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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 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. To analyze these general findings in-depth, 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 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 mostly benefits from such a cooperation whereas Saudi Arabia loses welfare. The Middle East benefits from a global cooperation and the cooperation with Europe, but the cooperation with China, India, or Russia can be welfare decreasing.

Keywords: climate mitigation, computable general equilibrium, emissions trading, Middle East, regional co-operation

JEL classification: C68, F13, F18, Q58

1 Introduction

We are at a defining moment with regard to climate change, caused by the anthropogenic greenhouse gas emissions, that may cause severe damages ranging from shortage in food production to rising sea levels and catastrophic flooding. The impacts of changing climatic pattern 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 cooperations.

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 of the individual countries have submitted national pledges of certain reductions in their carbon emissions by 2030. Note that, however, there are countries that 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. All in all, these so-called Nationally Determined Contributions (NDCs)¹ can be met through different instruments.

The 36th round of Energy Modeling Forum (EMF36) investigates various policy regimes to fulfill NDCs and the widespread economic impacts such regimes may bring about (Böhringer et al., this issue). The EMF36 Coalition Subgroup investigates coalition options including and beyond EMF36 Core scenarios (Akin-Olçum et al., this issue). The core of the analyzed EMF36 scenarios include 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 cost-effective policy instrument which internalizes the costs of climate damage into prices, and hence, allows 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.

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 in the world, there are countries such as Qatar and 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 toward emission mitigation in line with Iran’s Intended Nationally Determined Contribution (INDC). Alkan et al. (2018) examine Turkey’s INDC and suggest that reaching these targets seem impossible and more conceivable policies are needed. 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 Saudi in Iran and Saudi Arabia quite severe. These studies do not look specifically into the carbon price mechanism. One specific feature of the ME region is a high level of fossil fuel subsidies too. Chepeliev and van der Mensbrugghe (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.

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 dis-aggregated 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))).² The ME is not only the world’s largest producer and exporter of oil but also 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 (Aguiar 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) by means of introducing baseline carbon prices.³ After examining the abatement costs for the dis-aggregated regions, we apply four emission reduction targets, i.e. NDC, conditional NDC (NDC+), NDC to meet 2-degree global average temperature target (NDC-2C), and NDC to meet 1.5-degree global average temperature target (NDC-1.5C). We develop comprehensive scenarios covering various the cooperation options in the ME as well as scenarios representing important cooperation options between the ME and other regions. For the sake of completeness, we also examine a scenario in which the ME does not implement any climate policy when the rest of the world do. In addition, we conduct sensitivity analysis by varying some key elasticity values.

The results show that Iran has the lowest marginal abatement cost (MAC) in the ME, followed by XNE and XFE; Saudi Arabia has the highest MAC. In the reference cooperations (that is, without any cooperations), the average carbon prices in the ME are about 14 \$/tCO₂ for the lowest ambition level (NDC), it rises to about 290

¹The official NDC database can be found here:

<https://www4.unfccc.int/sites/NDCStaging/Pages/All.aspx>

²Note 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 capacity as well as clearer interpretation of results.

³For the sake of comparability of our results to the EMF36 core scenarios, the baselines and policy options are derived by means of introducing carbon prices, not through the elimination of subsidies.

$\$/\text{tCO}_2$ for the highest ambition level (NDC-1.5C). The results show that the terms-of-trade (ToT) in the ME will significantly deteriorate, which will not lead to welfare increases though the cooperations within the ME. Among the regions in the ME, Iran mostly benefits from cooperation within the ME, but Saudi Arabia does not. In the case that 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 cooperations with Europe as well as a global cooperation mainly due to the increase in ToT, the cooperations with China, India, and Russia are not beneficial because of further exacerbation in ToT. 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 4.2 presents the results on regional and sectoral MACs. The paper proceeds with the presentation and interpretation of cooperation results on the aggregate ME as well as regions in Section 4.3. Section 5 concludes the paper.

2 The Middle East in the Paris Agreement

According to EMF36 Core results, it is expected that the Middle East is affected significantly by the cutback in fossil fuel use required to achieve the Paris targets. Figure 1 depicts the marginal abatement cost curves (MACCs) based on the International Energy Outlook projections (the IEO baseline) (EIA, 2017) in 2030 (see the next section for details on the baseline) for the Middle East (MEA)⁴ aggregated over all countries in the area as well as for some selected regions (China, Europe, India, and Russia) submitted by the TU-Berlin Team in EMF36 Core scenarios. The benchmark for EMF36 core scenarios is the GTAP 9a Power database for the year 2011. Note that, to derive the MACCs, when the carbon price increase in a region, there is no climate policy implemented in other regions, and hence, the carbon prices in other regions are 0 $\$/\text{tCO}_2$. Also, Figure 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. As an example, for a reduction of about 19% (equivalent to 430 Mt) in CO_2 emission, a carbon price of 100 USD per tCO_2 ($\$/\text{tCO}_2$) is required in the MEA. That 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. However, 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 high MACC in the MEA region is that renewable generation technologies are not presented in the reference year of the GTAP 9a Power. For instance, Saudi Arabia has “0” share of renewable as of 2011. Correspondingly, there is no option of substitution from fossil fuels to renewable in the future, even under high carbon prices. Therefore, most of the emission reductions need to be achieved by reductions in the fossil-fuel based generation, which is quite expensive.

