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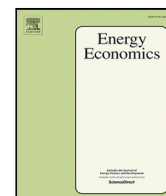
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The implication of the Paris targets for the Middle East through different cooperation options

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ABSTRACT

The core of the 36th round of the Energy Modeling Forum project shows that it is more likely that major fossil-fuel exporters, such as the Middle East, are highly affected because of the decrease in fossil-fuel extractions required for the worldwide fulfillment of the Paris agreement. We employ a multi-region, multi-sector computable general equilibrium model of global trade and energy to examine the effects of implementing the Paris agreement with a focus on the Middle East which is further disaggregated into Iran, Saudi Arabia, the rest of net fossil fuel exporting countries (XFE), and the rest of countries (XNE). After examining the abatement costs for the regions, we apply four emission reduction targets, ranging from a low ambition level to a high ambition level. We develop comprehensive scenarios covering several cooperation options within the Middle East and between the Middle East and selected regions outside. The results show that Iran has the lowest marginal abatement cost in the Middle East, followed by XNE, XFE, and Saudi Arabia. If the Middle East does not implement any climate policy, the welfare losses can be slightly compensated due to a carbon leakage to the Middle East. The cooperations within the Middle East are not welfare increasing for the region as a whole when Iran mainly benefits from such cooperation whereas Saudi Arabia loses welfare. The Middle East benefits from global cooperation and the cooperation with Europe, but the cooperation with China, India, or Russia can be welfare decreasing.

1. Introduction

We are at a defining moment concerning climate change, caused by the anthropogenic greenhouse gas emissions that may cause severe damages ranging from a shortage in food production to rising sea levels and catastrophic flooding. The impacts of changing climatic patterns are universal in scope and unprecedented in scale, which requires immediate action today. Among different approaches to alleviate the harmful results of climate change, emission abatement seems to be the most viable solution at hand but necessitates international efforts and cooperation.

At the 21st Conference of the Parties in Paris in 2015, parties to the United Nations Framework Convention on Climate Change (UNFCCC) reached a consensus to improve a sustainable low carbon prospect via acceleration of actions or intensification of green investments (Unfccc, 2015). The long-term goal of the Paris agreement is to keep the increase

in global average temperature to well below 2 °C above pre-industrial level and to pursue efforts to limit the increase to 1.5 °C (Unfccc, 2015). Through the Paris agreement, most individual countries have submitted national pledges of specific reductions in their carbon emissions by 2030.¹ These so-called Nationally Determined Contributions (NDCs)² can be met through different instruments.

The 36th round of the Energy Modeling Forum (EMF36) investigates various policy regimes to fulfill NDCs and the widespread economic impacts such regimes may bring about (Böhringer et al., 2021). The EMF36 Coalition Subgroup investigates coalition options including and beyond EMF36 Core scenarios (Akin-Olçum et al., 2021). The core of the analyzed EMF36 scenarios includes market-based instruments such as carbon pricing and emission trading system (ETS) (also known as “cap and trade”). Many politicians and economists regard carbon pricing as a cost-effective policy instrument that internalizes the costs

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¹ Some countries stated their announced reductions for other years, such as 2025 (e.g., the USA) or 2035 (e.g., Cameron), or some countries did not even provide any quantified commitments and only provided qualitative efforts.

² The official NDC database can be found here: <https://www4.unfccc.int/sites/NDCStaging/Pages/All.aspx>

of climate damage into prices, allowing for the international trade mechanism being brought into play. The High-Level Commission on Carbon Pricing advocates carbon pricing as a central policy instrument to the Paris targets for its relatively low costs (Stiglitz et al., 2017). ETS is widely recognized as an instrument to increase the efficiency of international greenhouse gas mitigation [Alexeeva and Anger, 2016; Nong and Siriwardana, 2018; Fujimori et al., 2016]. However, it is possible that linking of ETS results in welfare losses in some of participating countries [Flachsland et al., 2009; Fujimori et al., 2016]. Peterson and Weitzel (2016) suggest that to balance indirect market effects in a global ETS, transfer payments to energy exporters are essential (Peterson and Weitzel, 2016).

Among the various regions in the world, it is likely that major fossil-fuel exporters, such as the countries in the Middle East (ME), are affected relatively greater because of the decrease in fossil-fuel extractions required for the worldwide fulfillment of NDCs. The countries in the ME are very diverse. While, for example, Iran and Saudi Arabia are among the top 10 emitters globally, there are countries such as Qatar and the United Arab Emirates whose emissions are comparably very low. Therefore, the abatement potentials would vary significantly between the countries in the ME, and hence, a more careful investigation of the Paris agreement implication for the region is justified. To the best of our knowledge, so far, there is no study concerning the carbon pricing and ETS between the ME regions for achieving the Paris targets. There are few studies and reports that looked into individual countries in the ME from different angles. For example, Yetano Roche et al. (2019) report on some fields of action towards emission mitigation in line with Iran's Intended Nationally Determined Contribution (INDC) (Yetano Roche et al., 2019). Alkan et al. (2018) examine Turkey's INDC and suggest that reaching these targets seems impossible, and more conceivable policies are needed (Alkan et al., 2018). Dong et al. (2018) look into the possibility of achieving INDCs of the top ten CO₂ emitters, including Iran and Saudi Arabia and find the carbon reduction situations of Iran and Saudi Arabia quite severe (Dong et al., 2018). One specific feature of the ME region is a high level of fossil fuel subsidies too. Chepeliev and van der Mensbrugge (2020) show that the elimination of such subsidies may result in emission reductions and welfare improvement while, in some cases, subsidy elimination per se might be even enough to reach the INDC targets (Chepeliev and van der Mensbrugge, 2020). Nevertheless, these studies do not look specifically into the carbon price mechanism.

Following the EMF36 Core scenarios and Coalition Subgroup calculations [Böhringer et al., 2021; Akin-Olçum et al., 2021], this paper examines the effect of implementing the Paris agreement with a focus on the ME. The ME is further disaggregated into two individual countries (Iran and Saudi Arabia) and two aggregated regions (the rest of net fossil fuel exporting countries (XFE, which includes Bahrain, Kuwait, Oman, Qatar, and United Arab Emirates) and the rest of countries (XNE, which includes Israel, Jordan, Turkey, and the rest of West Asia (XWS))).³ The ME is the world's largest producer and exporter of oil and a major player in global natural gas markets. Thus, the economic development of the entire region depends crucially on the macroeconomic impacts of different climate policies. We employ a multi-region, multi-sector computable general equilibrium (CGE) model of global trade and energy. For the benchmark, we use GTAP 9a Power database for the year 2011 [Aguilar et al., 2016; Peters, 2016]. The baseline scenario in 2030 is forward-calibrated utilizing projected CO₂ emissions and GDP data from the International Energy Outlook (IEO) projections (EIA, 2017). After examining the abatement costs for the disaggregated regions, we apply four emission reduction

targets, i.e., NDC, conditional NDC (NDC+), NDC to meet the 2 ° C global average temperature target (NDC-2C), and NDC to meet the 1.5 ° C global average temperature target (NDC-1.5C). We develop comprehensive scenarios covering various cooperation options in the ME as well as scenarios representing important cooperation options between the ME and other regions. For completeness, we also examine a scenario in which the ME does not implement any climate policy when the rest of the world does. In addition, we conduct sensitivity analysis by varying some fundamental elasticity values.

The results show that Iran has the lowest marginal abatement cost (MAC) in the ME, followed by XNE, XFE, and Saudi Arabia. Among the regions in the ME, Iran mainly benefits from cooperation within the ME, but Saudi Arabia does not. If the ME does not implement any climate policy, especially in the high ambition levels, the welfare loss will be slightly compensated due to a net carbon leakage to the ME. While the ME benefits from cooperation with Europe as well as global cooperation, the coalitions with China, India, and Russia are not beneficial. The cooperation with Europe is so beneficial that Iran's welfare rises even beyond its level in the baseline.

The rest of the paper is organized in the following way: In the next section, we discuss the current ME position in the Paris Agreement, including the countries' INDCs and NDCs. Section 3 details the model, data, mapping, process, and assumptions in order to generate the baselines, MACs, and policy scenarios (cooperation options). Section 4 presents the results on baseline, MACs, cooperation scenarios, and a sensitivity analysis. Section 5 present a discussion, and Section 6 concludes the paper.

2. The Middle East in the Paris agreement

According to the EMF36 Core results (Böhringer et al., 2021), the Middle East will expectedly be affected significantly by the fossil fuel cutback required to achieve the Paris targets. Fig. 1 depicts the marginal abatement cost curves (MACCs) in 2030 calculated by TU-Berlin Team and submitted to the EMF36 Core scenarios for the Middle East (MEA)⁴ and some selected regions (China, Europe, India, and Russia). Also, Fig. 2 shows the percentage change in emission, GDP, and welfare (as a composite of representative agent's consumption) in the MEA in 2030 for the NDC target based on the calculations of the reference (Ref) EMF36 scenario submitted by the TU-Berlin Team. The high cost of abatement in the MEA is obvious. For example, for a reduction of about 19% (equivalent to 430 Mt) in CO₂ emission, a carbon price of 100 USD per tCO₂ (\$/tCO₂) is required in the MEA, which is a relatively high abatement cost in percentage change compared to the costs in China, India, and Russia. That is, only Europe has a MAC that is more expensive than MEA. In addition, in absolute terms, MEA has the most expensive MAC, similar to Russia. It may explain why for a relatively low emission reduction of about 2%, GDP and welfare would reduce by approximately 3% and 3.5%, respectively. One of the reasons for such a high MAC in the MEA region is that renewable generation technologies are only a low portion of power technologies in the reference year of 2011. Therefore, most of the emission reductions need to be achieved by reductions in the fossil-fuel based generation, which is quite expensive.

The EMF36 Core scenarios provide NDC, NDC+, and NDC-2C ambition levels for the regions compatible with regions in the GTAP9 data set (Böhringer et al., 2021). The EMF36 Coalition Subgroup investigates coalition options including and beyond the EMF36 Core scenarios for a higher ambition level compatible with the 1.5 ° C target (NDC-1.5C) (Akin-Olçum et al., 2021). The calculations may differ from the expressly stated INDCs by the regions because the baseline against which the NDCs are calculated may differ from what is promised by a specific region or even no quantified measures were in hand. Table 1

³ Note that XNE would still act as a fossil fuel exporter because fossil fuel exporters such as Iraq and Syria were already included in XWS. Nonetheless, we do not further disaggregate the region for the sake of computational capabilities and a more precise interpretation of results.

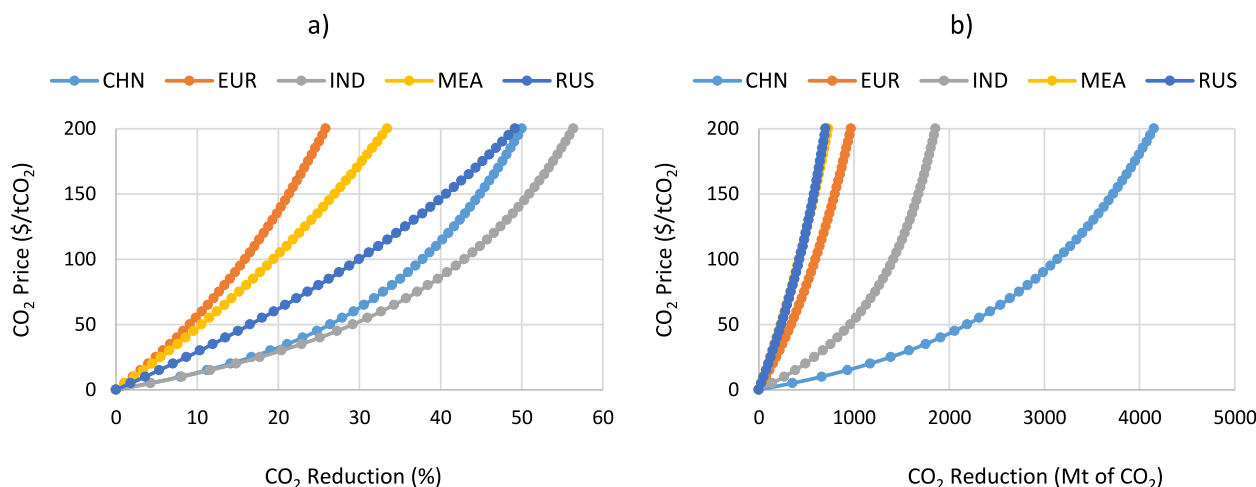


Fig. 1. MACCs in 2030 for the Middle East and selected regions (China, Europe, India, and Russia). Panel (a) shows percentage reductions vs. CO₂ prices in USD per tCO₂. Panel (b) shows absolute reductions in MtCO₂ vs. CO₂ prices in USD per tCO₂.
 Source: Calculations submitted by TU-Berlin Team to the EMF36 Core scenarios (Böhringer et al., 2021).

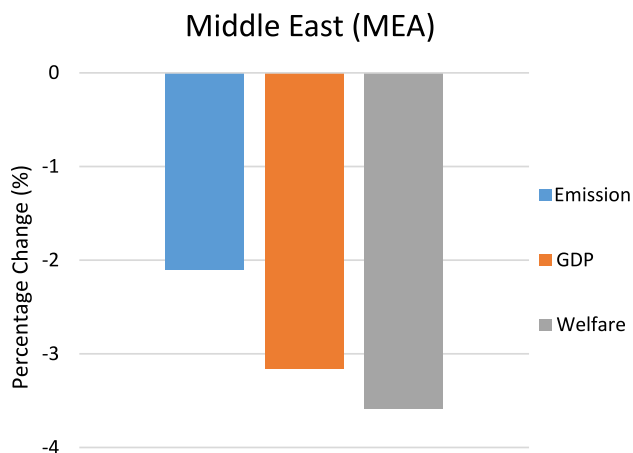


Fig. 2. Percentage change in emissions, GDP, and welfare in the Middle East in 2030 for the NDC target.
 Source: Calculations submitted by TU-Berlin Team to the EMF36 Core scenarios (Böhringer et al., 2021).

Table 1
 NDCs for the Middle East regions (expressed in percentage reduction as against the baseline in 2030).

Regions	NDC	NDC+	NDC-2C	NDC-1.5C
ARE (United Arab Emirates)	NA	NA	10.45	31.99
BHR (Bahrain)	NA	NA	10.45	31.99
IRN (Iran)	4.00	12.00	21.19	40.15
ISR (Israel)	26.00	26.00	33.73	49.67
JOR (Jordan)	NA	0.26	10.68	32.17
KWT (Kuwait)	NA	NA	10.45	31.99
OMN (Oman)	1.32	1.32	11.63	32.89
QAT (Qatar)	NA	NA	10.45	31.99
SAU (Saudi Arabia)	0.42	0.42	10.83	32.28
TUR (Turkey)	NA	NA	10.45	31.99
XWS (the rest of ME)	1.00	14.00	22.98	41.51

details these calculated NDCs in percentage reduction against the IEO baseline in 2030 for the Middle East regions.

