-1) + \varphi_{33}M_{LO}(t-1) \quad (13)$$

Where $M_{AT}(t)$ is the mass of carbon in the atmosphere at the end of the period, M_{UP} (t) represents the mass of carbon in the upper reservoir (biosphere and upper seas), ET(t) represents global CO2 emissions, including those produced by land-use changes, and $M_{LO}(t)$ represents the mass of carbon in the lower oceans. The coefficient φ_{ij} represents the rate of transfer from reservoir i to reservoir j (per period), where i and j indicate AT, UP, and LO, respectively.

Next stage is to investigate the link between GHG buildup and climate change. GHG accumulation causes global warming by increasing surface temperature caused by increased radiation. F(t), the link between increasing radiative forcing and GHG accumulations, is determined from empirical observations and climate models. The (14) equation of the relationship:

$$F(t) = \eta\{\log_2[\frac{M_{AT}(t)}{M_{AT}{}^{PI}}]/\log(2)\} + O(t) \quad (14)$$

$M_{AT}(t)$ represents atmospheric concentration at the end of the period t (GtC) and the increase in radiative forcing since pre-industrial levels (W/m2) is denoted by F(t). Other GHGs and aerosols (CFCs, CH4, N2O, and ozone) are represented by O(t).

The (14) equation shows how radiative forcing affects climate change. The atmosphere is warmed by increased radiative forcing, which warms the top ocean, which progressively warms the deep oceans. Thermal inertia of the various layers is the primary cause of the system's delays. The (15) and (16) equations are a representation of the model:

$$T(t) = T(t-1) + \sigma_1\{F(t) - \lambda T(t-1) - \sigma_2[T(t-1) - T_{LO}(t-1)]\} \quad (15)$$

$$T_{LO}(t) = T_{LO}(t-1) + \sigma_3\{T(t-1) - T_{LO}(t-1)\} \quad (16)$$

Where T(t) is the worldwide average atmospheric temperature for time t. $T_{LO}(t)$ is the increase in temperature in the deep oceans from pre-industrial levels. The σ_i indicates the increase in radiative forcing in the atmosphere, and the i are movement coefficients describing the flow rates and thermal capabilities of the various reservoirs.

It is considered that the amount of harm caused by greenhouse warming is proportional to the amount of warming. The (17) equation expresses the link between an increase in global temperatures and a loss of income:

$$D_J(t) = \theta_{1,J}T(t) + \theta_{2,J}[T(t)]^2 \quad (17)$$

Where $D_J(t)$ is the damage from climate change as a proportion of a region's production net of climate damages, and $D_J(t)$ is the damage as a function of the change in global mean temperature.

Finally, the damage function can be included into the production function in equation (4) using the Ω coefficient in (18) equation:

$$\Omega_J(t) = \frac{1}{[1+D_J(t)]} \tag{18}$$

The damage function is often multiplicative on production (e.g., Fankhauser & Tol, 1996; Nordhaus & Sztorc, 2013). $\Omega_J(t)$ represents a damage coefficient multiplied by the components of production, and it corresponds to the influence of climate change on output, as shown in Equation (4). As a result, using the Ω coefficient in equation (18), the damage function will enter into the production function in equation (4):

$$\Omega_J(t) = \frac{1}{[1+D_J(t)]} \tag{19}$$

$$Q_J(t) = \Omega_J(t)\{A_J(t)K_J^{\gamma}(t)L_J^{1-\beta_J-\gamma}(t)ES_J(t)^{\beta_J} - C_J^E(t)ES_J(t)\} \tag{20}$$

Or

$$Q_J(t) = \frac{1}{[1+D_J(t)]}\{A_J(t)K_J^{\gamma}(t)L_J^{1-\beta_J-\gamma}(t)ES_J(t)^{\beta_J} - C_J^E(t)ES_J(t)\} \tag{21}$$

4. Data Description

The RICE model, a dynamic general equilibrium model, is used to do this research. This framework is used to calibrate the economic and environmental features (For example temperature) in MENA region 2015 as the base year. Then, using the Business-as-Usual (BaU) scenario, a long-term path for economic and environmental decision variables is determined. The effects of measures to eliminate or modify fossil fuel subsidies in order to combat global warming, as well as their impact on MENA's economic and environmental decision factors up to 2105 will be examined in the next stage.