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

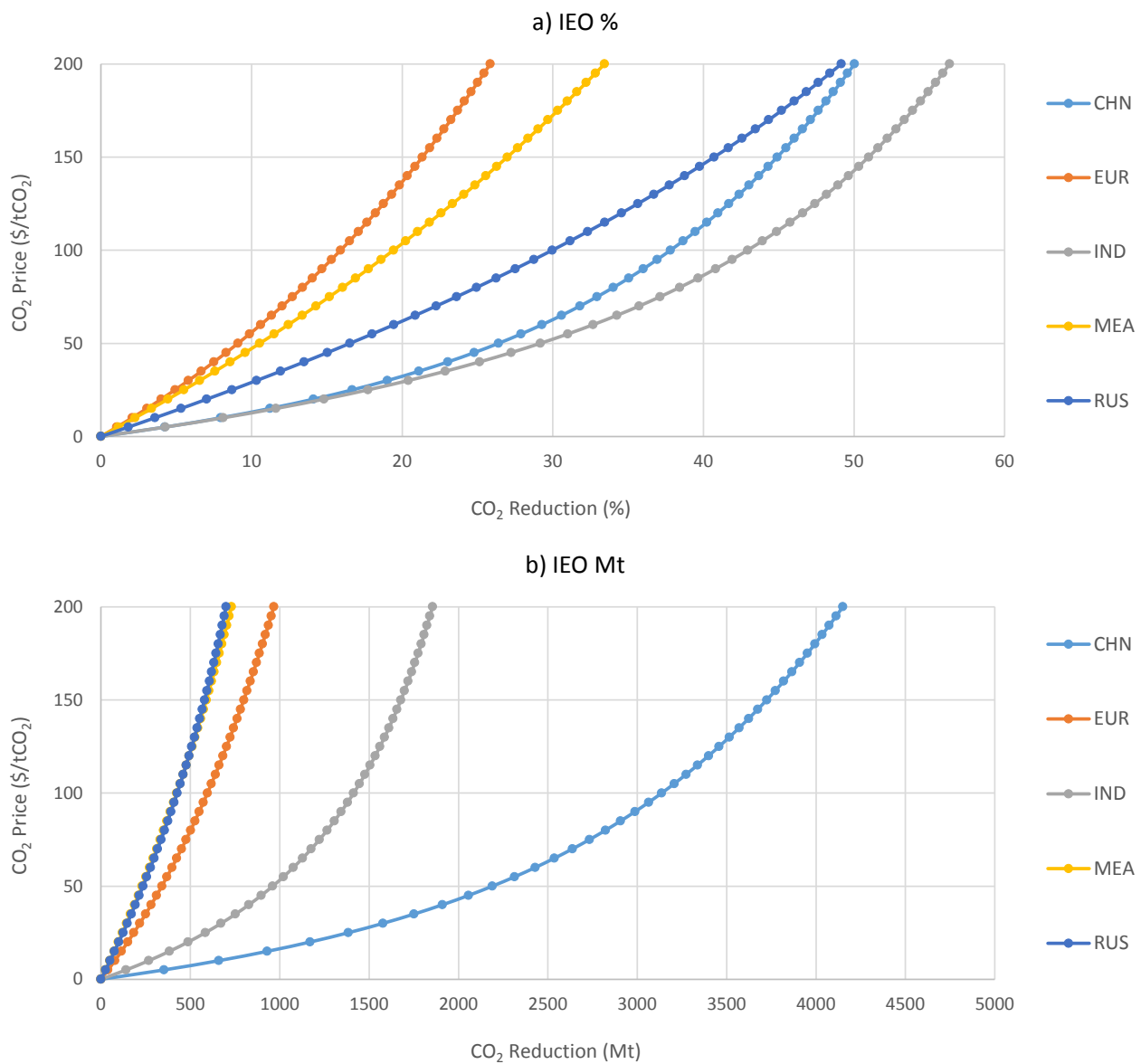


Figure 1: MACCs in 2030 for the Middle East and selected regions (China, Europe, India, and Russia). Panel a) shows percentage reductions vs. CO₂ prices in USD per tCO₂. Panel b) shows absolute reductions in MtCO₂ vs. CO₂ prices in USD per tCO₂.

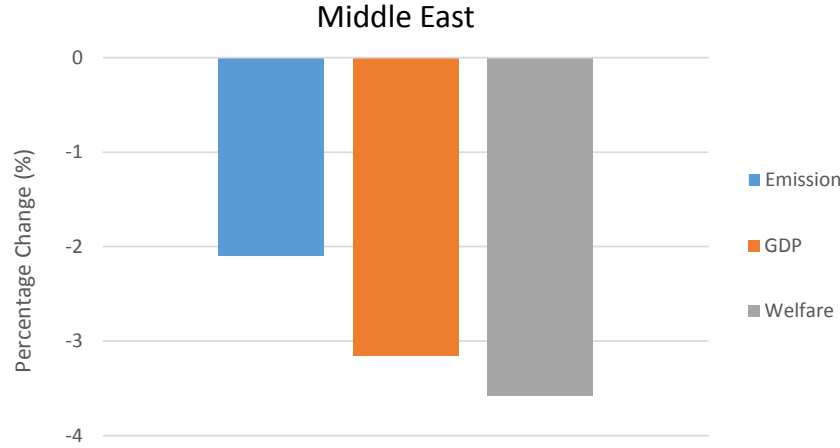


Figure 2: Percentage change in emissions, GDP, and welfare in the Middle East in 2030 for the NDC target.

EMF36 Core scenarios provide NDC, NDC+, and NDC-2C ambition levels for the regions compatible with regions in GTAP9 data set (Böhringer et al., this issue). The EMF36 Coalition Subgroup investigates coalition options including and beyond EMF36 Core scenarios for a higher ambition level compatible with 1.5C target (NDC-1.5C) (Akin-Olçum et al., this issue). The calculations may be different from the specifically stated INDCs by the regions because the baseline against which the NDCs are calculated may be different from what is promised by a specific region or even no quantified measures were in hand. Table 1 details these calculated NDCs in percentage reduction as against the IEO baseline in 2030 for ME regions.

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

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

The region undergoes politically difficult situations such as wars and international conflicts, which makes it a weak point in climate protection issues as well. 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 UNFCCC. 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. However, subject to termination of international sanctions, Iran has declared a potential of mitigating additional GHGs emission up to 8% against the BAU scenario (i.e. 12% in total) as the conditional INDC.⁶ EMF36 used these INDCs and NDCs for Iran. Turkey submitted an ambitious NDC of 21% reduction in

⁵The INDC data set can be found here:

<https://www4.unfccc.int/sites/submissions/INDC/Submission%20Pages/submissions.aspx>

⁶Iran'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.

its GHG emissions from the BAU level by 2030. As stated in Alkan et al. (2018), these targets seem “impossible” to achieve. EMF36 did not include Turkey’s INDCs into 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 the 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 equivalent economy, their INDCs solely present ideas and possible projects working on achieving this goal on a voluntary basis 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 EMF36 states 0.42% reductions in Saudi Arabia’s emission in 2030, Chepeliev and van der Mensbrugghe (2020) report the range of the NDC emission reductions for Saudi Arabia to be 3%-19% relative to the baseline in 2030.