⁴ We use MEA to refer to the Middle East in EMF36 core results, but ME refers to the Middle East in our results in this paper.

The region undergoes politically complex situations such as wars and international conflicts, making it a weak point in climate protection issues. Countries like Iraq and Syria, which are included in the region XWS, did not submit any INDCs. All countries mentioned in Table 1 have submitted their INDCs towards achieving the objective of the UN-FCCC. However, Iran and Turkey have not ratified the Paris agreement yet.⁵ Iran’s unconditional INDC intends to mitigate 4% of its GHGs emission in 2030 compared to the business as usual (BAU) scenario. Subject to termination of international sanctions, Iran has declared a potential of mitigating additional GHGs emissions up to 8% against the BAU scenario (i.e., 12% in total) as the conditional INDC.⁶ The EMF36 used these INDCs and NDCs for Iran. Turkey submitted an ambitious NDC of a 21% reduction in its GHG emissions. As stated in Alkan et al. (2018), these targets seem “impossible” to achieve (Alkan et al., 2018). The EMF36 excluded Turkey’s INDCs from consideration. INDC of the United Arab Emirates claims a target on the total mix of energy in 2030, not a quantified measure on the amount of mitigation. It aims at increasing clean energy to 24% of its total energy mix. Israel aims at achieving an economy-wide NDC by reducing its per capita greenhouse gas emissions to 7.7 tCO₂eq by 2030, which is equivalent to a reduction of 26% below the level in 2005 of 10.4 tCO₂eq per capita. Israel expects to achieve an interim target of 8.8 tCO₂eq per capita by 2025. Even though Bahrain, Kuwait, and Qatar show their interests to move to a low carbon economy, their INDCs solely present ideas and possible projects working on achieving this goal voluntarily and do not include any quantified measure for mitigation. Oman’s stated INDC is 2%, and Jordan’s unconditional INDC is 1.5% which can be conditionally increased to 14%. Saudi Arabia’s INDC seeks to mitigate up to 130 million tons of CO₂eq by 2030 annually. While the calculations for the EMF36 state 0.42% reductions in Saudi Arabia’s emission in 2030, Chepeliev and van der Mensbrugge (2020) report the range of the NDC emission reductions for Saudi Arabia to be 3%–19% relative to the baseline in 2030 (Chepeliev and van der Mensbrugge, 2020).

The ME is a very heterogeneous region, both economically and politically. The region includes massive fossil fuel exporters. According

⁵ The INDC data set can be found here: <https://www4.unfccc.int/sites/submissions/INDC/Submission%20Pages/submissions.aspx>

⁶ Iran’s oil export and consequently its economy can be significantly affected by oil and banking sanctions. Farzanegan et al. (2016) and Khabbazan and Farzanegan (2016) show that under these sanctions, Iran’s oil export and GDP can decrease by more than 73% and 14%, respectively, upon the stringency of sanctions [Farzanegan et al., 2016; Khabbazan and Farzanegan, 2016].

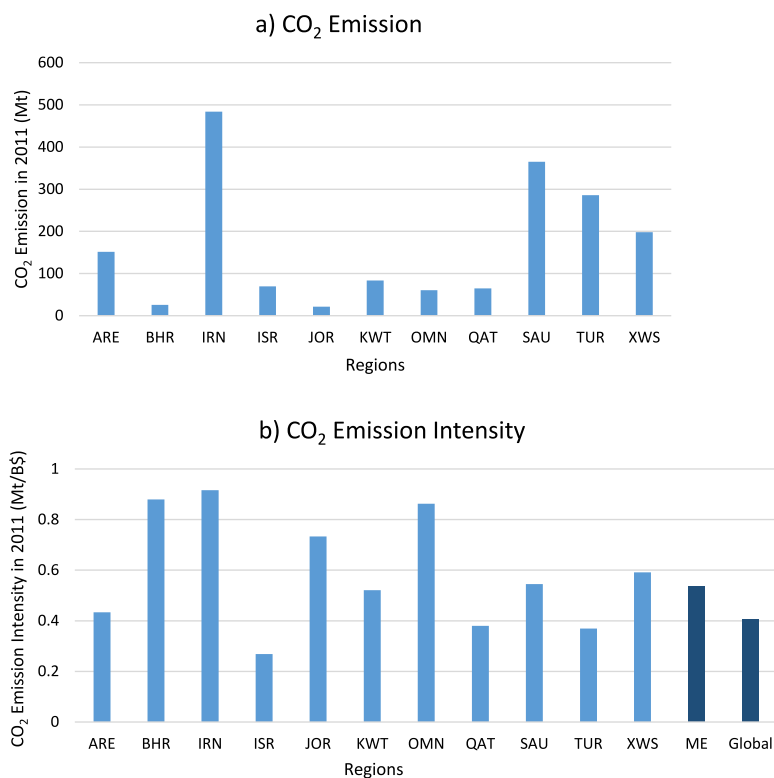


Fig. 3. CO₂ emissions and CO₂ emissions intensity by Middle Eastern countries in the benchmark in 2011.

to the U.S. Energy Information Administration (2020), Saudi Arabia, Iraq, United Arab Emirates, Kuwait, and Qatar are among the top 10 oil exporters globally, while Qatar also ranks the 2nd largest natural gas exporter in the world (Anon, 2020b).⁷ However, in this region, countries like Turkey and Israel are no fossil-fuel exporters. Turkey is Russia's 2nd largest export market for natural gas.

Moreover, the ME includes sizable CO₂ emitters. According to the Report by EU Joint Research Commission, Iran and Saudi Arabia are among the top 10 emitters in the world (Muntean et al., 2018). However, the ME also includes countries like Bahrain and Jordan, whose emissions are comparably low. Fig. 3 shows the amount of CO₂ emissions by Middle Eastern countries and CO₂ emissions intensity (EI), as CO₂ emissions per GDP (MtCO₂/B\$), for the region in 2011 using GTAP 9a Power database (Aguilar et al., 2016; Peters, 2016). Iran emits nearly 500 MtCO₂ which constitutes more than one-fourth of the CO₂ emissions in the region. Saudi Arabia and Turkey are the next biggest emitters in the region, with about 375 and 290 MtCO₂, respectively. Turkey is the greatest non-oil-rich country in the region. Countries with no specific national data in the GTAP data set (XWS) are collectively the fourth largest emitter in the region. Next are the United Arab Emirates, Kuwait, Israel, Qatar, Oman, Bahrain, and Jordan. Bahrain and Jordan together emit less than one-twentieth of total emissions in the region. The average EI in the ME is higher than the global average. While Iran has one of the highest EIs globally, Bahrain, Oman, Jordan, and XWS also have EIs higher than ME's average. These countries have heavily under-developed technologies. On the contrary, the EIs in Israel, Qatar, and Turkey are below the global average.

3. Framework

This section explains the theoretical and numerical framework to analyze the effects of implementing the Paris agreement for the ME. It

⁷ Note that Iran is potentially a prominent exporter of crude oil and natural gas, especially if sanctions are lifted.

details the model and data, regions and sectors, calibration of baselines, procedure to generate the marginal abatement costs (MACs), and policy scenarios (cooperation options).

3.1. Model and data

The model used in this paper is a static multi-region, multi-sector computable general equilibrium (CGE) model of global trade and energy. The core code is based on the GTAPinGAMS model type by Lanz and Rutherford (2016), allowing reading the standard GTAP data and initializing the model (Lanz and Rutherford, 2016). However, Lanz and Rutherford (2016) does not include carbon pricing and ETS (Lanz and Rutherford, 2016). Therefore, we further extended the model based on the model developed by Böhringer and Rutherford (2010) to include carbon pricing and ETS (Böhringer and Rutherford, 2010). We also modified the nesting structure according to the nestings used by Böhringer and Rutherford (2010), where a specific immobile factor is used in a nested CES fossil-fuel production (extractions) technology to calibrate local supply responses and natural resources income, including oil and natural gas (Böhringer and Rutherford, 2010). In addition, the electricity sector is disaggregated into four power generation technologies: renewables (comprising hydro, solar, and wind technologies), nuclear, fossil, and others (including geothermal and bio-fuel technologies). Following Lanz and Rutherford (2016), international commodity markets are competitive (Lanz and Rutherford, 2016). Exports and supply of domestic goods are imperfect substitutes according to constant-elasticity-of-transformation (CET) functions (Lanz and Rutherford, 2016). Also, imports are represented following the Armington approach, where goods that belong to the same category but are produced at different locations are treated as imperfect substitutes [Lanz and Rutherford, 2016; Armington, 1969].

Figs. 4 and 5 show the nesting structure for non-fossil-fuel and fossil-fuel productions, respectively. As a routine procedure in applied general equilibrium analysis, the benchmark data (quantities, prices, and exogenous elasticities) determine the free parameters of the functional forms. For the benchmark, the model builds on the GTAP 9a

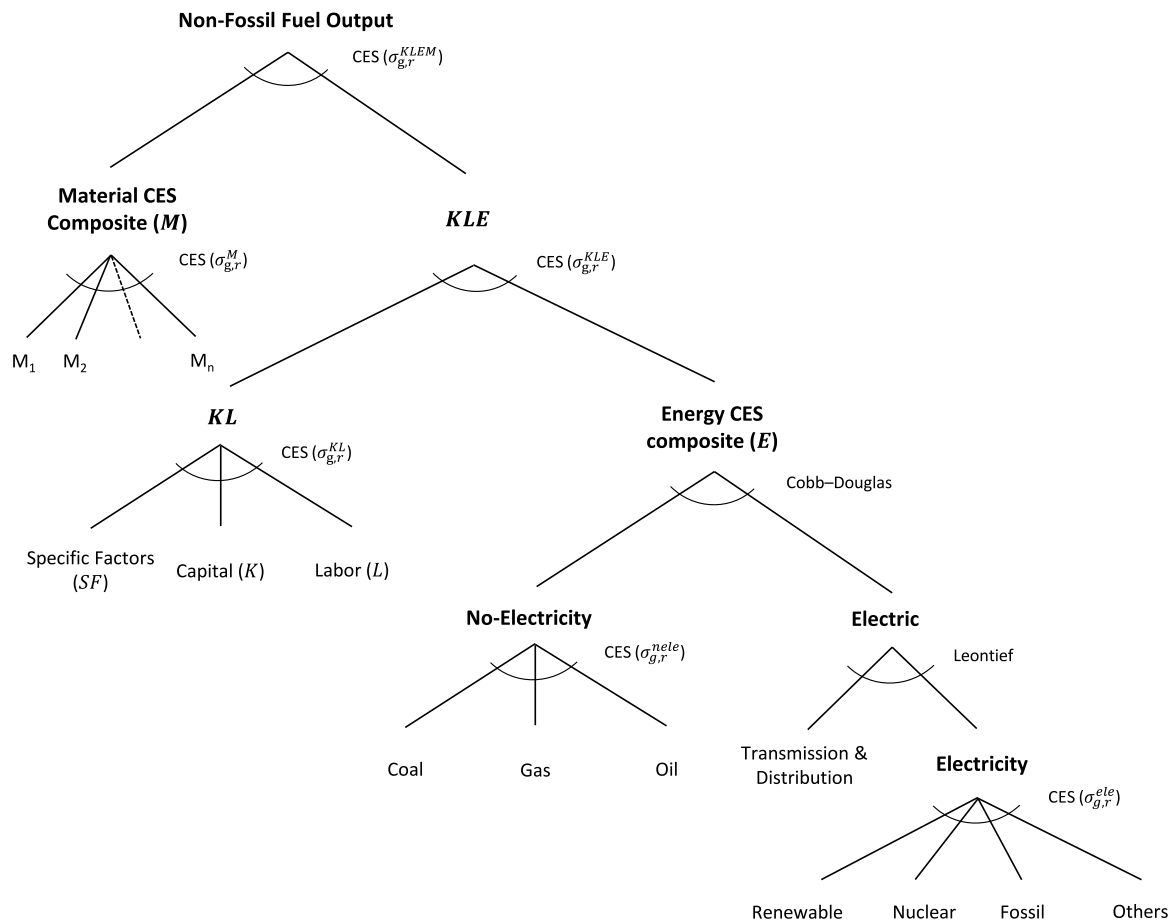


Fig. 4. Nesting structure in non-fossil-fuel production.

Power database with detailed accounts of regional production, consumption, bilateral trade flows, energy flows, and CO₂ emissions for the year 2011 (Aguilar et al., 2016; Peters, 2016). Substitution elasticities, such as elasticities in international trade (so-called Armington elasticities), elasticities between energy inputs and non-energy inputs, and elasticities between production factors (labor, capital, and resources), are provided in Table 2.⁸ All simulations have been implemented in General Algebraic Modeling System (GAMS) software (Brooke et al., 1996) and solved using the solver PATH (Dirkse and Ferris, 1995).

3.2. Regions and sectors

We build on the core regional and sectoral disaggregation proposed in the EMF36 and further disaggregate the ME for our analysis. For the sake of result tractability and numerical efficiency, we aggregate the regions in the ME into four regions, two individual countries (Iran and Saudi Arabia) and two aggregate regions (the rest of net fossil fuel exporting countries, including the United Arab Emirates, Bahrain, Kuwait, and Qatar (XFE) and the rest of regions, including Israel, Jordan, and Turkey (XNE)). Putting XFE and XNE in the context of Fig. 3, XFE and XNE emit about 385 and 574 MtCO₂, respectively, in 2011. Also, XFE and XNE have an emission intensity of 0.495 and 0.411 Mt/B\$, respectively. Note that XNE also includes the collective data for

⁸ CGE models are generally sensitive to key assumptions such as the elasticity levels in the nesting structure. Therefore, it is crucial to see how key results are sensitive to the current assumptions. In Appendix C, as sensitivity analyses, we apply different elasticity levels and examine the changes in results.

countries (such as Iraq and Syria) whose specific data are not available in the GTAP9 data set. As, for example, Iraq is a prominent fossil fuel exporter, XNE also substantially contributes to fossil fuels export. Model sectors and regions are shown in Table 3. In the rest of the paper we only focus on the regions in the ME (the bold regions in Table 3).

3.3. Baselines and NDCs

The baseline scenario is forward-calibrated utilizing projected CO₂ emissions and GDP data. Fig. 6 shows the CO₂ and GDP projected changes from 2011 to 2030 for the baseline. Emissions and GDP profiles in the baseline are based on the International Energy Outlook (IEO) (2017) projections (EIA, 2017). Note that projected CO₂ emissions and GDP data do not take into account the COVID-19 impacts.