The World Bank (2019) and the IEA databases were utilized to calibrate the relevant economic and meteorological factors in the base year. The majority of the economic factors were calculated using the databases described above, while a few of the essential climatic elements were derived from international scientific sources. The model is solved using the GAMS tool after the relevant parameters have been quantified. The parameter calibration is reported in Tables 2, 3, and 4.

Table 1. Exogenous variables in income groups specific

Variable name	Variable symbol	Unit	Initial value of variable in base year (2015)			
			High income	**Upper middle income**	**Lower middle income**	**Source**
Initial capital stock	K0	Billion dollar at a fixed price in 2010	3.94	2.72	0.89	Research findings & World bank data
Initial population	L(0)	Billion person	61.846	176	143.47	Research findings & World bank data
Initial population growth rate	Lgr (0)	Percent in decade	53.62	26.79	18.33	Research findings & World bank data
Population growth rate is slowing down	Lgrgr(0)	Percentage change over a decade	18.58	3.61	-2.39	Research findings & World bank data
Initial total factor productivity	Tfp(0)	Net value	0.9	0.7	0.1	Research findings & World bank data
Initial productivity growth rate	Tfpgr(0)	Percent per decade	3.9	3.61	11.52	Research findings & World bank data
Productivity growth rate is declining at a rapid pace	Tfpgrgr(0)	Percentage change every decade	1.40	3.27	4.13	Research findings & World bank data
output elasticity in relation to carbon services	β	Net value	0.041	0.040	0.010	Research findings , World bank data & IEA data
beginning carbon emissions-to-carbon-services ratio increasing rate	Phigr	Percentage change every decade	-28.32	-38.71	-26.00	Research findings & IEA data
Rate of decline of Phigr	Phigrgr	Percent per decade	2.32	4.381	2.16	Research findings & IEA data (IEA)

Table 1 (Continued). Exogenous variables in income groups specific

Damage coefficient on temperature	θ_1	Net value	-0.007	0.0039	0.0022	Nordhaus & Boyer (2000)
Damage coefficient on temperature squared	θ_2	Net value	0.003	0.0013	0.0026	Nordhaus & Boyer (2000)

Table 2. Exogenous parameters in MENA Region

Parameter name	**Parameter symbol**	**Unit**	**Initial parameter value**	**Source**
Initial social rate of time preference	or $\rho(t)$ SRTP0	Percent per year	4.73	Research findings & world bank
SRTP's rate of decrease	SRTPGR	Percent per year	0.12	Research findings & world bank
Output elasticity relative to capital	γ	Net value	0.1792	Research findings & world bank
Rate of depreciation of capital	δ_K	Percent	0.10	Nordhaus & Boyer (2000)
Carbon extraction has reached a point of decreasing returns	CARBMAX	GTC	6000	Nordhaus & Boyer (2000)
Initial atmospheric concentration of CO2	M0	GTC	854.36	Research findings - Nordhaus & Boyer (2000)
in the upper oceans, the Initial CO2 concentration was	$M_{UP}(0)$	GTC	841.14	Research finding by φ_{ij} in Nordhaus & Boyer (2000) study

[2] In order to calculate the elasticity of output to capital, first using the data of the World Bank (2019) the amount of gross capital was deducted from the depreciation of 10% and the amount of this difference by country for years Achieved from 2005 to 2014. Then, in order to obtain the amount of capital accumulation for each country in 2014 Year, the formula $\sum_{2005}^{2014} K$ was used. It was now obtained using the formula $K_J(t) = K_J(t-1)(1-\delta_K)^{10} + 10 \times I_J(t-1)$ amount capital in 2015 year. Then the difference of K was obtained in two consecutive years divided by K (2014). Also, the difference between real GDP (at constant prices) in 2015 and 2014 divided by GDP (2014) was obtained. Then, using the formula of elasticity $\frac{\Delta Y/Y}{\Delta K/K}$, the output elasticity to capital was obtained.