The ME is a very heterogeneous region, both economically and politically. The region includes massive fossil fuel exporters. According to the U.S. Energy Information Administration 2020 Saudi Arabia, Iraq, United Arab Emirates, Kuwait, and Qatar are among the top 10 oil exporters in the world, while Qatar also ranks the 2nd largest natural gas exporter in the world.⁷ However, in this region, countries like Turkey and Israel are no fossil-fuel exporter. Turkey is Russia’s 2nd largest export market for natural gas.

Also, the ME includes sizable CO₂ emitters. According to the Report by EU Joint Research Commission (Muntean et al., 2018), Iran and Saudi Arabia are among the top 10 emitters in the world. However, the ME also includes countries like Bahrain and Jordan whose emissions are comparably low. Figure 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 the in 2011 using GTAP 9a Power database (Aguiar 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 for which there is 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 emission in the region. The EI in the ME is on average higher than the global average. While Iran has one of the highest EI in the world, Bahrain, Oman, Jordan, and XWS have also EIs higher than ME’s average. These countries have heavily under-developed technologies. On the contrary. EIs in Israel, Qatar, and Turkey are below the global average.

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

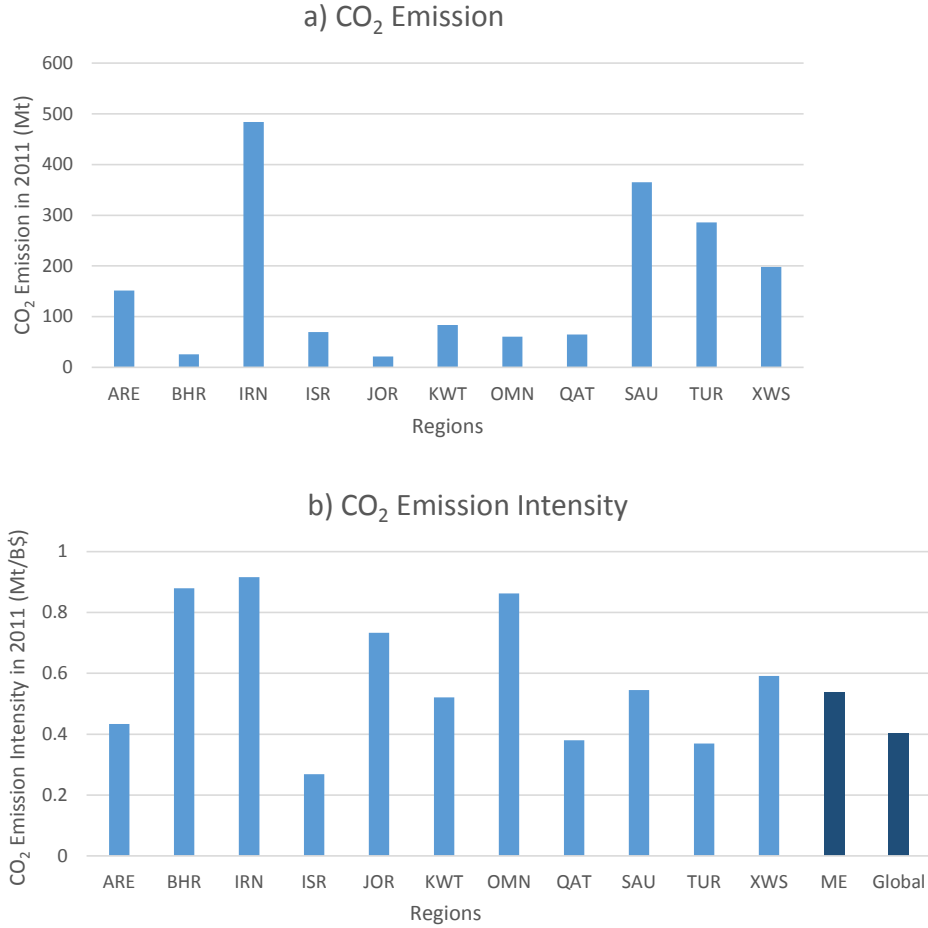


Figure 3: CO₂ emissions and CO₂ emissions intensity by Middle Eastern countries in the benchmark in 2011.

3 Framework

This section explains the theoretical and numerical framework to analyze the effects of implementation of the Paris agreement for the ME. It 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 standard multi-region, multi-sector computable general equilibrium (CGE) model of global trade and energy based on two models. The core code is based on the GTAPinGAMS model type (see Lanz and Rutherford (2016), for the latest version) and has been extended for inclusion of carbon pricing and ETS based on the model developed by Böhringer and Rutherford (2010). The model is further extended with an elaboration on the electricity sector in which four power generation technologies are active: renewables (comprising hydro, solar, and wind technologies), nuclear, fossil, and others (including geothermal and bio-fuel technologies). International commodity trade is represented following the Armington approach where goods that belong to the same category, but are produced at different locations are treated as imperfect substitutes (Armington, 1969).

Figure 4 and Figure 5 show the nesting structure for non-fossil fuel production and fossil fuel production, 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 (BMK), the model builds on GTAP 9a Power database with detailed accounts of regional production, consumption, bilateral trade flows as well as energy flows and CO₂ emissions for the year 2011 (Aguiar et al. 2016; Peters, 2016). Substitution elasticities, such as between energy inputs and non-energy inputs, are mostly provided in Figure 4 and Figure 5. The elasticities in international trade (so-called Armington elasticities) and between production factors (labor, capital, and resources) are based on empirical estimates reported in the GTAP 9a

Power database. All other elasticities 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).