For calibration, we simultaneously: i) adjust regional endowment growth of the labor force, capital, and natural resources by the same factor, ii) introduce a regionally unique energy efficiency annual increase that is capped at 3% of the baseline values, and iii) introduce, if necessary, a regionally unique tax rate imposed on the use of CO₂ emitting intermediate inputs (i.e., coal, natural gas, and refined oil). In this process, the real values of government and investment spendings grow at the same rate as private consumption does. Following the EMF36 Core procedure, we only target the total emission in each region, not a specific emission share per fuel. Then, the endowment growth factors and fossil-fuel tax rates are kept constant in their 2030 levels in our static CGE model when deriving the MACs and implementing the policy counterfactuals in 2030. Also, for the counterfactuals and MACs, the government and investment real value spendings are fixed to their 2030 levels. For an alternative approaches to and detailed discussion on long-term baseline construction, see Faehn et al. (2020) and Foure et al. (2020) [Faehn et al., 2020; Foure et al., 2020].

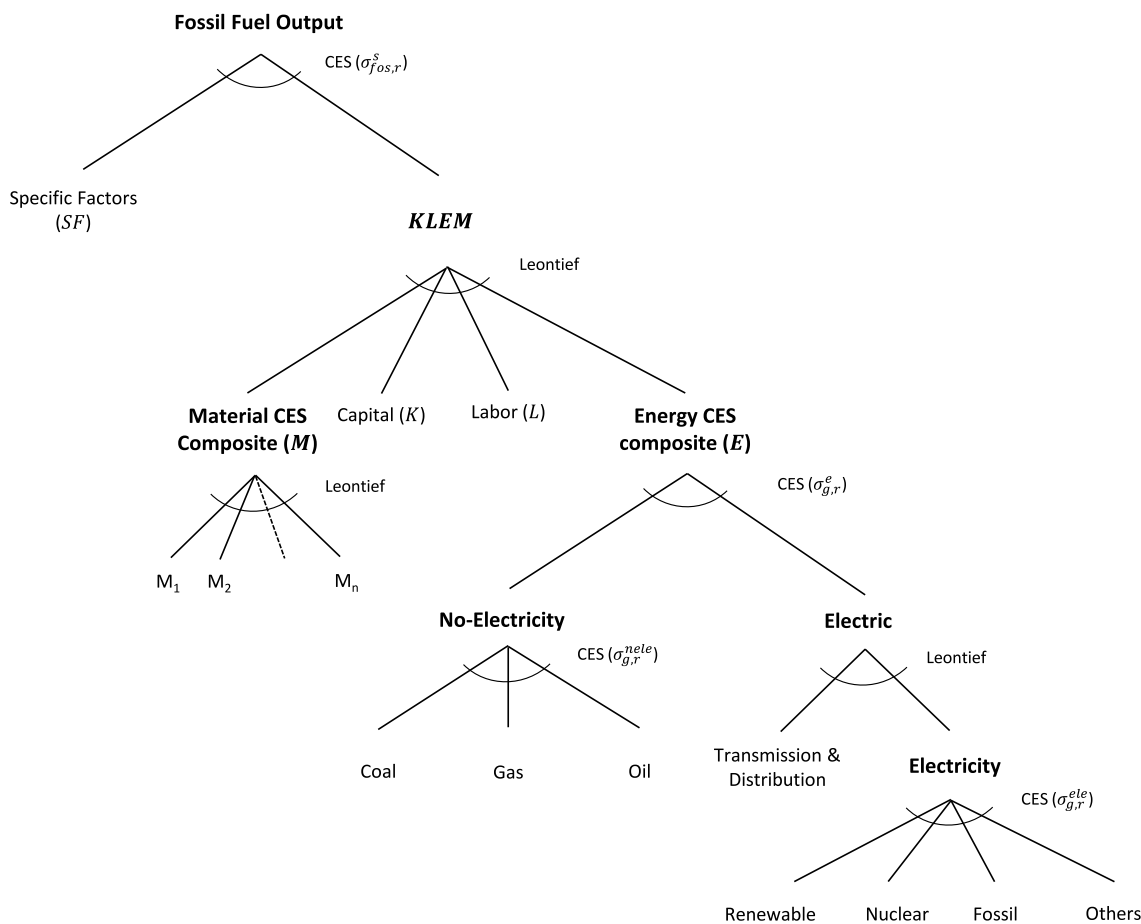


Fig. 5. Nesting structure in fossil-fuel production.

Table 2
Main elasticity values.

Item	Value
Elasticity of supply of fossil fuels	Beckman et al. (2011) (Beckman et al., 2011)
Elasticity of substitution on top of technology nest in fossil production ($\sigma_{fos,r}^s$)	Beckman et al. (2011) (Beckman et al., 2011)
Armington Elasticities for gas and oil	Böhringer and Rutherford (2010) ^a (Böhringer and Rutherford, 2010)
CET Elasticities for gas and oil	Böhringer and Rutherford (2010) ^a (Böhringer and Rutherford, 2010)
Other CET and Armington Elasticities	GTAP ^a ; Lanz and Rutherford (2016) ^a (Lanz and Rutherford, 2016)
Elasticity of substitution between factors ($\sigma_{g,r}^{KL}$)	Okagawa and Ban (2008) (Okagawa and Ban, 2008)
Elasticity of substitution between composite factors and energy ($\sigma_{g,r}^{KLE}$)	Okagawa and Ban (2008) (Okagawa and Ban, 2008)
Elasticity of substitution between power technologies ($\sigma_{g,r}^{ele}$)	4
Elasticity of substitution between non electricity energy ($\sigma_{g,r}^{nele}$)	Böhringer and Rutherford (2010) (Böhringer and Rutherford, 2010)
Elasticity of substitution between non electricity and electricity ($\sigma_{g,r}^e$)	Böhringer and Rutherford (2010) ^a (Böhringer and Rutherford, 2010)
Elasticity of substitution between intermediate inputs ($\sigma_{g,r}^M$)	Okagawa and Ban (2008) (Okagawa and Ban, 2008)
Elasticity of substitution between KLE and intermediate inputs ($\sigma_{g,r}^{KLEM}$)	Okagawa and Ban (2008) (Okagawa and Ban, 2008)

^aElasticities that are 50% increased in 2030 compared to their values in the benchmark.

For NDC targets, we mostly rely on the NDCs provided by the EMF36 Core and Cooperation Subgroup (see Table 1 for the regions in the ME and see Böhringer et al. (this issue) for details on the derivation of NDCs) (Böhringer et al., 2021).⁹ For NDC and NDC+ in

⁹ There are different interpretations of NDCs of some regions in the ME than those used in the EMF36 Core project. Some regions' NDC commitments also provide emission baselines within the commitment that differs from the IEO. As the most crucial example, Saudi Arabia pledges to cut emissions by around 130 Mt in 2030 relative to the baseline (annual cut), and its baseline emissions are projected to be around 1000 Mt in 2030. Therefore, the average NDC and NDC+ would result in emissions reduction by around 13%, while in the EMF36 Core project, the 0.42% reduction target is used. In this context, Chepeliev

Saudi Arabia, we use the lowest estimations in Chepeliev and van der Mensbrugge (2020), 3% (Chepeliev and van der Mensbrugge, 2020). For the rest of the regions in the ME, we rely on the calculations of the EMF36 Core project. Note that the NDC targets for XFE and XNE are weighted averages over the included regions. The weights are CO₂

and van der Mensbrugge (2020) report the range of the NDC emissions reduction for Saudi Arabia to be 3%–19% relative to the baseline in 2030 (see Appendix D in Chepeliev and van der Mensbrugge (2020) (Chepeliev and van der Mensbrugge, 2020)). Other estimates of NDC targets by countries are also available (e.g., du Pont et al. (2017) and Climate Action Tracker (2020) [du Pont et al., 2017; Anon, 2020]).

Table 3
Model regions and sectors.

Countries and Regions	Sectors and Commodities
<i>Individual countries</i>	<i>Non-Electric Energy</i>
Brazil (BRA)	Coal
Canada (CAN)	Crude oil
China (CHN)	Natural gas
India (IND)	Petroleum and oil products (refined)
Iran (IRN)	<i>Electric Energy</i>
Japan (JAP)	Fossil-fuel-based electricity
Saudi Arabia (SAU)	Nuclear-based electricity
South Korea (KOR)	Renewable-based electricity (including hydro, solar, and wind)
Russia (RUS)	Other electricity (including geothermal and bio fuels)
The United States (USA)	Transmission and distribution of electricity
<i>Aggregated regions</i>	<i>Non-Energy</i>
Africa (AFR)	Agriculture
Australia and New Zealand (ANZ)	Energy-intensive trade-exposed
Europe (EU28 + EFTA + ...) (EUR)	Other manufacturing
Other Americas (OAM)	Services
Other Asia (OAS)	Transport
Fossil fuel exporters in ME (XFE)	<i>Final Demand</i>
Rest of ME (XNE)	Representative agent (household)
	Government
	Investment

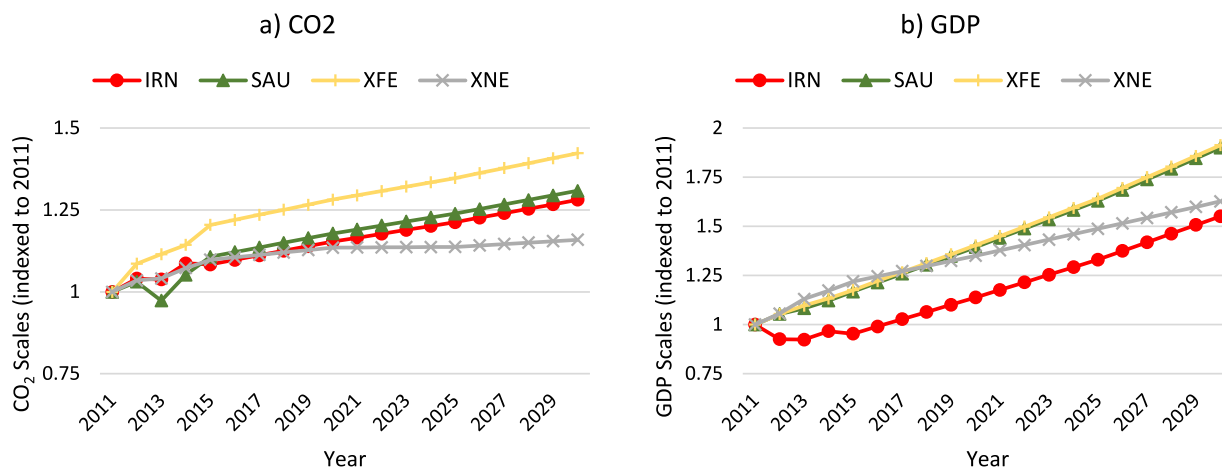


Fig. 6. CO₂ and GDP scales for the IEO baseline in 2011–2030 (used for calibration).

Table 4
NDCs for all regions in the model (expressed in percentage reduction against the baseline in 2030).

Regions	NDC	NDC+	NDC-2C	NDC-1.5C
<i>Middle East</i>				
IRN	4.00	12.00	21.19	40.15
SAU	3.00	3.00	10.83	32.28
XFE	0.22	0.22	10.65	32.14
XNE	3.07	7.80	17.44	37.30
<i>Rest of the world</i>				
AFR	1.83	11.05	20.34	39.50
ANZ	4.73	4.81	14.75	35.26
BRA	18.86	18.86	27.34	44.82
CAN	21.81	21.81	29.98	46.82
CHN	5.00	5.00	14.92	35.39
EUR	24.90	25.04	32.87	49.02
IND	5.00	5.00	14.92	35.39
JPN	8.14	8.14	17.74	37.53
KOR	33.38	33.38	40.34	54.69
OAM	5.96	9.30	18.77	38.32
OAS	12.17	21.70	29.88	46.75
RUS	1.05	1.32	11.63	32.89
USA	15.57	18.20	26.75	44.37

emission in regions, and the regions without NDC targets are bound by their baseline emissions.

3.4. Marginal abatement cost curves (MACCs)

For the MACCs, the carbon price increases beyond the baseline prices per region from 0 to 300 \$/tCO₂ (in 10 \$/tCO₂ intervals). MACCs are simulated for 2030. When the carbon price increases in a region, there is no climate policy implemented in other regions, and hence, the carbon prices in other regions are 0 \$/tCO₂. Given that all actors in a specific region face a common uniform CO₂ price and that markets are competitive, then the CO₂ price will equal the social marginal cost of abatement.

3.5. Policy scenarios

Policy scenarios are implemented in CO₂ emissions reduction in 2030 relative to the baseline CO₂ emissions. Four ambition levels in policy scenarios are considered — NDC (unconditional NDC target), NDC+ (conditional NDC target), NDC-2C (scenario consistent with 2 °C pathway), and NDC-1.5C (scenario consistent with 1.5 °C pathway) (see Table 4). In these policy scenarios, emission targets can be reached in various coalitions ranging from using a regional carbon price to a global carbon price under an emission trading scheme. When regions cooperate, the emission trading scheme applies to all the commodities (including the emission-intensive goods) in those cooperating regions. The regions outside the cooperation (including the regions for which

Table 5
Policy scenarios (cooperations).

Name of scenarios	Regions implementing climate policy/Regions in the cooperation
Ref	Climate policy in all model regions (All Regions)/No region
No_ME	Climate policy in non-Middle Eastern regions/No region
IRN_SAU	All Regions/IRN and SAU
IRN_XFE	All Regions/IRN and XFE
IRN_XNE	All Regions/IRN and XNE
SAU_XFE	All Regions/SAU and XFE
SAU_XNE	All Regions/SAU and XNE
XFE_XNE	All Regions/XFE and XNE
IRN_SAU_XFE	All Regions/IRN, SAU, and XFE
IRN_SAU_XNE	All Regions/IRN, SAU, and XNE
IRN_XFE_XNE	All Regions/IRN, XFE, and XNE
SAU_XFE_XNE	All Regions/SAU, XFE, and XNE
IRN_SAU_XFE_XNE	All Regions/IRN, SAU, XFE, and XNE (ME)
ME_CHN	All Regions/ME and CHN
ME_EUR	All Regions/ME and EUR
ME_IND	All Regions/ME and IND
ME_RUS	All Regions/ME and RUS
Global	All Regions/All regions (including non-reported regions)

we do not report) should still comply with their ambition levels without forming any cooperation.