Table 2 (Continued). Exogenous parameters in MENA Region

CO2 concentration in the deep oceans at the start	$M_{LO}(0)$	GTC	19249.66	Research finding by φ_{ij} in Nordhaus & Boyer (2000) study
Temperature of the atmosphere at the start	T(0)	The temperature is in °C	0.87	IPCC
Initial temperature of deep oceans	$T_{LO}(0)$	°C temperature scale	0.06	Nordhaus & Boyer (2000)
cumulative carbon emissions	CUMCARB(0)	GTC	22.6	Research findings & IEA data
industrial carbon emissions	CA(0)	GTC	0.34	Research findings & IEA data

Table 3. Endogenous variables

			Variable value in horizon year (2100) in Diffrent Scenario				
Variable name	**Variable symbol**	**Unit**	**Baseline or Business as Usual (BaU) scenario (1)**	**Carbon subsidy phase out scenario (2)**	**Carbon taxation scenario (3)**	**difference (3) from (1)**	**Source**
Output	Q(t)	Billion dollar at a fixed price in 2010	2090.250304	2100.741444	2105.990259	15.7399551	Research finding
consumption	c(t)	Billion dollar at a fixed price in 2010	1808.176502	1817.066622	1820.930102	12.75359949	Research finding

Table 3 (Continued). Endogenous variables

Capital accumulation	K(t)	Billion dollar at a fixed price in 2010	3204.090112	3218.57024	3228.889036	24.798923 27	Research finding
Labor force	L(t)	Million person	2927.336394	2927.336394	2927.336394	0	Research finding
industrial carbon emissions	CA(t)	GTC per year	23.42668503	23.19879903	22.24441848	-1.18226655	Research finding
Damage Cofficient	DAMCOEFF(t)	Percent	0.958111948	0.952909659	0.947988662	-0.01012328	Research finding

5. Empirical Results

Three scenarios have been created for this research:

1) Baseline or Business as Usual (BaU) scenario: Carbon price is estimated to be US$ -40 per tCO_2 in the MENA region, assuming fossil fuel subsidies and no intervention policy to reduce CO_2 emissions. This value is based on an estimate from the International Monetary Fund (IMF) (IMF, 2019).

2) Carbon subsidy phase out scenario: In this scenario, the MENA region's fossil fuel subsidies are phased out, and the price of carbon emissions is set to zero.

3) Carbon emissions are taxed at US$ 40 per tCO_2 in order to reduce global temperatures and improve economic indicators in the Middle East and North Africa (MENA).

5.1 Trend of Temperature

Figure 4 shows that if no policy to limit temperature rise is implemented and current fossil fuel subsidies in the MENA region continue, the average global atmospheric temperature rise will reach 4.74 degrees °C by the end of the twenty-first century, which is significantly higher than the goals of recent international agreements to limit temperature rise to 2 degrees °C by the end of the century. Furthermore, the average global temperature rise will be greater than 4.24 degrees °C if the policy of eliminating fossil fuel subsidies is implemented, while the average global temperature rise will be greater than 4.49 degrees °C if the policy of reforming fossil fuel subsidies (carbon mark-up) is implemented.

According to the results of the three above mentioned scenarios, a US$ 40 mark-up on carbon policy in the MENA region lowers world temperature by

0.5°C when compared to subsidized fossil fuel policy. In other words, a US$ 40 carbon tax in the MENA region could contribute to a 0.5°C reduction in global temperatures by the end of the century.

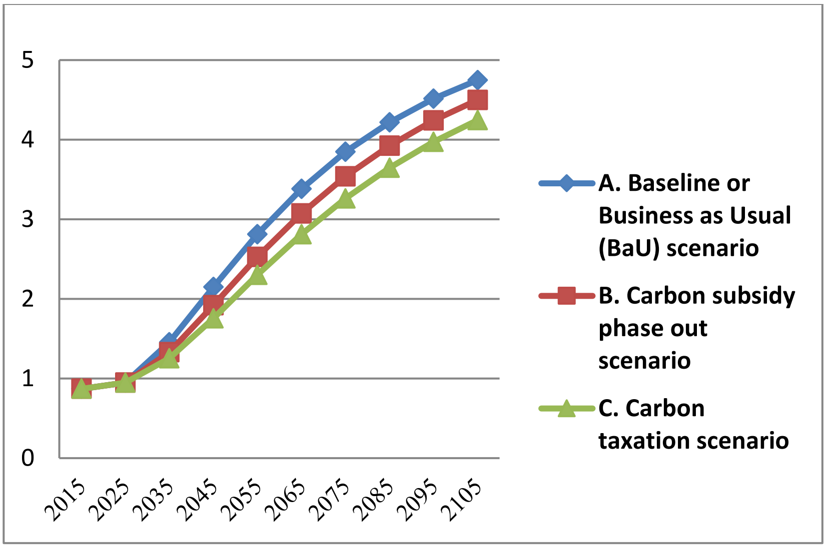

Figure 4. Increase in the average temperature of the atmosphere
Source: *Research Findings.*