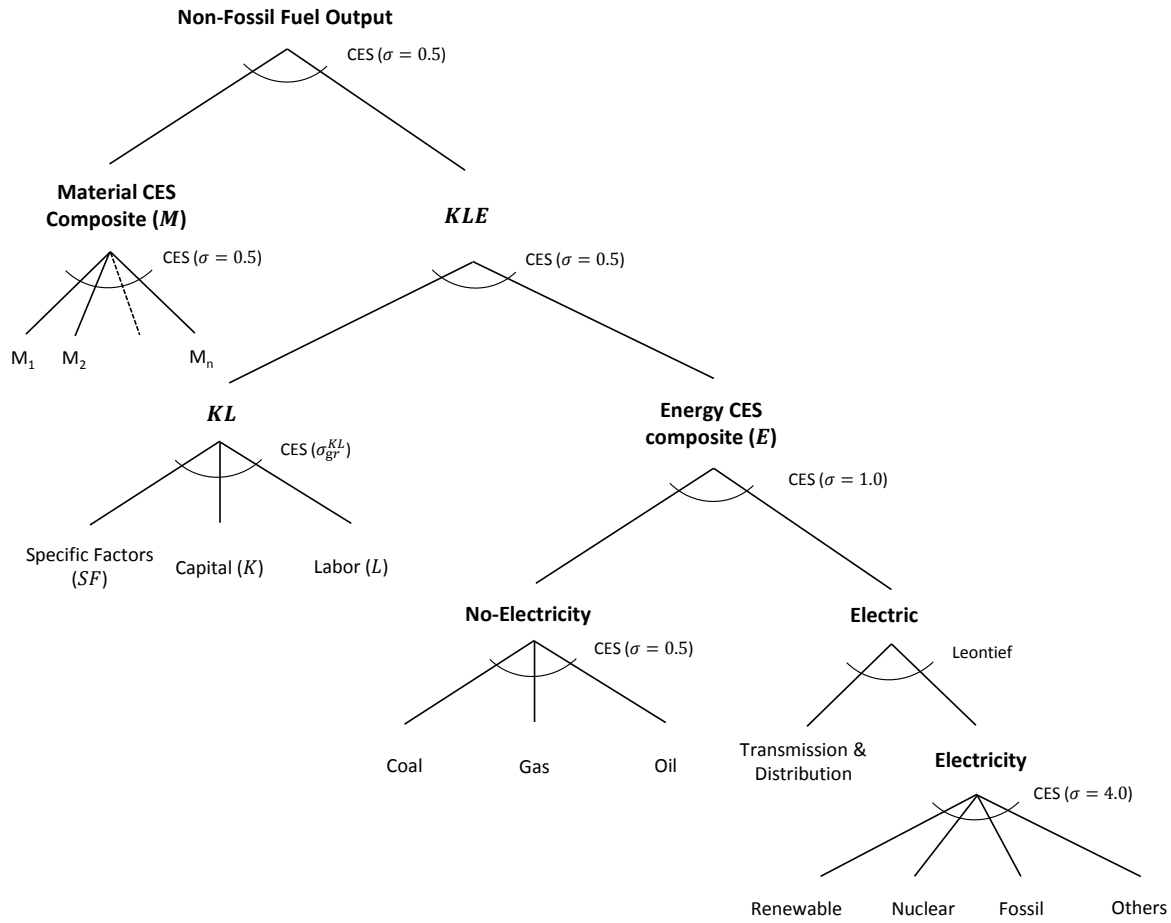


Figure 4: Nesting structure in non-fossil fuel production.

⁸CGE 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.