Table 5 shows the cooperations and regions involved. The cooperations presented in Table 5 include: I) Ref, in which all model regions comply with the targets, but there is no coalition formed among any regions. II) No_ME is a scenario in which the countries in the ME do not implement any climate policy, but the other model regions comply with their targets without any coalitions formed. III) Cooperations within the ME, in which various possible combinations of regions in the ME form a coalition (eleven scenarios). IV) Cooperations between the ME and others, in which all regions in the ME cooperate with selected regions (five scenarios). Among the possible cooperations, we selected cooperations that perhaps make most sense geopolitically for the ME: We include China, Europe, India, and Russia into the analysis and investigate cooperations formed between all the regions in the ME and these regions. The assumption here is that all the regions within the ME are already collaborating. In addition, as an ultimate case, we consider Global cooperation in which all the regions in the model cooperate. While there are possibilities that each region in the ME autonomously forms a coalition with regions outside the ME, we limit our analysis to those mentioned in Table 5.

4. Results

In this section, we first present the emission share of each fuel for the regions in the Middle East (ME) region. Then we present the MACs for the ME regions, followed by the policy options result within the ME and between the ME and regions outside the ME. Finally, we present a sensitivity analysis on the supply elasticity of fossil-fuel productions.

4.1. Baseline

Table 6 presents the emission share of fuels (%) in the baseline in 2030 for the ME regions after the calibration (see Section 3.3 for details on the calibration). The production technologies and energy mix can give important information about the differences in the economy of the regions in the ME in 2030. According to Table 6, except for XNE, in which coal constitutes about 16% of total emission, coal usage is a negligible source of emission (lower than 1% of total emission) in other regions in the ME. Note that Saudi Arabia does not use coal in 2030.¹⁰ In addition, oil usage is the primary source of emitted CO₂ in Saudi Arabia, XNE, and Iran, but XFE's emissions majorly root from

Table 6

Emission share of fuels (%) and CO₂ Price (\$/tCO₂) in baseline in 2030 for the Middle East regions.

Regions	Emission share of fuel (%)		
	COL	GAS	OIL
IRN	0.02	46.93	53.04
SAU	–	24.56	75.44
XFE	0.78	65.40	33.82
XNE	15.88	19.09	65.03

burning natural gas. It is noticeable that, unlike Iran, Saudi Arabia and XNE are mainly dependent on oil. These results give a clear view of the technological differences in the ME regions and can facilitate the interpretation of results in the coming sections.

4.2. Marginal abatement cost curves

Marginal abatement costs (MACs), from a regional perspective, hinge upon many circumstances, including domestic potentials for emission reduction and abatement opportunities by importing commodities with lower emissions. Fig. 7 shows the MACCs in percentage and absolute changes in the ME regions in 2030. Given that markets are competitive and that all actors in a specific region face a uniform CO₂ price, then the CO₂ price will equal the social marginal cost of abatement. MACCs in both percentage and absolute changes are informative. While panel (a) is necessary to check the carbon prices regarding the targets presented in percent change reduction in carbon emission, panel (b) can show how much a specific region may supply or demand in a theoretical emission permit market.

Regions in the ME are diverse concerning their MACs. Iran has the cheapest attainable abatement in both percentage and absolute reductions. For a carbon price of 300 dollars per ton of CO₂ (\$/tCO₂), Iran can reduce its CO₂ emission by more than 51%, which constitutes more than 317 megatons of CO₂ (MtCO₂) emission. XNE has the second cheapest MACs, and for a carbon price of 300 \$/tCO₂, XNE can reduce its CO₂ emission by about 42%, which constitutes about 270 MtCO₂ emissions. Saudi Arabia and XFE similarly have the most expensive MACs in percentage changes. Saudi Arabia and XFE can only mitigate about 31% of their CO₂ emission for a carbon price of 300 \$/tCO₂, which is equivalent to nearly 150 MtCO₂ emissions in Saudi Arabia and 167 MtCO₂ emissions in XFE.

The results can be explained through: I) dependency of each economy on fuels, II) the potentials for further emission reductions, and III) the emission intensity. As a measure for the dependency on fuels, the share of emission by fuels in baseline can be taken into account (see Table 6). As Saudi Arabia and XFE are highly dependent on oil,

¹⁰ For faster computation, the data are rounded to four decimals. Therefore, negligible numbers lower than 10e-4 are rounded to zero, and so may be true for the amount of coal used in Saudi Arabia.

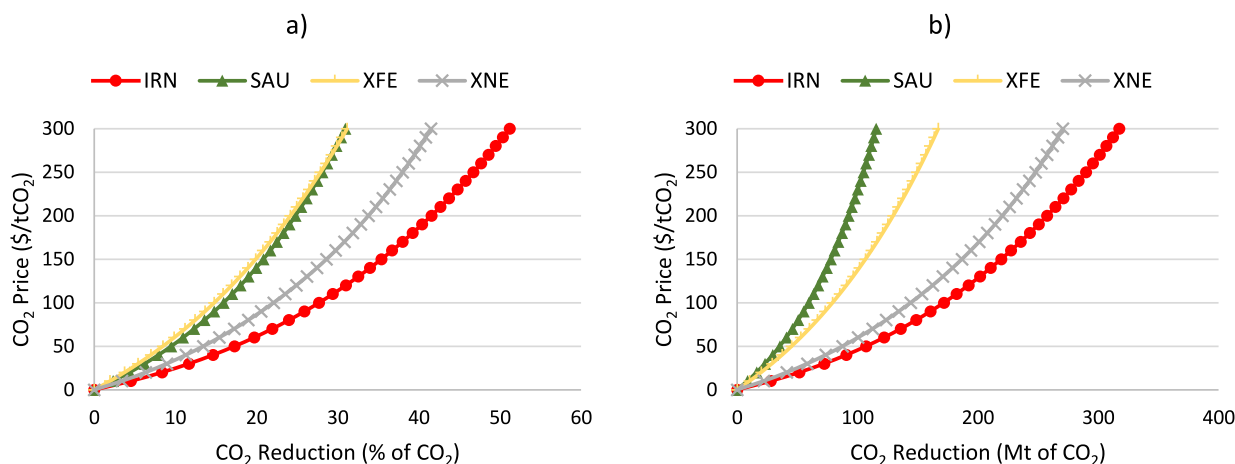


Fig. 7. MACCs in 2030 per region. Panel (a) shows percentage reductions vs. CO₂ prices in USD per tCO₂. Panel (b) shows absolute reductions vs. CO₂ prices in USD per tCO₂.

abatement costs may increase due to the stringency of substitutions of fuels in the production process. Such a dependency is lower for Iran and XNE. However, Iran and XNE have different abatement opportunities. Iran mainly substitutes oil with natural gas for abatement. But, XNE can either substitute oil with natural gas or reduce coal usage. As a measure for the potentials of further abatement, emission intensity can also be considered. As the emission intensity in XNE is almost half of the emission intensity in Iran, it implies that abatement in Iran can be less costly than XNE.

While these figures suggest that Iran will likely act as an emission permit supplier in cooperation scenarios and Saudi Arabia may become an emission permit demander, two remarks are necessary. Firstly, the position in the emission market not only depends on the MACCs of specific countries but also on the exact positions on the MACCs, which are accordingly defined by the countries' NDCs. As the NDCs are generally low without significant differences, one may not expect a considerable welfare-increasing potential for cooperations in the ME. Secondly, as the MACs are derived without a climate policy in other regions, the speculations about ETS formations cannot be accurate because international trade, as a crucial factor in multi-regional models, is mostly ignored. Therefore, the following section investigates the policy options and cooperations scenarios in more detail.

4.3. Policy scenarios

In this section, policy scenarios are implemented in CO₂ emissions reduction in 2030 relative to the baseline CO₂ emissions. In these policy scenarios, emission targets can be reached in various coalitions ranging from a regional carbon price to a global carbon price under an emission trading scheme (see Table 5 in Section 3.5). First, we investigate the aggregate macroeconomic results for the cooperations. Then we report the results for the regions in the ME. For the sake of brevity, we only present the results on the ambition levels NDC and NDC-1.5C as the lowest and highest possible targets (we report the results for NDC+ and NDC-2C for selected variables in Appendices A and B). Also, we only present the results for selected scenarios that have noticeable welfare effects.

4.3.1. Aggregate results

This section presents the results on the aggregate macroeconomic variables in the ME. Fig. 8 shows the percentage change in the total CO₂ emission, and Fig. 9 shows the corresponding average CO₂ price in USD per tCO₂ for the region. The average CO₂ price is simply the weighted average of CO₂ prices in the ME regions. Figs. 10 and 11 depict the percentage change in aggregate welfare and aggregate CO₂ revenues, respectively. Welfare is calculated as a composite of representative agent's consumption. By definition, if there is no cooperation

with regions outside the ME, the aggregate CO₂ emission for the ME does not change along with cooperation levels and only differs with ambition levels (NDCs). The aggregate emission reductions in the Ref and cooperations within the ME are about 2.6% in NDC and nearly 36% in NDC-1.5C. The corresponding average carbon prices for the Ref scenario in NDC and NDC-1.5C are, respectively, 15 \$/tCO₂ and 310 \$/tCO₂. In the Ref scenario and under NDC targets, welfare reduction is about 3.2%. Welfare loss amounts to about 12.2% in NDC-1.5C. Also, the results show that aggregate CO₂ revenues are about 32 B\$ and 435 B\$, respectively, for NDC and NDC-1.5C in the Ref scenario.

The results show leakages of emission to the ME under the No_ME scenario (by about 0.77% and 3.7% of the emission in the baseline, respectively, in NDC and NDC-1.5C). However, such leakages can only result in a partial elevation in welfare under high ambition levels, compared to Ref, meaning that much of the welfare loss in the ME is due to the massive cutback in importing fossil fuels from the ME. In addition, the cooperations within the ME are not notably welfare-increasing or welfare-decreasing. One reason is that even though Saudi Arabia and XFE have the most expensive MACs, their ambition levels are so low that the carbon prices in Saudi Arabia and XFE may not increase to a high amount that brings about significant benefits from cooperation with regions such as Iran and XNE with lower MACs. However, this does not preclude benefits for specific regions in the ME. The following section will elaborate on the regional results and present a short discussion on them.

Moreover, several important insights emerge. I) In coalitions with China, India, and Russia, the ME is an emission permit demander. While China and India have relatively lower MACs, Russia promises comparably lower NDCs. Thus, the common carbon price is lower in such coalitions. Consequently, two effects prevent the ME from welfare gains: Firstly, China and India are great importers of fossil fuels from the ME, and their efforts to reduce emissions will finally hit the total export of fossil fuels in the ME. Secondly, the effects of payments from the ME to China, India, and Russia are significant and cancel out the possible gains. Indeed, in the high ambition levels, the payments are dominant, and the ME welfare is slightly worsened. II) The ME highly benefits from cooperation with Europe. Europe has comparably very high promises, which result in higher carbon prices in the Ref scenario than the average carbon prices in the ME. Europe is also a major fossil fuel importer from the ME. Therefore, there are massive payments from Europe to the ME, and at the same time, fossil fuel exports increase. Consequently, the ME significantly gains welfare—the welfare losses are almost one-third of the welfare losses in the Ref scenario. Furthermore, III) the Global coalition is also beneficial for the ME. In low ambition levels, similar to the cooperation with Europe, the ME is a supplier of emission permits, and ME fossil fuel

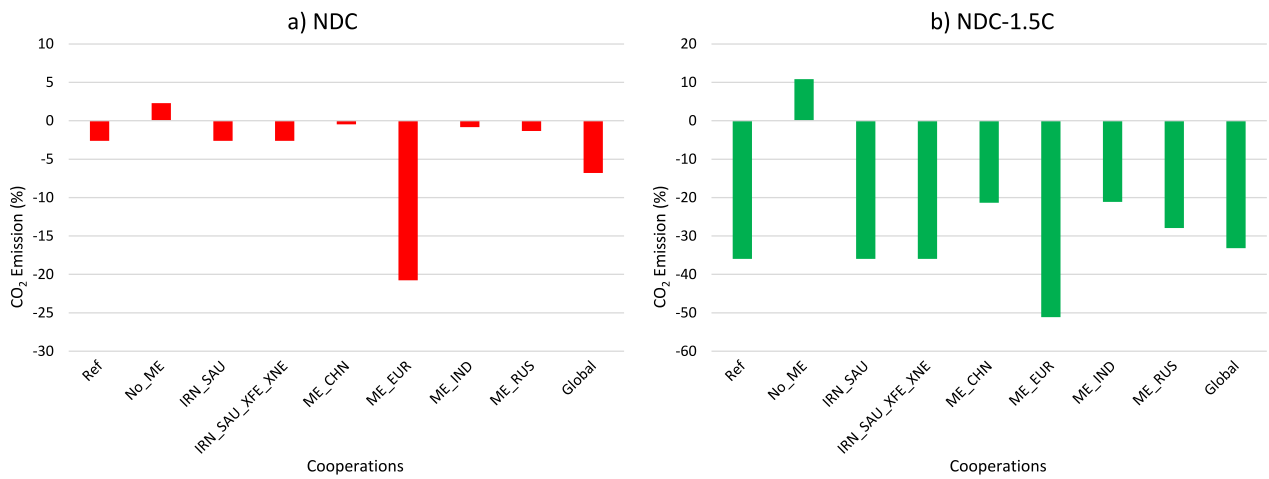


Fig. 8. Percentage change in aggregate CO₂ emission in the Middle East for different levels of cooperation and NDCs.

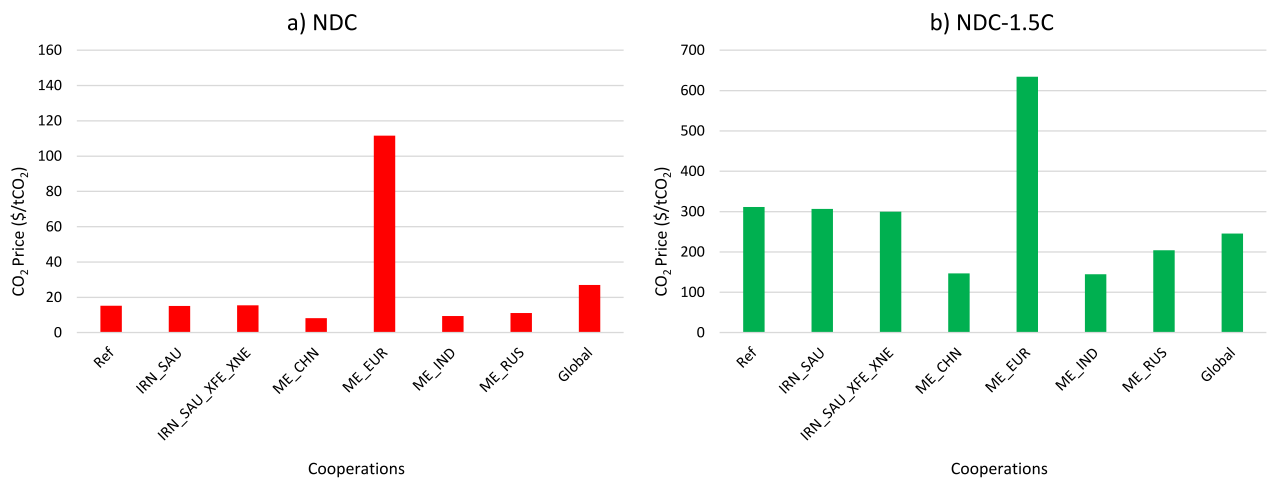


Fig. 9. Average CO₂ price in the Middle East in USD per tCO₂ for different levels of cooperation and NDCs.