5.2 Trend of Gross Domestic Product (GDP)

In the long run (through the end of the twenty-first century), GDP in the mark-up on carbon scenario will be greater than in the carbon BaU and subsidy phase-out scenarios. In other words, a US$ 40 carbon tax boosts GDP over time compared to the no-policy scenario. Carbon taxes will raise the cost of utilizing carbon-based fossil fuels, resulting in a reduction in fossil fuel use over time. In the long run, as fossil fuel consumption declines, temperature rises will reduce as environmental harm decreases. In terms of GDP damages, the amount of GDP lost will be more than in the BaU and subsidy phase out scenarios. In a nutshell, fossil fuel subsidy phase out and carbon price policies will create considerable influence on the MENA region's GDP or economic growth (Figure 5).

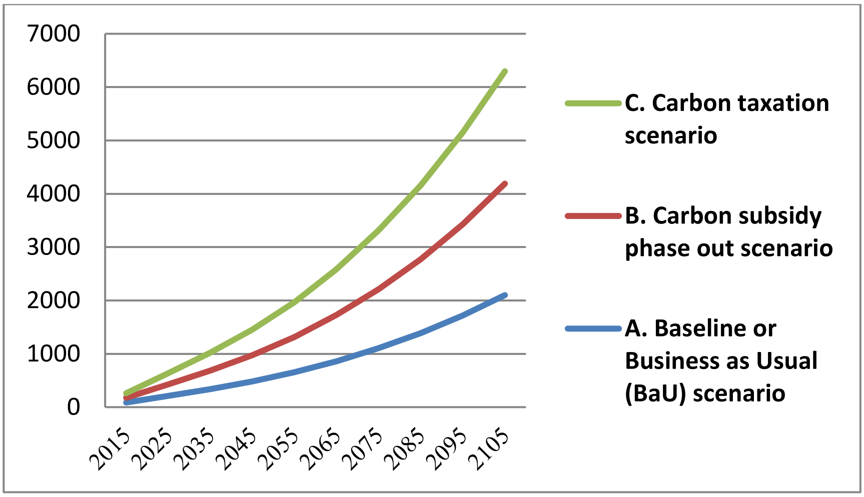

Figure 5. Increase in Gross domestic product (GDP)
Source: *Research Findings.*

5.3 Trend of Consumption

Figure 6 shows that in the long term, consumption under the carbon tax scenario will be greater than in the BaU and subsidy phase-out scenarios. This outcome appears logical since imposing a carbon tax raises the fossil fuel prices, reducing their use. The emission of greenhouse gases, particularly CO2, has decreased as a result of reduced fossil fuel consumption, indicating an increase in both current and future environmental investment. The environmental investment may be seen in the widespread use of renewable energy, which helps to mitigate the effects of global climate change.

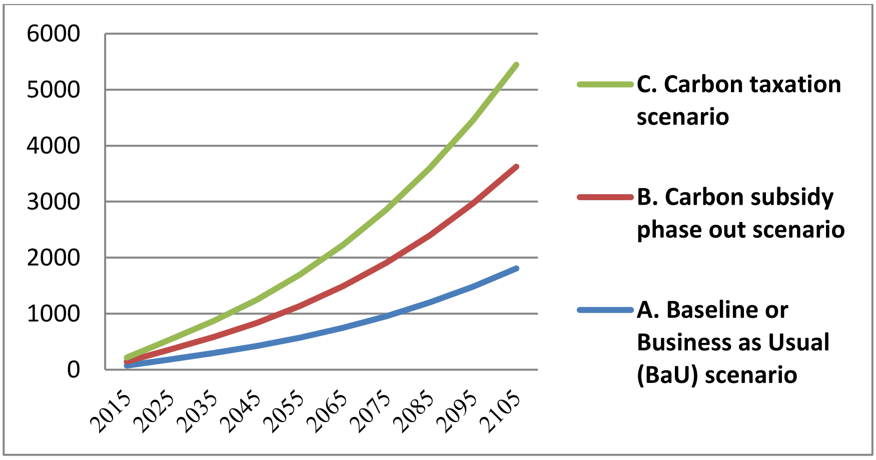

Figure 6. Increase in consumption
Source: *Research Findings.*

5.4 Trend of Capital Accumulation

Capital accumulation in the carbon tax scenario will be larger in the long run than in the other two scenarios. A carbon price of $40 increases capital accumulation by guaranteeing that environmental taxation provides a sufficient incentive for the development of renewable energy technology. Up to the end of the century, consumers will cut their usage of fossil fuels and invest more money in environmentally beneficial technology. It appears that when the usage of an energy carrier is less expensive, particularly Consumption of carbon-based fossil fuels is higher in this case study; hence capital savings are achieved in a shorter period of time (Figure 7).