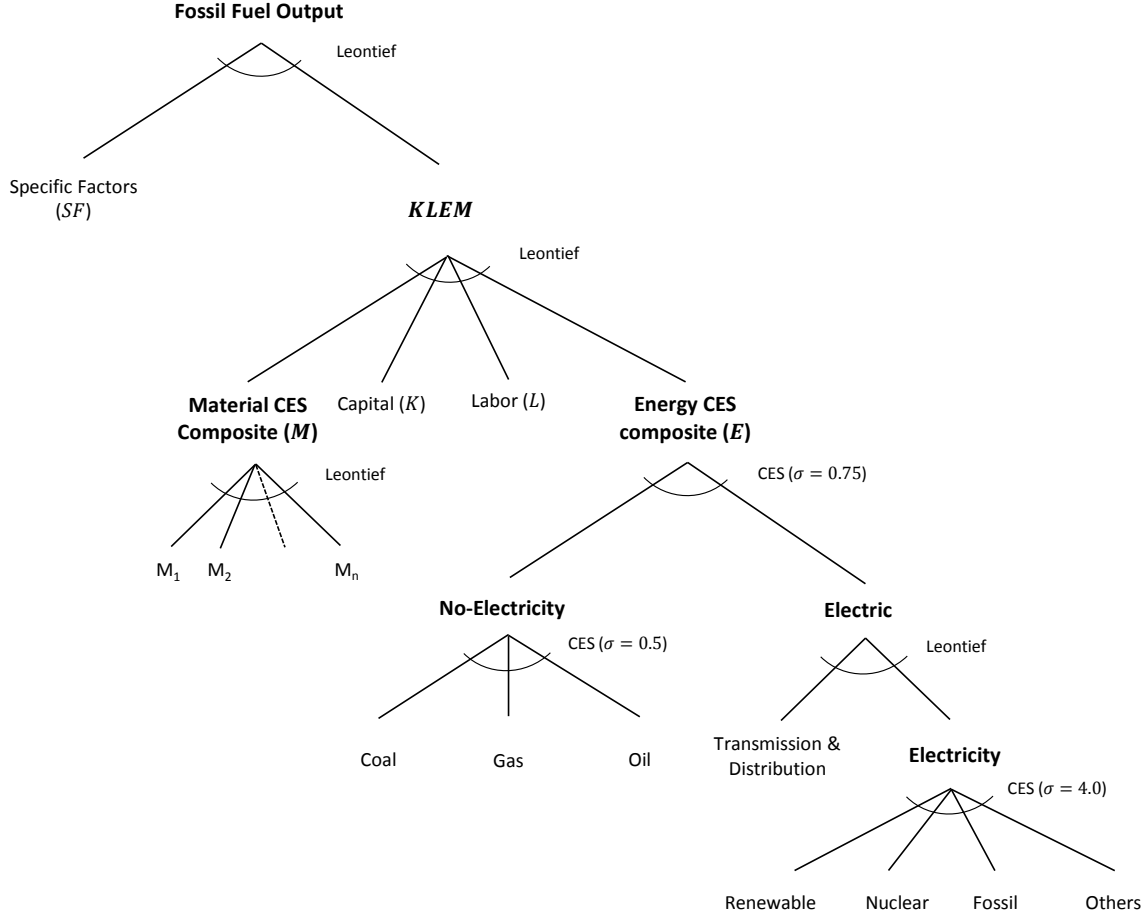


Figure 5: Nesting structure in fossil fuel production.

Item	Value
Elasticity of supply of of coal	1.0
Elasticity of supply of of gas	0.6
Elasticity of supply of of oil	0.5
Armington-Elasticities for gas	ESUBD = 5, ESUBM = 10
Armington-Elasticities for oil	ESUBD = 4, ESUBM = 8

Table 2: Other main elasticity values.

3.2 Regions and sectors

We build on the core regional and sectoral disaggregation proposed in EMF36 and further disaggregate the ME for the purpose of 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 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 Figure 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 countries (such as Iraq and Syria) whose specific data are not available in the GTAP9 data set. As, for example, Iraq is a large 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 the Table 3).

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

Table 3: Model regions and sectors.

3.3 Baselines and NDCs

The baseline scenario is forward-calibrated utilizing projected CO₂ emissions and GDP data. Figure 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) 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, and ii) introduce a regionally-unique CO₂ price in order to match regional GDP and CO₂ emissions for 2011 to 2030 with the provided values. The revenues from baseline CO₂ price are only transferred to the representative agents in the corresponding region and are not used for further transfers to sectors nor enter the emission permit market. In this process, the share of government and investment spendings are fixed to their benchmark levels. The endowment growth factors are kept constant in their 2030 levels in our static CGE model when deriving the MACs and implementing the policy counterfactuals in 2030. For the counterfactuals and MACs, while government spendings are fixed in their 2030 levels, investment spendings can evolve to keeps its share equal to the benchmark levels. The reported CO₂ prices in the counterfactuals and MACs are the deviations from the CO₂ prices in the baseline.⁹

Table 1 shows the NDCs expressed in percentage reduction as against the baseline in 2030 for all regions in the model. For NDC targets, we mostly rely on the NDCs provided by EMF36 Core and Cooperation Subgroup (see Table 1 for the regions in the ME and see Böhringer et al. (this issue) for details on derivation of NDCs).¹⁰

⁹An alternative approach to calibrating the baseline is introducing a regionally-unique CO₂ tax (or subsidy) rate imposed on the use of CO₂ emitting intermediate inputs (i.e. coal, natural gas, and refined oil). This approach will result in carbon prices being zero in the baseline. In addition, a mixed approach (that is, having carbon prices and fuel tax/subsidy reforms) for calibrating the baseline is possible. We do not go beyond the approach introduced above as it requires extra computations beyond the scope of this paper.

¹⁰There 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 and van der Mensbrugghe (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 Mensbrugghe (2020)). Other estimates of NDC targets by countries are also available (e.g. du Pont et al. (2017) and Climate Action Tracker (2020)).

For NDC and NDC+ in Saudi Arabia, we use the lowest estimations in Chepeliev and van der Mensbrugghe (2020), which is 3%. For the rest of regions in the ME, we rely on the calculations of EMF36 Core project. Note that the NDC targets for XFE and XNE are weighted averages over the included regions. The weights are CO₂ emission in regions and the regions without NDC targets are bound by their baseline emissions.

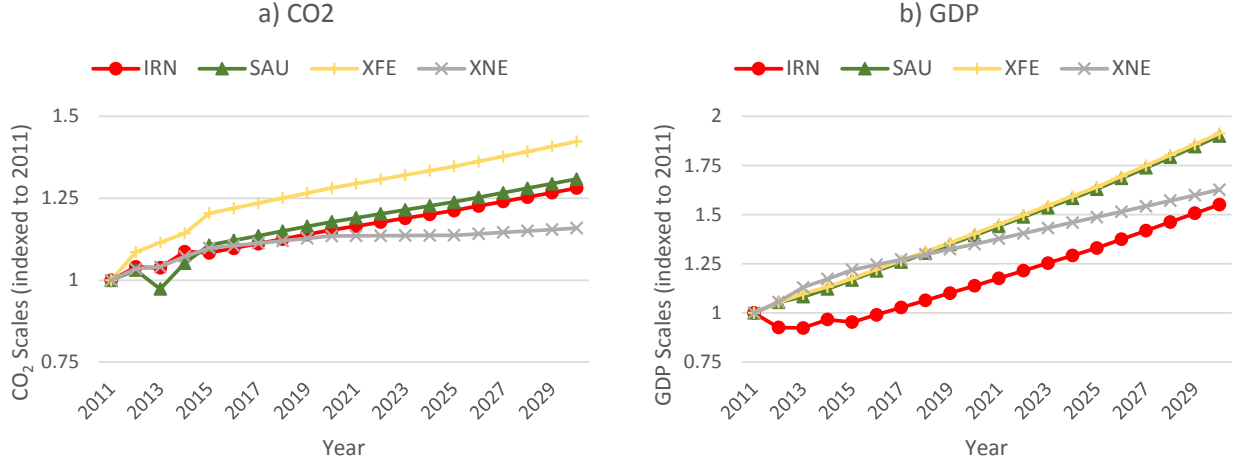


Figure 6: CO₂ scales and GDP scales for the IEO baseline in 2011-2030 (used for calibration).