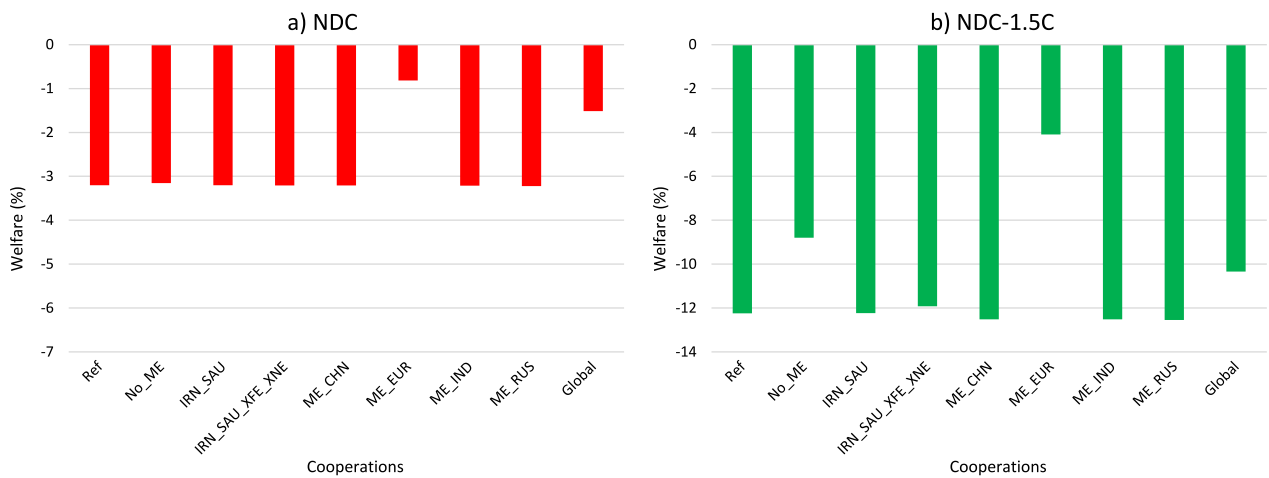


Fig. 10. Percentage change in aggregate welfare in the Middle East for different levels of cooperation and NDCs.

exports increase. However, the advancement in ME fossil fuel exports in the Global cooperation is much more significant than the cooperation with Europe due to the more efficient redistribution of carbon permits worldwide. In higher ambition levels, the ME takes the position of emission permit demander. Nevertheless, the effect of the export is dominant, ME welfare increases.

4.3.2. Regional results

This section presents the regional results in the ME. Figs. 12 and 13 show the percentage change in regional CO₂ emission and the corresponding regional CO₂ price in USD per tCO₂, respectively. Also, Figs. 14 and 15 show the percentage change in regional welfare and CO₂ revenues. In addition, Tables 7 to 10 show the percentage changes

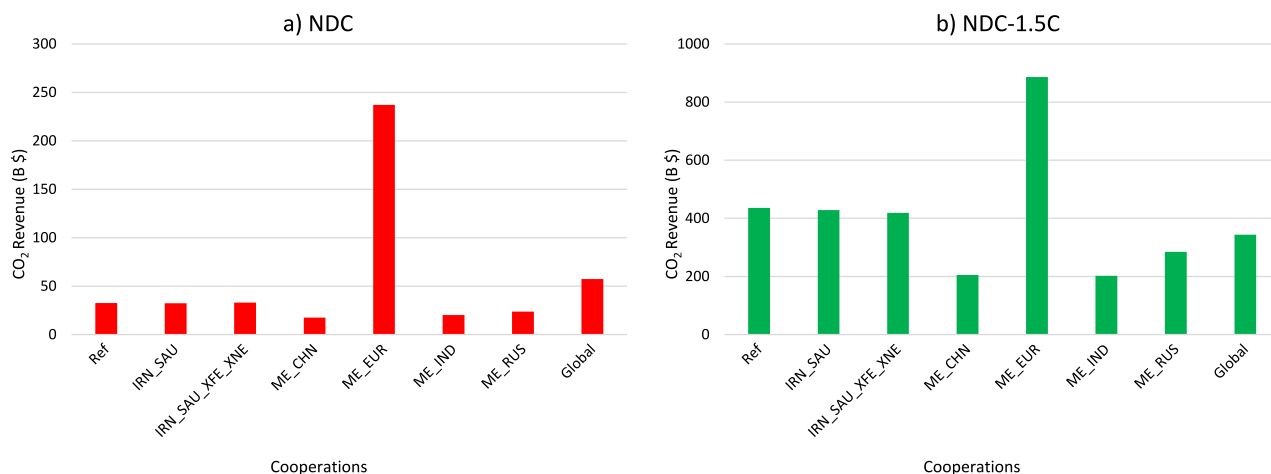


Fig. 11. Aggregate CO₂ revenues for the Middle East for different levels of cooperation and NDCs.

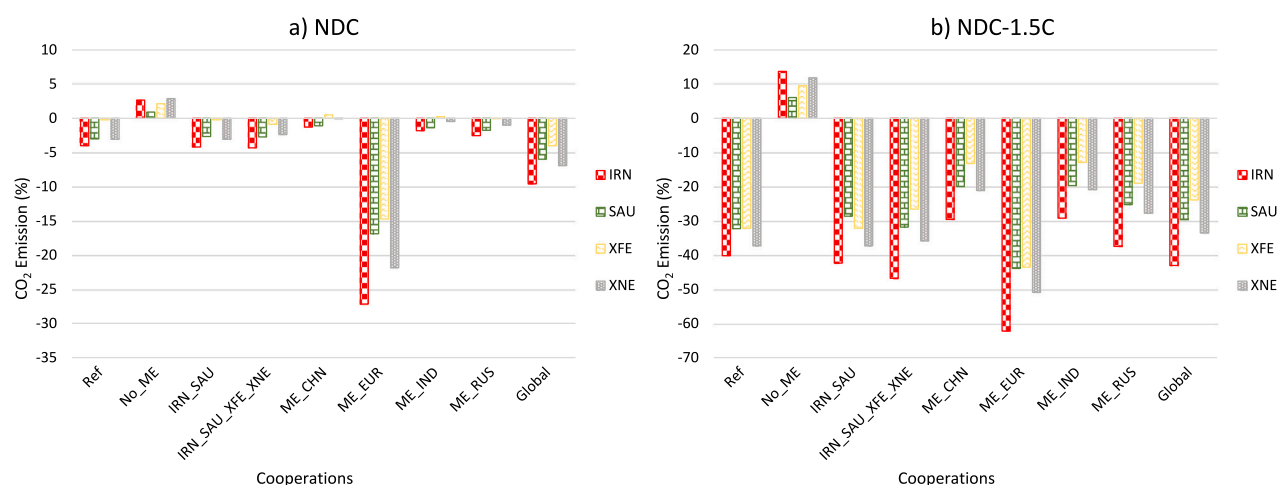


Fig. 12. Percentage change in regional CO₂ emission in the Middle East for different levels of cooperation and NDCs.

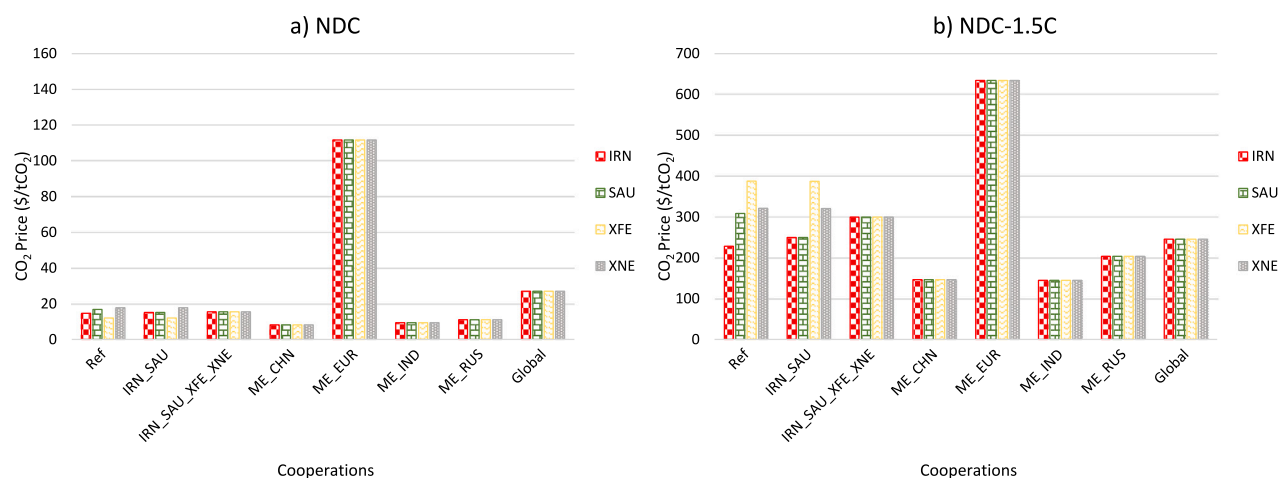


Fig. 13. Regional CO₂ price in the Middle East in USD per tCO₂ for different levels of cooperation and NDCs.

in selected regional macro-indicators. In the Ref scenarios, the regions are bounded to their promised ambition levels, and the carbon prices reflect the astringency of the ambition level and availability of domestic abatement potentials.

In the Ref scenario, Saudi Arabia and XFE NDC targets are so low that the required carbon prices to meet their promises are similar

to the levels required in Iran and XNE, whose MACs are cheaper. Under the Ref, the carbon prices in Iran and XNE are, respectively, about 14.6 \$/tCO₂ and 17.7 \$/tCO₂, and the carbon prices in Saudi Arabia and XFE are about 16.8 \$/tCO₂ and 12.0 \$/tCO₂. Concerning higher ambition levels, only the emission reduction needed in XFE is high enough to increase its carbon price to the highest level. The

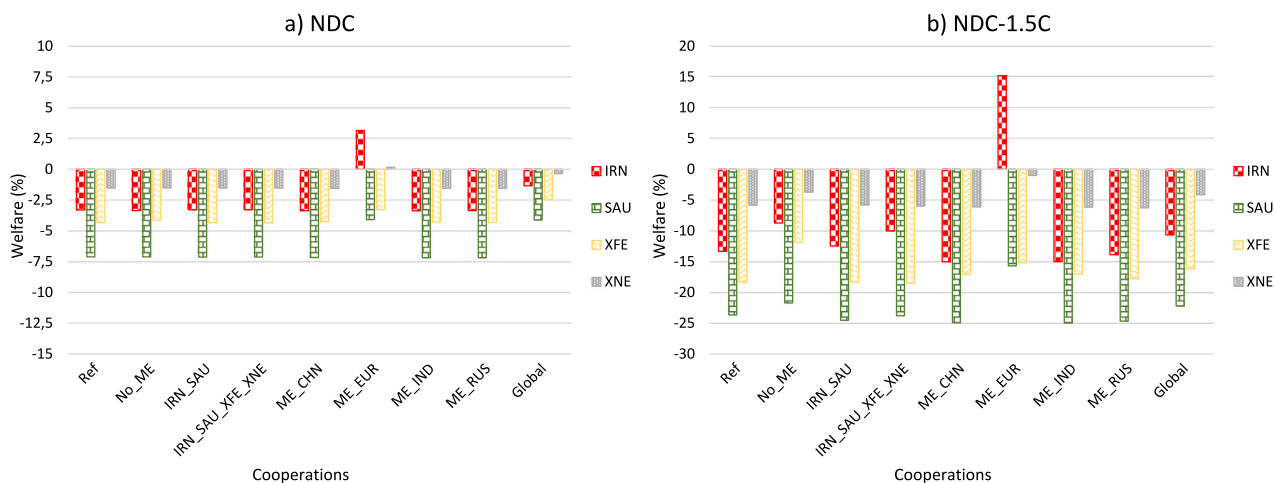


Fig. 14. Percentage change in regional welfare in the Middle East for different levels of cooperation and NDCs.

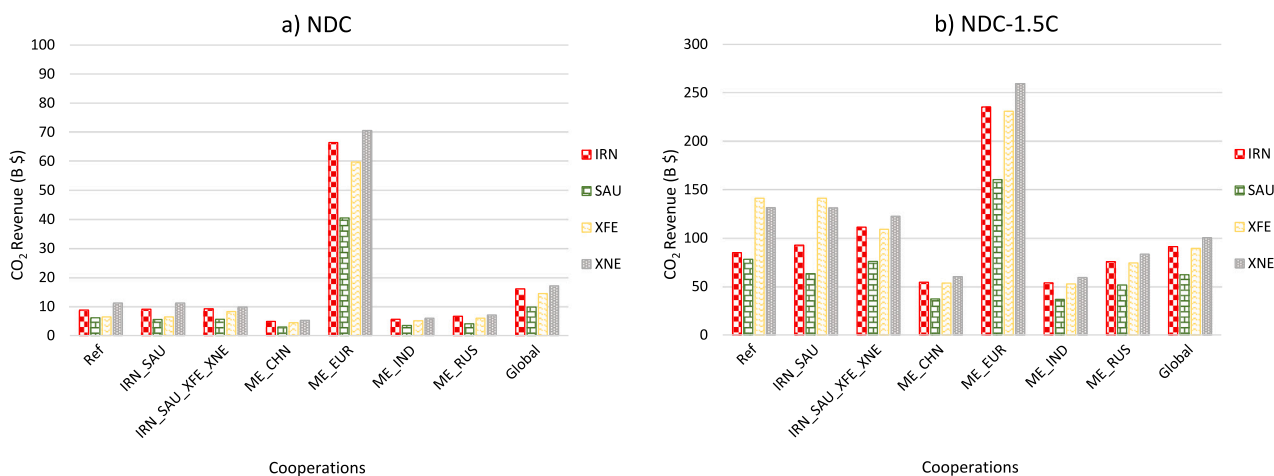


Fig. 15. Regional CO₂ revenues in the Middle East for different levels of cooperation and NDCs.

Table 7
Macro-indicator changes (%) in Iran.