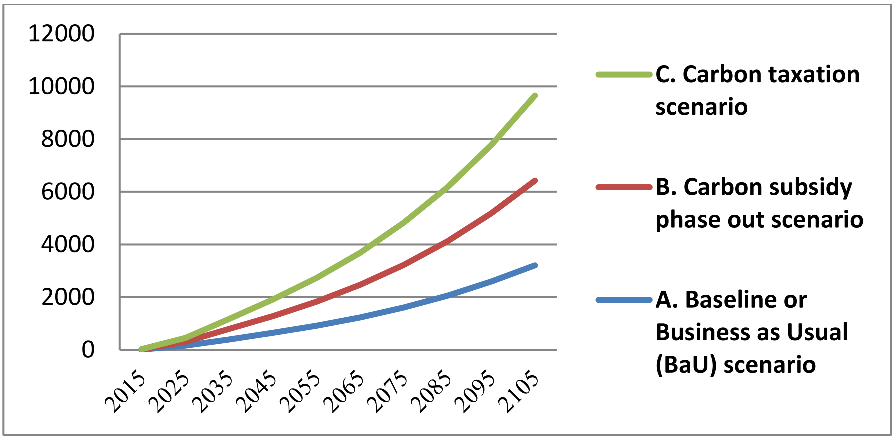

Figure 7. Increase in capital accumulation

Source: *Research Findings.*

5.5 Trend of Labor Employment

The long-term employment trends in all three scenarios are completely aligned in Figure 8. It may be inferred that the introduction of a carbon price policy in the MENA area will have no impact on labor employment. This finding is in line with a study by Wang et al. (2016), which found that increasing carbon prices in the United Arab Emirates, Kuwait, Egypt, and China had no effect on labor employment.

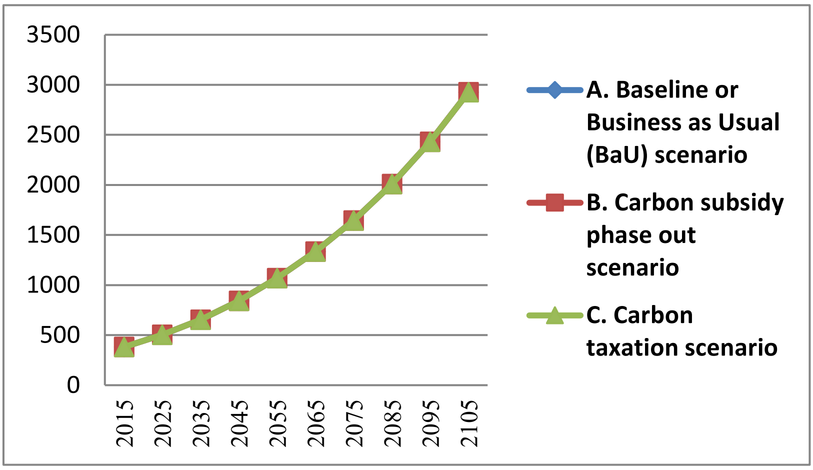

Figure 8. The process without changing labor employment

Source: *Research Findings.*

5.6 Trend of Industrial Carbon Emissions

Under many scenarios, the trend of industrial carbon emissions falling towards the end of the twenty-first century appears to be highly sensible. Because the carbon tax policy scenario cuts industrial carbon emissions significantly more than the other two scenarios. Fossil fuel reliance has resulted in increased carbon emissions in the first two scenarios (BaU and subsidy phase out). Of course, in the long run, the reduction in industrial carbon emissions appears to be convergent, but in the short run, the carbon tax scenario outperforms the other two in terms of reducing industrial carbon emissions and preventing temperature rise and environmental degradation over the period 2015-2100. This lowers CO2 levels in the atmosphere and helps to slow the rise in global temperatures (Figure 9).