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

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

3.4 Marginal Abatement Cost Curves (MACCs)

For the MACCs, the carbon price increases beyond the baseline prices per sector 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.

3.5 Policy scenarios

Policy scenarios are implemented in the form of 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° pathway), and NDC-1.5C (scenario consistent with 1.5° pathway). In these policy scenarios, emission targets can be reached in a variety of coalitions ranging from using a regional carbon price to a global carbon price under 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 (that includes the regions for which we do not report) should still comply with their ambition levels but without forming any cooperation.

Table 5 shows the cooperations and regions involved. The cooperations presented in 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. As terms-of-trade may be an explaining force for the outcomes in the ME, No_ME scenario may help in singling out this effect. III) Cooperations within ME, in which various possible combinations of regions in the ME form a coalition (five scenarios). IV) Cooperations between 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 individual region in the ME autonomously form a coalition with regions outside the ME, we limit our analysis to those mentioned in Table 5 for the sake of brevity.

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
SAU_XFE	All Regions/SAU and XFE
IRN_SAU_XFE	All Regions/IRN, SAU, and XFE
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)

Table 5: Cooperations.

4 Results

In this section, we firstly present the results on the baseline and the emission share of each fuel for the Middle East (ME) region. Then we present the overall and decomposed MACs for the ME regions. Finally, we present the result on policy options as cooperation scenarios within the ME and between the ME and some other regions outside the ME.

4.1 Baseline

Table 6 presents the emission share of fuels (%) and CO₂ Price (\$/tCO₂) in the baseline in 2030 for the ME regions after the calibration (see Section 3.3 for details on the calibration). It is noticeable that Iran has the lowest baseline carbon price (80 \$/tCO₂) to meet its projected GDP and CO₂ emission growth presented in Figure 6. On the contrary, Saudi Arabia has the highest (306 \$/tCO₂) while XFE (225 \$/tCO₂) and XNE (150 \$/tCO₂) have the next highest places. One reason for these results can be the difference between the projected GDP growth and CO₂ emission growth. Assuming that this difference is positive (the projected GDP growth is higher than the projected emissions), the larger the difference, the higher the baseline carbon price. For example, while Saudi Arabia and XFE have quite similar GDP growth projections, Saudi Arabia's projected

emissions are significantly lower. As another example, Iran and Saudi Arabia have similar projected emission growth, but Iran's projected GDP growth are markedly lower.

The production technologies and energy mix also 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 2030.¹¹ In addition, oil usage is the main source of emitted CO₂ in Saudi Arabia, XNE, and Iran, but XFE's emissions majorly root from burning natural gas. It is noticeable that, unlike Iran, Saudi Arabia and XNE are largely 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.

Regions	Emission share of fuel (%)			Baseline CO ₂ Price (\$/tCO ₂)
	<i>COL</i>	<i>GAS</i>	<i>OIL</i>	
IRN	0.02	46.84	53.14	79.53
SAU	-	21.58	78.42	305.6
XFE	0.80	64.45	34.75	224.5
XNE	16.15	19.28	64.57	150.3

Table 6: Emission share of fuels (%) and CO₂ Price (\$/tCO₂) in baseline in 2030 for the Middle East regions.

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 the opportunities of abatement by importing commodities with lower emissions. Figure 7 shows the MACCs in percentage change and absolute change in the ME regions in 2030. Regions in the ME are very diverse with respect to their MACs. Note that the baseline carbon prices could already give us an indication about what to expect from MACs. Iran has the cheapest attainable abatement in both percentage and absolute reductions. For a carbon price of 300 dollar per ton of CO₂ (\$/tCO₂), Iran can reduce its CO₂ emission by about 50% which constitutes more than 310 mega ton of CO₂ (MtCO₂) emission. XNE and XFE are in 2nd and 3rd places, respectively: For a carbon price of 300 \$/tCO₂, XNE and XFE can reduce their CO₂ emission by about 42% and 28%, respectively, which constitutes about 280 and 150 MtCO₂ emissions respectively. Saudi Arabia has the most expensive MAC in both percentage and absolute changes. Saudi Arabia can only mitigate about 22% of its CO₂ emission for a carbon price of 300 \$/tCO₂ which is equivalent to nearly 80 MtCO₂ emission. In addition to the baseline carbon prices, the results can be further 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, abatement costs may increase due to stringency of substitutions of fuels in production process. Such a dependency is lower for Iran and XNE. However, note that Iran and XNE have different abatement opportunities. Iran mostly substitute oil by natural gas for abatement. But, XNE can either substitute oil by natural gas or reduce coal usage. As measures for potentials of further abatement, emission intensity and baseline carbon prices can be considered. The lower baseline carbon prices in Iran and XNE mean that these regions have exploited less of their potentials for abatement compared to Saudi Arabia and XFE. Yet, emission intensity in XNE is almost half of the emission intensity in Iran, which implies that abatement in Iran can be less costly than XNE.

¹¹For the purpose of a 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.