	NDC					NDC-1.5C				
	Ref	No_ME	ME	ME_EUR	Global	Ref	No_ME	ME	ME_EUR	Global
GDP	-2,79	-2,62	-2,79	0,36	-1,27	-12,03	-6,95	-10,34	4,48	-9,36
Labor Inc.	-1,89	-0,26	-1,97	-7,34	-2,27	-21,05	1,16	-23,49	-23,69	-19,21
Capital Inc.	-3,67	-2,43	-3,73	-8,15	-3,15	-21,79	-6,71	-23,49	-24,72	-20,00
Nat. Res. Inc.	-11,75	-14,00	-11,61	1,21	-4,54	-24,09	-45,93	-20,70	-20,24	-19,07
Tax Reven.	-4,06	-1,57	-4,18	-10,85	-4,69	-27,32	-1,01	-28,97	-24,50	-26,37
Private Cons. Q	-1,94	-1,44	-1,96	-0,84	-1,68	-14,17	-3,48	-13,68	-5,18	-14,01
Private Cons. P	-1,39	-1,94	-1,36	4,03	0,34	0,98	-5,42	4,24	21,51	3,9
Oil Prod.	-1,49	-2,01	-1,46	0,83	-0,36	-1,33	-8,69	-0,64	-1,60	-0,70
Oil Exp.	-3,84	-5,70	-3,74	6,06	-0,02	3,41	-25,22	8,52	17,92	7,15
Oil Dom.	2,58	4,37	2,49	-8,19	-0,96	-9,52	19,84	-16,44	-35,29	-14,26
Nat. Gas Prod.	-6,05	4,09	-6,57	-53,21	-12,87	-65,31	29,59	-80,21	-98,84	-64,54
Nat. Gas Exp.	-5,94	1,21	-6,33	-51,17	-9,93	-60,12	27,94	-78,43	-98,99	-60,55
Nat. Gas Dom.	-6,08	4,85	-6,63	-53,74	-13,65	-66,67	30,02	-80,68	-98,80	-65,59
Electricity Prod.	0,58	4,45	0,37	-12,11	-3,36	-6,34	22,84	1,81	55,39	-5,14
Electricity Exp.	24,93	56,27	23,24	-55,79	-11,90	-43,38	323,04	-55,16	-64,08	-52,07
Electricity Dom.	-0,64	1,87	-0,77	-9,93	-2,94	-4,50	7,91	4,64	61,34	-2,81
Total Exp. Q	-0,94	-0,85	-0,95	-2,27	-0,47	-1,63	-3,42	-2,26	-7,07	-0,42
Total Exp. P	-3,43	-3,18	-3,44	-3,64	-1,94	-13,25	-7,20	-14,21	-15,78	-11,57
Total Imp. Q	-4,37	-3,82	-4,38	1,21	-2,74	-17,28	-9,03	-12,97	16,52	-14,75
Total Imp. P	-0,82	-0,94	-0,82	0,21	0,06	-0,87	-3,05	-0,46	1,84	1,17

carbon prices in the NDC-1.5C in Iran, Saudi Arabia, XFE, and XNE are approximately 229, 309, 388, and 321 \$/tCO₂. Also, Saudi Arabia has the highest welfare loss (-7.1% and -23%, respectively, for NDC and NDC-1.5C ambitions levels), whereas XNE has the lowest welfare loss

(-1.5% and -5.8%). Besides having the highest MACs and the lowest diversity in the mitigation options, Saudi Arabia is highly dependent on oil export revenues, and hence the fall in Saudi Arabia's oil export results in a relatively high loss in its total export. However, XNE has

Table 8
Macro-indicator changes (%) in Saudi Arabia.

	NDC					NDC-1.5C				
	Ref	No_ME	ME	ME_EUR	Global	Ref	No_ME	ME	ME_EUR	Global
GDP	-4,01	-3,97	-4,01	-2,50	-1,95	-13,68	-12,43	-13,73	-10,01	-11,00
Labor Inc.	-4,22	-4,02	-4,22	-3,57	-2,04	-17,21	-13,67	-17,12	-15,81	-12,94
Capital Inc.	-2,54	-1,91	-2,49	-5,12	-1,65	-15,74	-5,66	-15,55	-23,02	-11,58
Nat. Res. Inc.	-15,72	-15,72	-15,78	-12,26	-9,54	-45,45	-49,27	-45,52	-37,74	-43,75
Tax Reven.	-3,87	-2,92	-3,81	-6,68	-2,82	-20,52	-8,31	-20,36	-23,37	-16,44
Private Cons. Q	-5,89	-5,27	-5,87	-6,84	-4,35	-27,17	-16,44	-27,1	-27,28	-25,48
Private Cons. P	-1,29	-1,96	-1,35	2,95	0,23	4,81	-6,31	4,5	15,95	4,38
Oil Prod.	-2,20	-2,27	-2,21	-1,41	-1,30	-7,16	-9,53	-7,20	-4,65	-7,30
Oil Exp.	-2,91	-3,26	-2,95	-0,64	-1,37	-7,11	-13,92	-7,22	-1,89	-7,41
Oil Dom.	1,61	3,05	1,73	-5,58	-0,95	-7,38	13,96	-7,11	-19,42	-6,71
Nat. Gas Prod.	0,15	1,94	0,29	-7,41	-1,61	-9,69	9,93	-9,32	-25,63	-7,05
Nat. Gas Exp.	0,90	0,54	0,87	-6,06	2,31	-16,38	12,67	-15,05	-53,76	-2,82
Nat. Gas Dom.	0,04	2,15	0,20	-7,61	-2,20	-8,69	9,52	-8,45	-21,40	-7,69
Electricity Prod.	-3,88	-1,69	-3,72	-11,90	-4,44	-29,80	-4,62	-29,45	-38,24	-26,39
Electricity Exp.	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Electricity Dom.	-3,88	-1,69	-3,72	-11,90	-4,44	-29,80	-4,62	-29,45	-38,24	-26,39
Total Exp. Q	-1,16	-1,32	-1,17	-0,32	-0,42	-3,06	-5,58	-3,09	-2,31	-2,44
Total Exp. P	-4,73	-4,55	-4,73	-4,37	-2,55	-16,44	-13,81	-16,41	-16,54	-13,13
Total Imp. Q	-6,66	-6,58	-6,68	-4,76	-4,02	-22,99	-21,45	-23,07	-18,02	-21,35
Total Imp. P	-0,79	-0,83	-0,80	-0,20	-0,07	-1,55	-2,80	-1,58	-0,08	-0,08

relatively more diverse mitigation possibilities and is less dependent on fossil fuel exports than other regions in the ME. Welfare losses in Iran and XFE are in the middle between Saudi Arabia and XNE. While Iran has the cheapest MAC, its higher dependency on fossil fuel revenues than XNE makes Iran more vulnerable.

Under the No_ME scenario, there are emission leakages to all the regions in the ME. That can be explained by the substitutability the export of fossil fuels by their domestic use when the demand for and prices of fossil fuels drop. Nevertheless, the global decrease in fossil fuel use is still dominant, and all regions experience welfare losses compared to the baseline. Compared to the Ref scenario, under higher ambition levels, as the leakages rise, the No_ME scenario is welfare-improving, especially in Iran, XFE, and XNE.

When cooperations form within the ME, there are no significant welfare changes in lower ambition levels because the minor differences in the carbon prices in the Ref leave no significant room for a beneficial coalition. Under higher ambition levels, however, Iran benefits from coalitions within the ME, whereas Saudi Arabia experiences welfare losses. Obviously, the effects of payments in the emission market are dominant for Iran and Saudi Arabia, but in different directions (Iran is always a supplier of emission permits, whereas Saudi Arabia is mostly a demander). The welfares of XFE and XNE mainly do not change.

The ME regions are demanders of emission permits when forming coalitions with China, India, or Russia. In low ambition levels, the benefits from higher emission and losses from the ETS payments mostly cancel out each other. However, in the high ambition levels, the coalitions with China, India, or Russia are slightly welfare-decreasing evidently for the ME regions because the payment effect is dominant.

All the regions in the ME highly benefit from the coalition with Europe. The carbon prices in the Ref scenario in Europe are very high due to Europe's high pledges. Europe is also a major destination for fossil fuel exports from the ME. Therefore, the ME regions receive massive payments from Europe, and simultaneously oil exports increase compared to the Ref scenario, resulting in significant welfare gains. Iran's welfare even improves beyond the baseline, by about 3.1% in NDC and 15% in NDC-1.5C. In addition to Iran's cheapest MAC, the increase in Iran's oil export is the highest among the regions, by about 18% beyond the baseline. Furthermore, the regions in the ME also benefit from the Global coalition. While the ME supply emission permits in the global emission trade market in low ambition levels, they act as demanders of emission permits in high ambition levels. Under low ambition levels, the ME regions' oil export markedly improves and dominates the ETS payment effect. Under the high ambition levels, only Iran benefits from an increase in total export beyond the baseline. Nevertheless, all the ME regions enjoy receiving substantial ETS payments, and hence their welfare increase.

4.4. Sensitivity analysis on fossil fuel supply elasticity

In our study, we assumed that all markets, including fossil fuel markets, are competitive. Also, in our model, a specific immobile factor is used in the nested CES production technology of fossil fuel to calibrate local supply responses and natural resources income. While assuming market power in the oil and natural gas markets are relevant for studying climate policies in the ME, deviating from the competitive market is beyond the scope of this study. Nevertheless, here we test the sensitivity of our results to the supply elasticity of fossil fuel as a potentially critical factor. We deviate from the main values by $\pm 20\%$, and we present the aggregate results for the ME. Note that, for the sensitivity analyses, it is essential to re-calibrate the model as these assumptions will affect the baseline too. We present the results on the welfare and CO₂ revenues as a percentage change against the absolute values for the cooperations and baseline.¹¹

Figs. 16 and 17 respectively show the sensitivity analyses of $\pm 20\%$ changes in supply elasticity values (LSup and HSup stand for lower and higher supply elasticity values, respectively) on welfare and CO₂ revenue in the ME. The results show that welfare and CO₂ revenue results are not significantly affected under these scenarios. In lower ambition levels, the changes in welfare may fluctuate by 0.15% in both directions. However, for higher ambition levels, the changes in welfare are slightly more pronounced with lower supply elasticities such that the welfare may rise by 0.4%. In addition, in lower ambition levels, the changes in CO₂ revenue in the ME may fluctuate by less than 1% in both directions. However, for higher ambition levels, the changes in welfare are even less pronounced (the fluctuations are less than 0.3%).

5. Discussion

In this study, we rely on the NDCs and baseline calculations provided by the EMF36 Core project and use a static CGE model of global trade and climate policy under the assumption of competitive markets without active economic sanction to investigate the Paris implications for resource-rich regions in the ME. In this section, we briefly discuss several points that may help better interpreting our results or highlighting areas for improvement.

¹¹ Note that we did not present the absolute welfare values in the previous sections but only compared them to baseline values. Here, however, as the changes in assumptions will also change the baseline, presenting the changes in changes might be misleading.

Table 9
Macro-indicator changes (%) in XFE.

	NDC					NDC-1.5C				
	Ref	No_ME	ME	ME_EUR	Global	Ref	No_ME	ME	ME_EUR	Global
GDP	-3,04	-2,85	-3,06	-2,66	-1,56	-13,53	-8,27	-13,29	-12,04	-10,44
Labor Inc.	-1,49	-1,18	-1,57	-2,57	-0,90	-12,93	-2,66	-11,51	-14,06	-8,03
Capital Inc.	-2,99	-2,23	-3,19	-7,67	-2,42	-25,03	-6,68	-21,70	-32,02	-16,86
Nat. Res. Inc.	-14,84	-15,10	-14,57	-8,13	-8,03	-35,00	-47,66	-38,42	-28,37	-36,90
Tax Reven.	-2,12	-1,22	-2,36	-7,01	-2,29	-21,10	-1,36	-18,40	-25,24	-14,91
Private Cons. Q	-2,95	-2,67	-2,98	-3,25	-2,22	-16,54	-7,86	-16,13	-15,88	-15,33
Private Cons. P	-1,43	-1,49	-1,4	-0,03	-0,26	-2,18	-4,36	-2,85	0,83	-1,01
Oil Prod.	-2,12	-2,29	-2,04	-0,31	-1,08	-3,42	-10,38	-4,82	-1,00	-5,64
Oil Exp.	-2,56	-2,89	-2,43	0,76	-1,00	-0,88	-13,36	-3,41	4,25	-4,60
Oil Dom.	0,55	1,36	0,31	-6,77	-1,58	-18,65	7,49	-13,25	-32,44	-11,86
Nat. Gas Prod.	-1,16	-0,78	-1,23	-3,30	-0,55	-10,92	0,25	-8,22	-19,19	-4,31
Nat. Gas Exp.	-1,30	-1,72	-1,14	1,79	0,93	-0,43	-2,14	0,83	-6,82	4,58
Nat. Gas Dom.	-0,81	1,40	-1,44	-15,15	-4,02	-35,31	5,81	-29,28	-47,96	-24,99
Electricity Prod.	-2,97	-0,75	-3,57	-15,97	-5,31	-39,21	-2,18	-34,70	-48,12	-30,97
Electricity Exp.	41,71	67,80	34,13	-63,82	-13,52	-86,53	267,34	-75,55	-96,14	-71,71
Electricity Dom.	-2,99	-0,78	-3,59	-15,95	-5,31	-39,19	-2,30	-34,68	-48,10	-30,95
Total Exp. Q	-0,54	-0,50	-0,55	-0,94	-0,27	-3,59	-1,92	-3,02	-5,24	-2,02
Total Exp. P	-3,55	-3,42	-3,56	-3,23	-1,83	-12,31	-9,57	-11,96	-12,28	-9,29
Total Imp. Q	-3,63	-3,39	-3,65	-3,25	-2,40	-15,99	-9,60	-16,15	-13,50	-15,02
Total Imp. P	-0,95	-0,98	-0,95	-0,24	-0,08	-2,03	-3,16	-2,27	-0,44	-0,22

Table 10
Macro-indicator changes (%) in XNE.