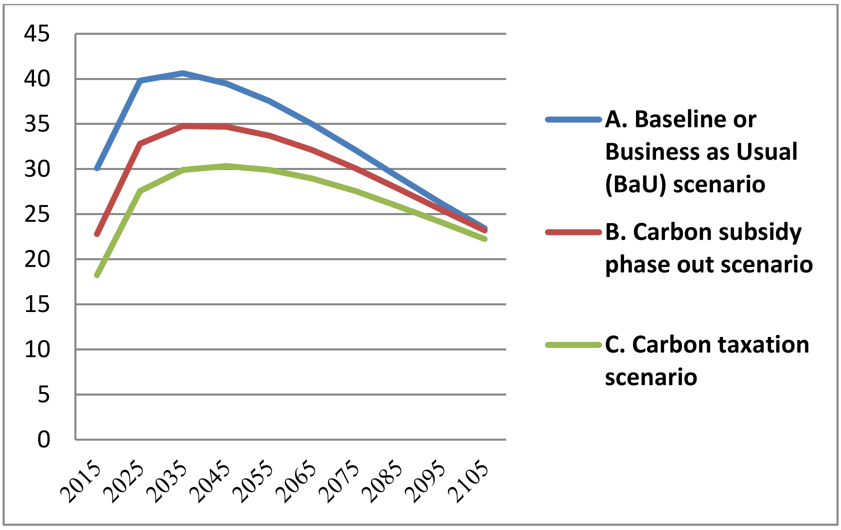

Figure 9. Decrease in Industrial Carbon Emissions
Source: *Research Findings*

5.7 Trend of Damage Coefficient

The amount of environmental harm in the carbon price scenario will be lower than in the BaU and subsidy phase out scenarios, according to Figure 10. This result is consistent with prior findings because, in the long run, GDP in the BaU scenario is lower than the other scenarios due to the higher level of environmental damage. Carbon emissions will be lowered as fossil energy consumption is reduced.

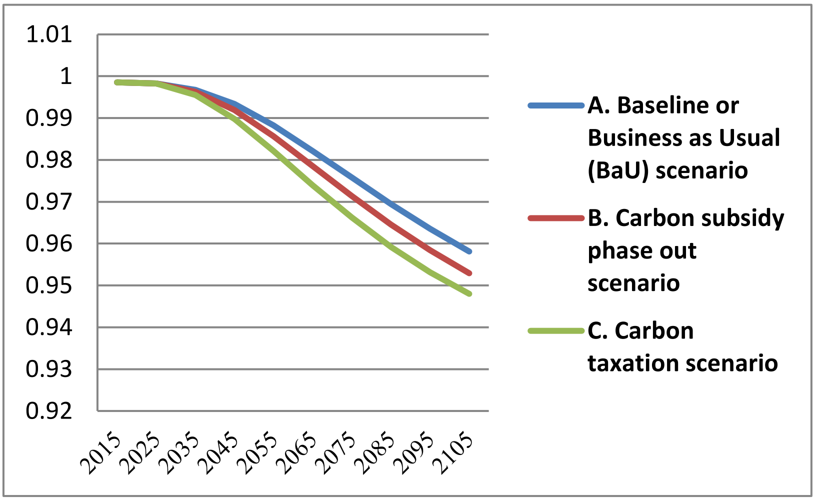

Figure 10. Decrease in Damage Coefficient
Source: *Research Findings*

6. Concluding Remarks

Global warming is an ongoing vital issue, and the majority of studies focus on temperature rises and their influence on the entire world, with a few modest studies focusing on the MENA region. The current research focuses on the various effects of CO2 emissions on both economic and environmental variables in MENA.

Three scenarios are created in order to examine these effects. First, there's baseline, or business as usual (BaU), which is a no-intervention policy with a price tag of US$ -40 per ton of CO2. Second, subsidy phase out which results in a zero carbon price, and finally, a US$ 40 per tCO2 carbon tax policy.

6.1 The Results of the Research

-Carbon tax measures in the MENA area will lower average world temperature increase by 0.5°C compared to other scenarios.

- By the twenty-first century's end, the second and third scenarios will have a considerable impact on the MENA region's GDP or economic growth. In the carbon price scenario, consumption will be higher than in the BaU and subsidy phase out scenarios.

-Capital accumulation in carbon tax scenario will be higher than the other two scenarios as a result of carbon-based fossil fuels cost increase and subsequently, its use decrease while investing more capital in the renewable energy technologies.