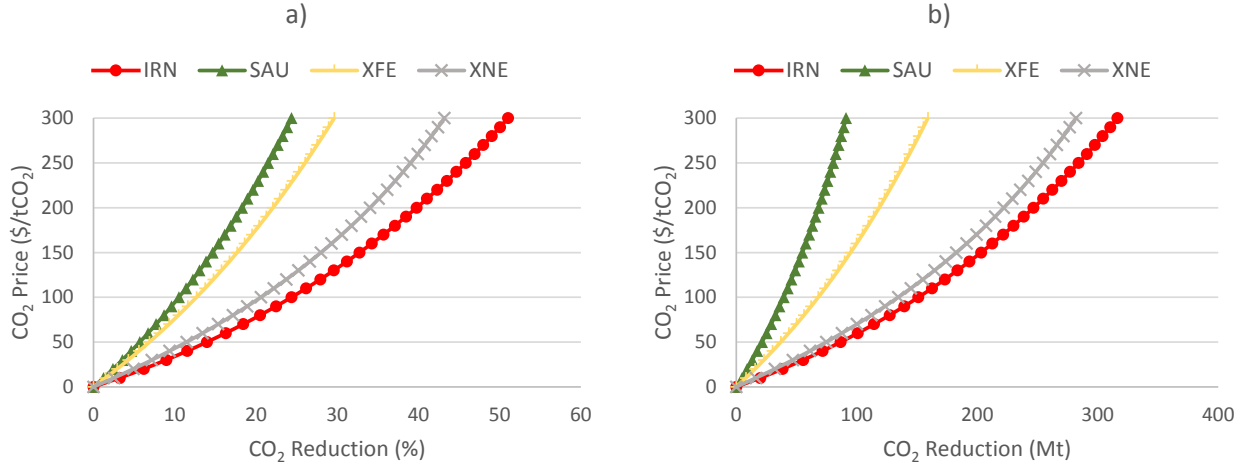


Figure 7: MACCs in 2030 per region. Panel a) shows percentage reductions vs. CO₂ prices in USD per tCO₂. Panel b) shows absolute reductions vs. CO₂ prices in USD per tCO₂.

Figure 8 and Figure 9 detail the emission reductions by fuels, showing the de-composed MACs in percentage and absolute changes respectively. Note that the absolute reductions by fuels in Figure 9 must add up to the total absolute reductions in Figure 7. The figures show that Iran and XFE have similar emission reduction patterns. That is, Iran and XFE will reduce their emissions by, firstly, less use of natural gas, secondly, by oil, and finally, by coal. However, note that coal is not a major fuel in Iran and XFE even though the percentage reductions in coal are the highest in both regions. Notably, the percentage reductions in coal is also the highest in XNE. The reason behind the significant percentage reductions in coal usage in Iran, XFE, and XNE is that coal emits more CO₂ in relation to the energy it produces when burned compared to oil and natural gas. Therefore, the reduction in coal usage is more cost-efficient compared to reductions in oil and natural gas. Nevertheless, while the percentage reduction in oil and natural gas are similar in Saudi Arabia, oil is the main fuel used in Saudi Arabia. As Saudi Arabia's economy highly depends on the oil production and oil exportation (as the largest oil exporter in the world), the overall MAC becomes relatively more expensive compared to the other regions in the ME. Finally, similar to Saudi Arabia, oil and natural gas are the main sources for emission reductions in XNE. However, coal constitutes a significant portion in fuel basket in XNE, nearly similar to natural gas. Therefore, because coal is comparably the cheapest fuel, the overall MAC in XNE becomes relatively cheap too, taking the second cheapest place after Iran.

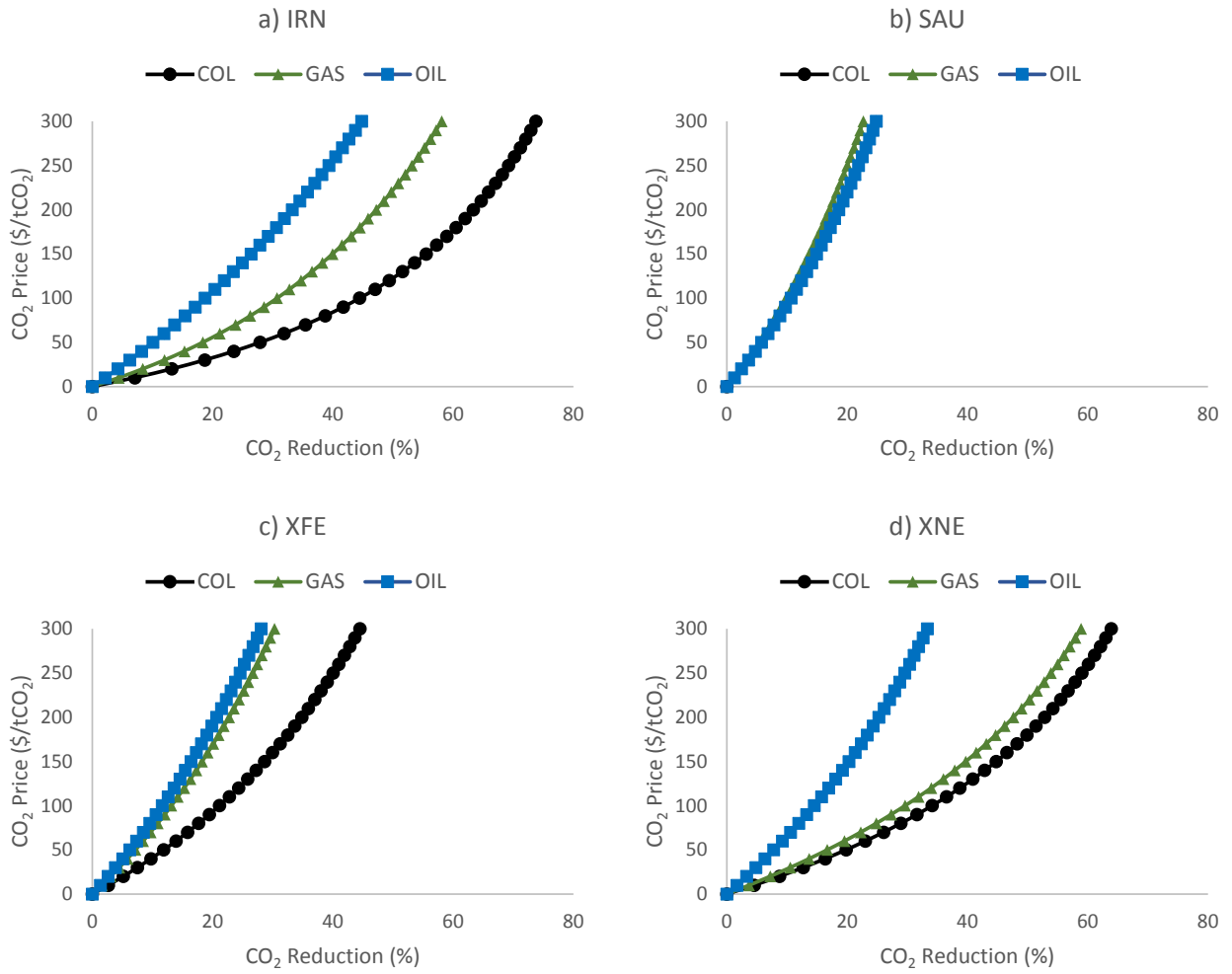


Figure 8: MACCs in 2030 per region. Figure shows percentage reductions in CO₂ emission by fuels vs. CO₂ prices in USD per tCO₂.