	NDC					NDC-1.5C				
	Ref	No_ME	ME	ME_EUR	Global	Ref	No_ME	ME	ME_EUR	Global
GDP	-1,41	-1,34	-1,41	-0,30	-0,37	-5,77	-3,30	-5,83	-2,50	-3,86
Labor Inc.	-1,69	-1,11	-1,62	-3,17	-0,73	-12,16	-3,05	-11,80	-13,93	-7,47
Capital Inc.	-1,41	-0,95	-1,35	-2,63	-0,87	-8,32	-2,06	-8,03	-11,20	-6,01
Nat. Res. Inc.	-19,54	-19,67	-19,65	-15,87	-11,83	-60,88	-62,58	-61,13	-56,24	-56,69
Tax Reven.	-1,89	-1,00	-1,78	-4,61	-1,56	-13,60	-1,22	-13,19	-16,65	-10,95
Private Cons. Q	-0,47	-0,25	-0,45	-0,66	-0,41	-5,18	-0,17	-5,1	-4,64	-4,73
Private Cons. P	-1,06	-1,27	-1,09	0,82	0,04	-0,68	-3,54	-0,91	3,82	0,62
Oil Prod.	-3,19	-3,26	-3,22	-2,51	-1,88	-13,62	-15,06	-13,74	-12,11	-12,69
Oil Exp.	-4,41	-4,82	-4,48	-1,76	-2,22	-15,53	-22,13	-15,92	-10,52	-14,38
Oil Dom.	2,21	3,65	2,40	-5,82	-0,37	-5,13	16,23	-4,10	-19,17	-5,18
Nat. Gas Prod.	-4,79	-2,91	-4,65	-14,86	-3,30	-26,55	1,09	-25,34	-45,98	-15,93
Nat. Gas Exp.	-3,48	-3,78	-3,61	-5,47	-0,36	-7,45	-0,69	-6,73	-27,23	2,47
Nat. Gas Dom.	-6,46	-1,81	-5,97	-26,81	-7,05	-50,88	3,35	-49,04	-69,86	-39,36
Electricity Prod.	-0,74	1,90	-0,46	-1,59	-2,10	23,31	8,30	20,53	57,91	13,90
Electricity Exp.	18,24	44,75	21,24	-33,07	-6,44	-22,15	212,72	-22,29	-4,54	-21,20
Electricity Dom.	-1,25	0,74	-1,04	-0,74	-1,99	24,53	2,81	21,68	59,59	14,84
Total Exp. Q	-0,88	-0,44	-0,82	-3,40	-0,61	-8,24	-1,41	-7,76	-14,17	-5,03
Total Exp. P	-1,73	-1,70	-1,73	-1,14	-0,71	-3,96	-3,22	-3,93	-3,73	-3,14
Total Imp. Q	-1,50	-0,99	-1,45	-2,08	-0,91	-9,48	-1,20	-9,37	-8,08	-7,77
Total Imp. P	-1,07	-1,15	-1,08	-0,22	-0,19	-2,24	-3,66	-2,31	-0,42	-0,59

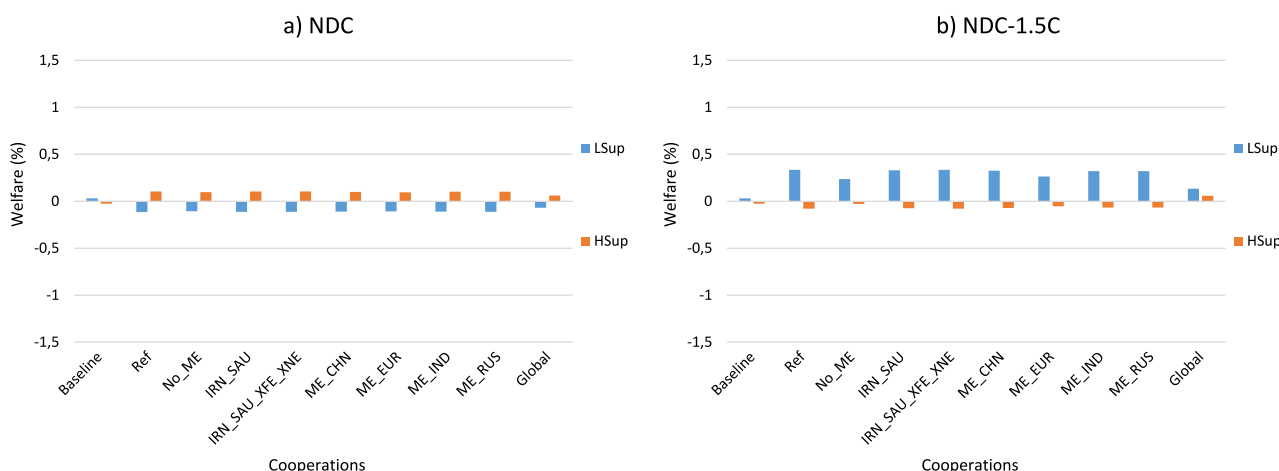


Fig. 16. Percentage changes in welfare of the Middle East in baseline and different cooperation levels and for different NDCs.

While we mostly rely on the NDC targets calculated by the EMF36 Core project, different interpretations of NDCs of some regions in the

ME exist. Some regions also provide emission baselines that differ from the IEO used in the EMF36 Core project. Applying these different NDC

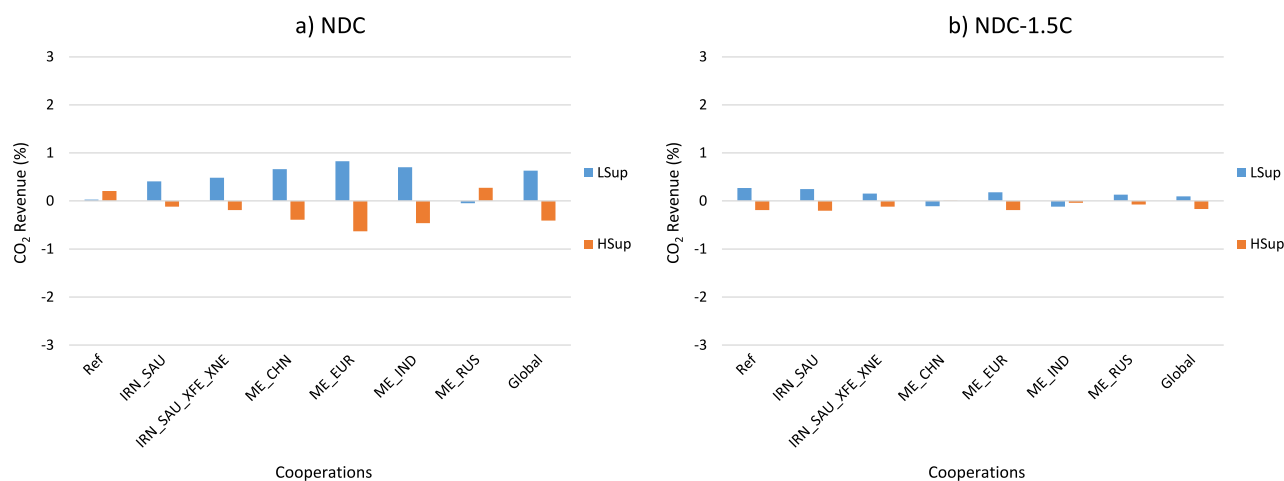


Fig. 17. Percentage changes in CO₂ revenue of the Middle East in different cooperation levels and for different NDCs.

interpretations and baselines might change the simulation results. For instance, Saudi Arabia pledges to cut emissions by around 130 Mt in 2030 relative to the baseline (annual cut), and its baseline emissions are projected to be around 1000 Mt in 2030. Therefore, Saudi Arabia's NDC would reduce emissions by around 13% (on average). While in the EMF36 Core project, NDC and NDC+ are estimated to be 0.42%, we used 3%, which is in line with the lowest range calculated in Chepeliev and van der Mensbrugge (2020) (Chepeliev and van der Mensbrugge, 2020). Nonetheless, applying higher NDCs for Saudi Arabia can be a critical assumption for the results of the current assessment, and hence, the interpretation of the results must take into account this point. Some other estimates of NDC targets by countries are also available (e.g., du Pont et al. (2017) and Climate Action Tracker (2020) [du Pont et al., 2017; Anon, 2020]). If such targets are implemented, regions in the ME may need to provide much more ambitious mitigation, and hence, the emission trading may be more efficient in terms of increased welfare for the ME as a whole.

The technological representations in our model strictly follow the representations in the GTAP 9a Power data set, and there are no backstop technologies in the forward calibration of the model or counterfactual scenarios, which may impact the results. Concerning six countries in the MENA region, including Iran and Saudi Arabia, Poudineh et al. (2021) outline possible electricity systems transitions with a high share of renewable resources (Poudineh et al., 2021). Considering the lack of such rapid transitions towards renewables in our model, we state that our MACs may be overestimated. Nevertheless, we believe that these high renewables require significant socio-political sacrifice in the region, which challenges the possible achievement of these ambitious goals.

Our analysis is based on the assumption that no effective economic sanctions, namely oil and banking sanctions, are placed on Iran. Farzanegan et al. (2016) and Khabbazan and Farzanegan (2016) show that under such sanctions, Iran's oil export and GDP can decrease by more than 73% and 14%, respectively, upon the stringency of sanctions [Farzanegan et al., 2016; Khabbazan and Farzanegan, 2016]. Considering sanctions can dramatically change our study. In an extreme case, sanctions may disrupt any international transactions with Iran, including the receipt and payment in the ETS market. In addition, sanctions can affect both GDP and CO₂ baseline projections.

In our analysis, we assume competitive market structures in all sectors, including oil and natural gas, and we use a specific factor in the nested CES production technology of oil and natural gas to calibrate natural resources income. We show that the results are not sensitive to the changes in the elasticity of fossil fuel supplies. However, as Saudi Arabia is a significant oil exporter, assuming some degree of market power for Saudi Arabia is not unrealistic. Some degree of market power

can also be valid for Iran or generally the ME countries that are OPEC members. Simulating with numerical general equilibrium model and assuming OPEC as the dominant producer, Bohringer et al. (2014) analyzed leakage and costs of unilateral climate policies and found that the overall leakage can be reduced compared to a competitive oil market (Bohringer et al., 2014). Although we do not consider unilateral climate policies, as all the regions have their specific NDCs in the Ref scenario, considering the market power may affect our results. In addition, the stringency of the climate targets may trigger a shift in the market structure or the supply strategy of the influential fuel exporters. We leave this to future research.

Finally, it is also relevant to discuss our results in the context of the Green Paradox and the weak Green Paradox [Sinn, 2012; Gerlagh, 2011]. Our analysis is based on a static CGE model that is forward-calibrated to a baseline in which each region must meet a particular CO₂ emission. Also, we assess future effects of future climate policies. The Green Paradox states that oil consumption may be brought forward if carbon taxation is put off, thus accelerating global warming (Sinn, 2012). In our framework, carbon pricing is not neglected. Therefore, the Green Paradox may be less of a concern regarding affecting our results. However, due to the static nature of our model, some dynamic mechanisms, such as the weak Green Paradox effect, where announcing to price carbon in the future can increase current oil demand and carbon emissions (Gerlagh, 2011), may not have been well investigated. Also, our used baseline already captures mitigation efforts that were set in some regions before the Paris agreement. Therefore, consideration of the weak Green Paradox may even require revision of the baseline too. We leave this to future studies.

6. Conclusion

Following the calculations of the EMF36 Core scenarios and Coalition Subgroup, this paper examines the effect of implementing the Paris agreement with a focus on the ME which is further disaggregated into two individual countries (Iran and Saudi Arabia) and two aggregated regions (the rest of net fossil fuel exporting countries (XFE including Bahrain, Kuwait, Oman, Qatar, and United Arab Emirates) and the rest of countries (XNE including Israel, Jordan, Turkey, and the rest of West Asia (XWS))). We employ a static multi-region, multi-sector computable general equilibrium (CGE) model of global trade and energy. Our CGE model is extended in the electricity sector in which four power generation technologies are active: renewables, nuclear, fossil, and others. The model is forward-calibrated based on the International Energy Outlook projections (IEO). After examining the baseline and marginal abatement costs (MACs) for the regions in the ME, we apply four emission reduction targets, i.e., Nationally Determined Contribution

(NDC), conditional NDC (NDC+), NDC to meet the 2 °C global average temperature target (NDC-2C), and NDC to meet the 1.5 °C global average temperature target (NDC-1.5C). We develop comprehensive scenarios covering various cooperation options within the ME and between the ME and some selected regions outside the ME. These scenarios go beyond the cooperation options examined in EMF36 Core scenarios and Coalition Subgroup.

The baseline results show that oil is the primary source of emission in Saudi Arabia, XNE, and Iran, whereas XFE emits mainly by burning natural gas. Besides, XNE is the only region that has a sizable amount of coal in its energy mix. The results suggest that Iran and XNE have the lowest MACs in order, whereas Saudi Arabia and XFE have the highest MACs. Under the Ref scenario, Saudi Arabia has the highest welfare loss, whereas XNE has the lowest welfare loss. Welfare losses in Iran and XFE are in the middle between Saudi Arabia and XNE.

The results show that the ME is mainly affected by the changes in CO₂ revenues and oil exports. Due to the drawbacks in fossil fuel importation by the rest of the world, the ME will be significantly hit by the climate policies in other regions even if the ME does not implement any climate policy. In addition, if the ME does not implement any climate policy, there will be leakages of emission in the regions in the ME. Such leakages, only under high ambition levels, can partly moderate the welfare losses in the ME.

Furthermore, the coalitions within the regions in the ME are not welfare increasing if aggregate welfare is considered. However, under high ambition levels, Iran mostly enjoys such coalitions, whereas Saudi Arabia experiences welfare losses. Under cooperation with China, India, or Russia, the regions in the ME will demand emission permits. The ME regions do not benefit from cooperation with China, India, or Russia, primarily because of their payments to the emission trading market. On the contrary, the regions in the ME highly benefit from cooperation with Europe, where the ME regions act as suppliers of emission permits and receive massive payments from Europe. Also, the oil exports increase beyond the Ref when cooperating with Europe. Cooperation with Europe will increase Iran's welfare exceptionally beyond its baseline values. Global cooperation is also highly beneficial to the ME regions when the position of the ME in the global emission market shifts from a demander of emission permits to a supplier of emission permits when ambition levels increase. Under the low ambition levels, fossil fuel importation by the rest of the world significantly elevates and increases the ME regions' welfare compared to the Ref scenario. However, under high ambition levels, the substantial CO₂ revenues are the dominant effect for welfare increases in the ME regions.

CRedit authorship contribution statement

Mohammad M. Khabbazan: Implemented the codes, Simulations, Visualization, Interpreted the results, Writing – original draft, Initialized the research idea, Designed the scenarios, Revised the nesting structure and elasticities, Formulated the policy implications, Writing – review & editing. **Christian von Hirschhausen:** Initialized the research idea, Designed the scenarios, Revised the nesting structure and elasticities, Formulated the policy implications, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Selected aggregate results under NDC+ and NDC-2C

See Figs. 18 and 19.

Appendix B. Selected regional results under NDC+ and NDC-2C

See Figs. 20 and 21.