- The trend of labor employment in all three scenarios is very similar, demonstrating the ineffectiveness of environmental taxes on manpower activities. However, the carbon price policy will have a significant impact on industrial carbon emissions and damage costs.

Most studies focus on the consequences of rising temperatures in the MENA region, such as Zittis et al. (2021) studies, which suggest that the region would see unprecedented ultra-extreme heat wave conditions in the second part of the twenty-first century.

Furthermore, by the end of the century, nearly half of the MENA's population (about 600 million people) might be subjected to periodic ultra-extreme heat waves.

These studies simply point to the existence of rising heat and its damaging impacts in the MENA region in the middle and end of the twenty-first century, but they don't discuss preventative solutions.

The problem of heating, on the other hand, is a worldwide concern that must be handled on a bigger scale. As a rule, the MENA region is a part of the entire world. As a result, policies for the elimination and pricing of carbon in the MENA region, as one of the world's most important CO2 emitting areas, were implemented in the current study in order to prevent rising CO2 emissions and, as a result, global warming. The current study was unique in that it looked at the impact of these major policies being implemented in the MENA area as a part of the world on global warming.

According to many research, global temperatures would rise by 3 to 4 degrees °C by 2100 if no legislation is enacted to mitigate them. The findings of this study are consistent with recent forecasts by the IPCC and NASA (2021), studies suggest that unless CO2 emissions are reduced, average global temperature rises would approach 2 degrees °C in the next 15-20 years, and more than 4 degrees °C by the end of the century.

Previous research focused on the environmental consequences of global warming (temperature rise) in the MENA area, but did not address the implications of mitigation attempts to minimize temperature rise, as the current study does. Furthermore, previous studies have focused on the majority of the environmental consequences of global warming (temperature rise) in the MENA region, with only a few cases focusing on the economic consequences of global warming in the MENA region, such as effects of global warming on sectors affecting the economy, such as agriculture, industry, transportation, and so on, or only the damage caused by temperature increases on economic growth (GDP) in the MENA region.

This study looked at the environmental (temperature rise) and economic consequences of using mitigation strategies to prevent temperature rise, as well as the effects of these policies on GDP and economic growth indicators (GDP).

6.2 Specific Policy Suggestion

Finally, based on the findings, it is suggested that stronger regulations to curb fossil fuel consumption will be adopted to attain lower global temperatures, as well as higher economic growth and improved metrics by the end of the twenty-first century.

6.3 Our Recommendation for Next Studies

1) It appears that a larger carbon tax should be imposed in the MENA region; therefore, the optimal carbon tax in this region should be determined first, followed by a scenario of carbon pricing and an assessment of the policy's impact on economic and environmental parameters.

2) Assess the impact of other potential policies in this region to minimize fossil fuel usage, such as the use of clean energy, solar, and other renewable energy sources, on economic and environmental aspects.

3) The economic and environmental effects of enacting policies to limit fossil fuel consumption in the MENA area, taking into consideration the existence of commerce between MENA member nations for the purchase and sale of CO2 emissions licenses.

4) Identify other locations of CO2 emissions in the world with a high percentage of emissions and investigate the economic-environmental effects of enacting policies to limit fossil fuel usage in those places, as well as their contribution to global warming. Perhaps it would be preferable to look at the top ten CO2 emitting regions in the globe as a business block and then look at their contribution to global warming.

5) It is preferable for MENA member states to be obligated to reduce fossil fuel consumption, and this should be considered in the form of a treaty such as the Paris Agreement, and then considered if the Paris Agreement is implemented and the temperature limit of 2 degrees °C is limited. By the end of the twenty-first century, what will be the economic and environmental trends in this region?

6.4 Application of Research Results

- Policy proposals of this research can be at the top of government policy goals in order to achieve higher economic growth along with less greenhouse gas emissions, or in other words, attention to sustainable development.

- The results of this study can help analysts and policy makers of economic issues in the countries of the Mena region that in addition to predicting the effects of climate change on the economy as a whole, the effects of climate change on the important parameters of this The section should also pay attention.

- The results of the present study can contribute to the development of global warming economics and even knowledge of climate change.

- Assessing the positive or negative consequences of climate change on important economic variables if carbon tax policy is implemented will guide the government and policymakers in determining whether or not to implement this policy.

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The authors declare no conflict of interest.

Data Availability Statement:

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