Appendix C. Sensitivity analyses

Like all models, CGE models, too, are sensitive to key assumptions. In our study, many assumptions can be the focus of a thorough sensitivity analysis. Armington elasticity values in multi-regional trade models seem promising candidates for further inspections regarding their effects on the results. In addition, the results can be driven by the structure of production trees and substitution elasticity levels used. While there is no standard agreement on the best structure for production trees, it is slightly easier to examine different substitution elasticity levels. Among them, we choose the elasticity of substitution in the composite electricity (that is, the elasticity of substitution between electricity produced by different technologies) as a promising candidate for affecting the results. For the sensitivity analyses, it is essential to re-calibrate the model as these assumptions will affect the baseline too. We present the welfare and CO₂ revenues results as percentage changes against the absolute values for the baseline and coalition scenarios. For the sensitivity analyses, we deviate from the central values by $\pm 20\%$. Also, for the brevity of the analyses, we only present the results on the ME.

Figs. 22 and 23 respectively show the sensitivity analyses of $\pm 20\%$ changes in Armington elasticities (LArm and HArm stand for lower and higher Armington elasticity values, respectively) and $\pm 20\%$ changes in elasticity of substitution in electricity composite (LSub and HSub stand for lower and higher values of elasticity of substitution between different technologies the electricity sector) on welfare and CO₂ revenue in the ME. The results suggest that welfare results are not significantly affected under all sensitivity analyses scenarios. In lower ambition levels, the changes in welfare may fluctuate by 0.25% in both directions. However, for higher ambition levels, the changes in welfare are slightly more pronounced such that the fluctuations may rise to 0.9%. Also, one may notice that welfare is generally more affected by assumptions regarding Armington elasticity than the assumptions about elasticity composite.

In addition, the results show that CO₂ revenues are not significantly affected by the changes in Armington elasticities, and the fluctuations are generally below 5%. Nonetheless, CO₂ revenues are affected by the assumptions about the composite electricity such that the fluctuations may rise to above 25% for lower ambition levels. When lower substitution elasticities in the composite electricity are used, the CO₂ revenue increases mainly due to the higher CO₂ prices. The effects of changes in substitution elasticity in electricity composite on CO₂ revenue are lower under higher ambition levels.

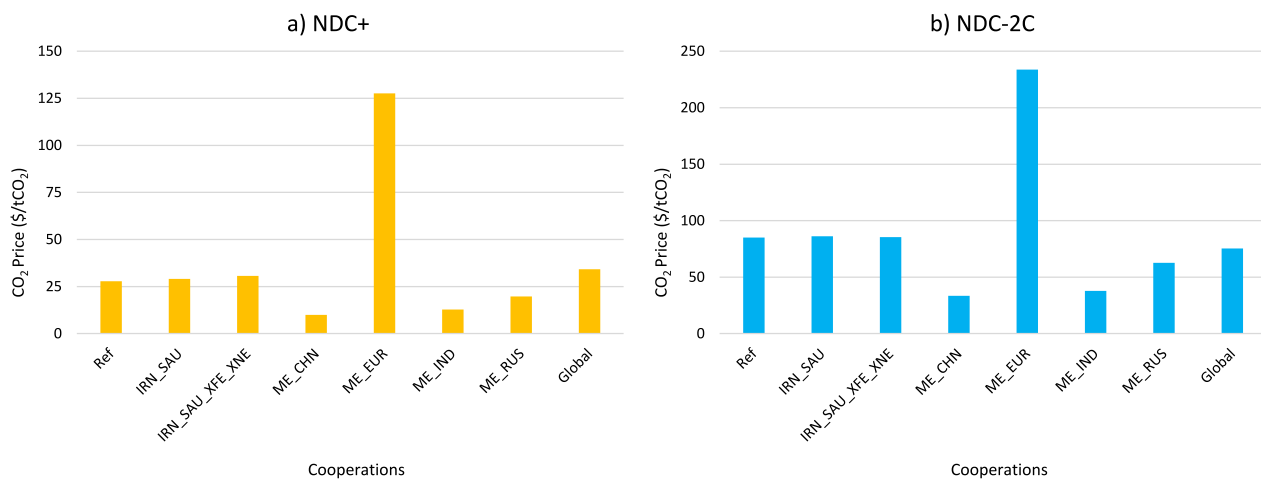


Fig. 18. Average CO₂ price in the ME in USD per tCO₂ for different levels of cooperation and NDCs.

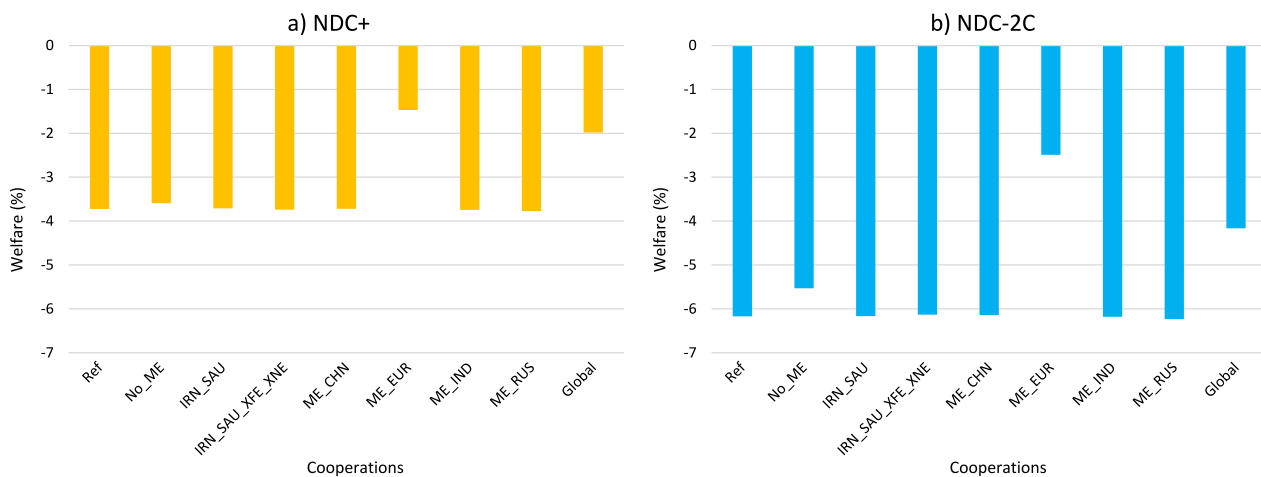


Fig. 19. Percentage change in aggregate welfare in the ME for different levels of cooperation and NDCs.

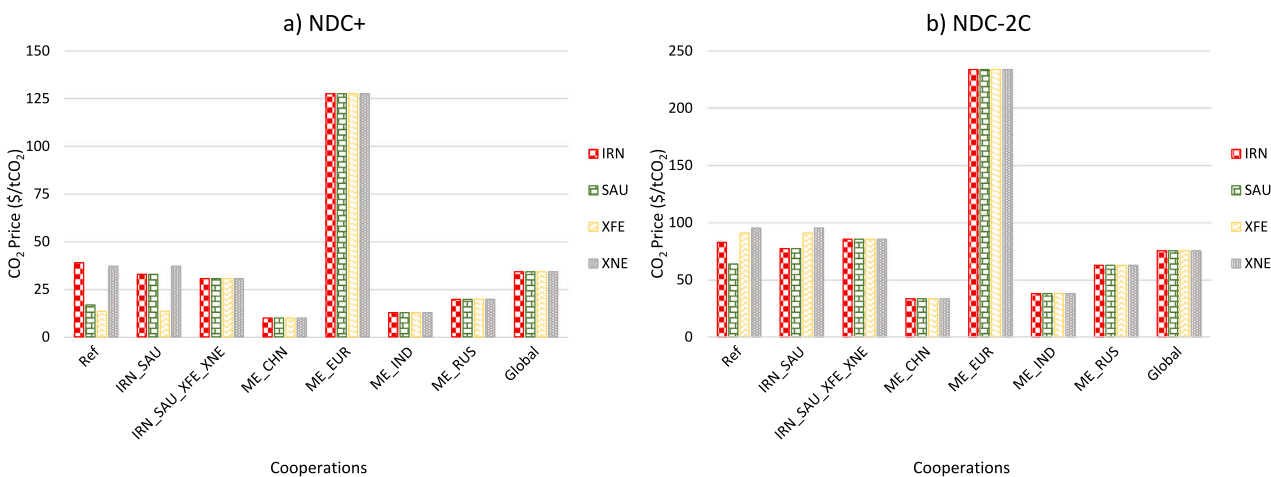


Fig. 20. Regional CO₂ price in the ME in USD per tCO₂ for different levels of cooperation and NDCs.

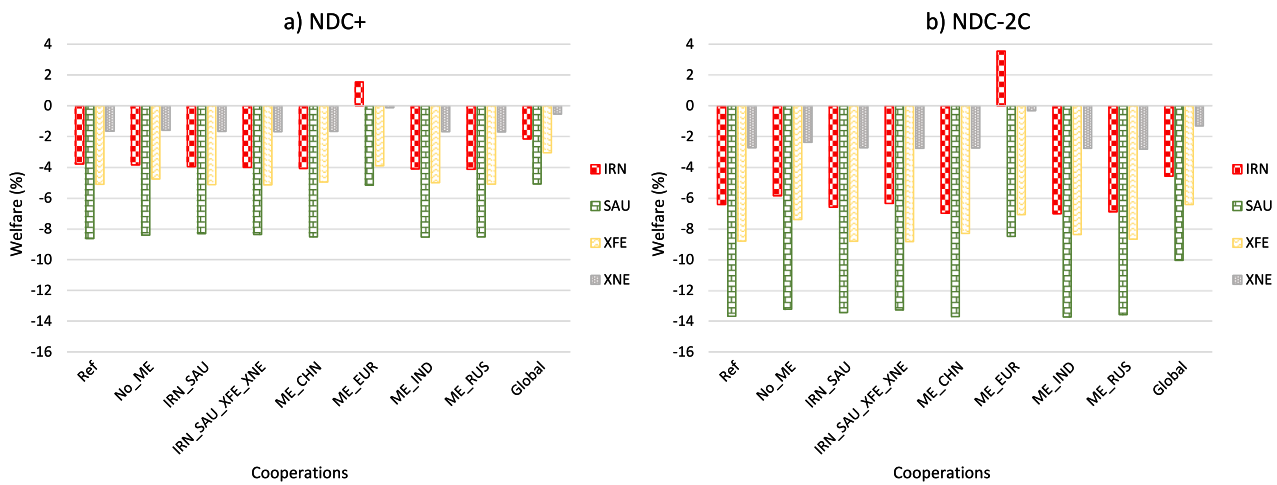


Fig. 21. Percentage change in regional welfare in the ME for different levels of cooperation and NDCs.

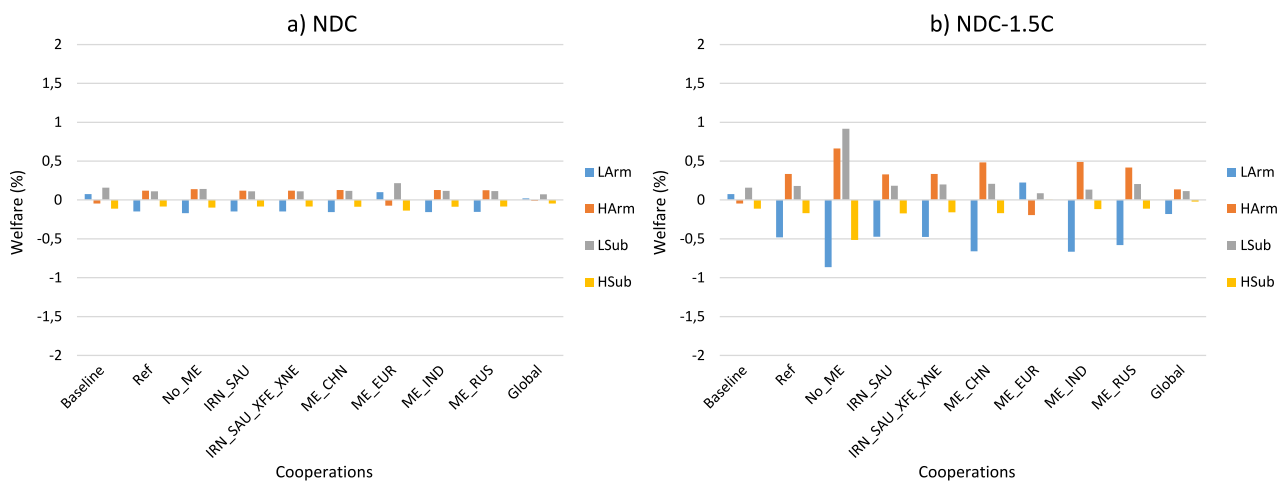


Fig. 22. Percentage changes in welfare of the Middle East in baseline and different cooperation levels and for different NDCs.

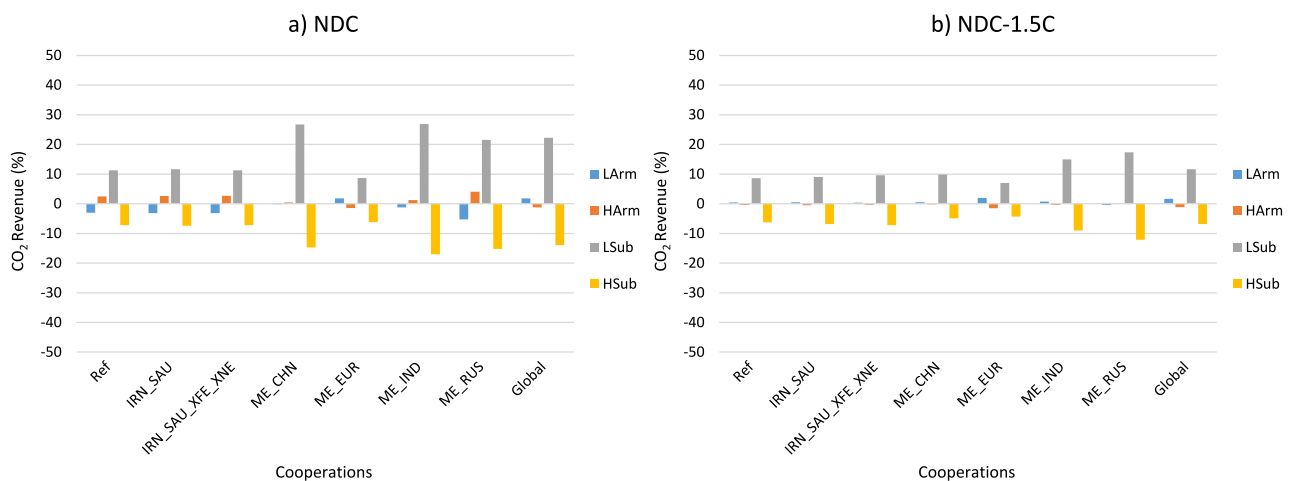


Fig. 23. Percentage changes in CO₂ revenue of the Middle East in different cooperation levels and for different NDCs.

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