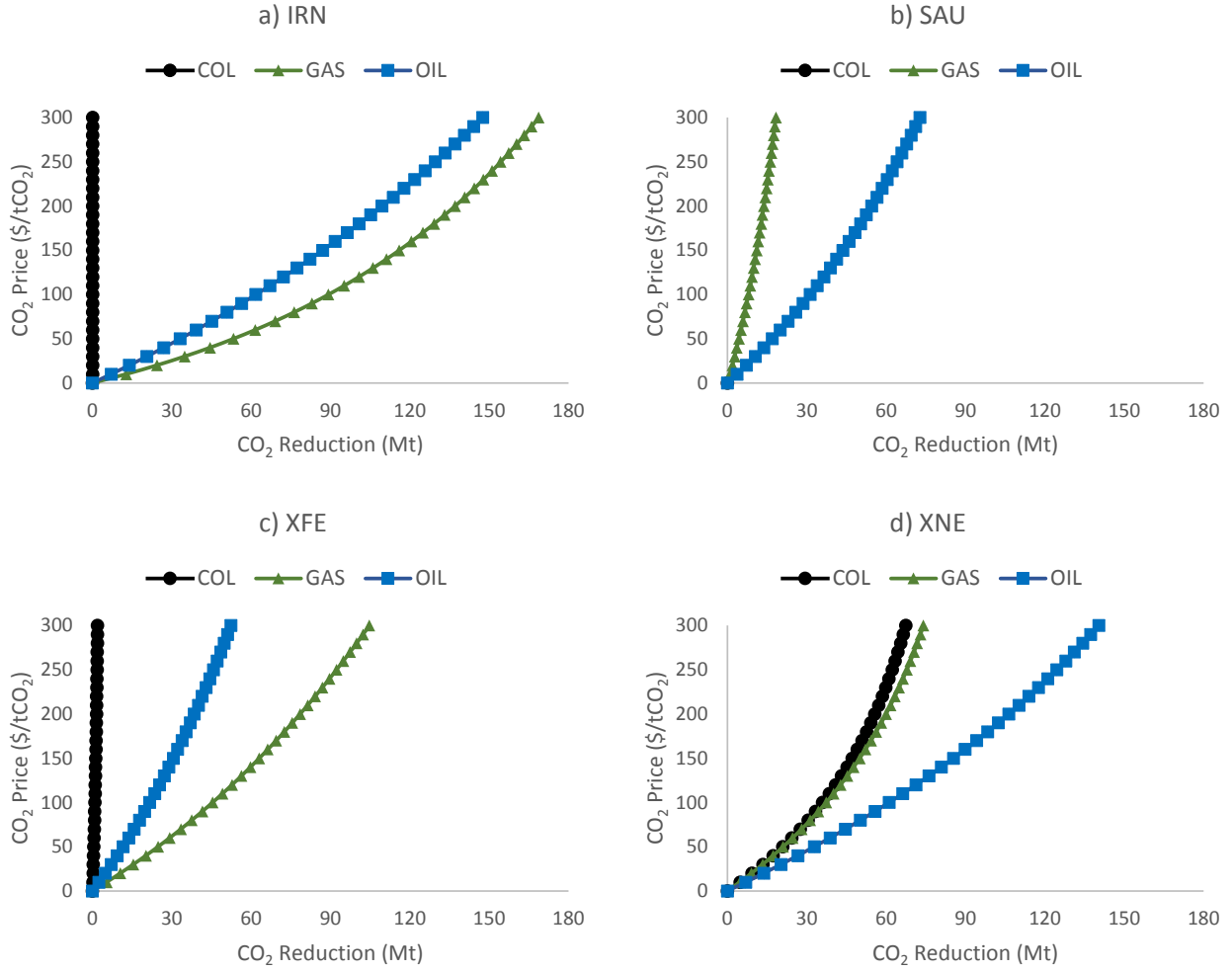


Figure 9: MACCs in 2030 per region. Figure shows absolute reductions in MtCO₂ in CO₂ emission by fuel vs. CO₂ prices in USD per tCO₂.

Comparing Panel a) and Panel b) in Figure 7, assuming an equal NDC for example, along the MACCs in Panel a) for Iran and Saudi Arabia, Iran will have a lower carbon price than Saudi Arabia. Then, along the MACCs in Panel b), the common carbon price in an emission trading market will be relatively near to the carbon price in Iran rather than in Saudi Arabia. However, while these figures suggest that in cooperation scenarios Iran can most likely act as an emission permit supplier while Saudi Arabia may take the position of an emission permit demander, three remarks are necessary: Firstly, the position in the emission market not only depends on the MACs of specific countries, but also on the exact positions on the MACs which are accordingly defined by the countries' NDCs. While the NDCs of the regions in the ME are different, these NDCs are generally low and the differences do not seem to be significant, especially in the lower ambition levels. For this reason, one may not expect a significant welfare increasing potentials for cooperations in the ME. Nonetheless, the NDCs of model regions outside ME are significantly different (see Figure 1), and hence, benefits from cooperations are more likely. Secondly, the MACs are derived without a climate policy in other regions. In other words, the speculations can not be accurate because the terms-of-trade effects, as a crucial factor in multi-regional models, are mostly ignored. Therefore, the next section investigates the policy options and cooperations scenarios in more detail. Thirdly, our analyses is solely based on the technologies available in the GTAP 9a Power data set in which the share of renewables are limited in the ME, and hence, the MACs are overestimated.

4.3 Policy Scenarios

In this section, policy scenarios are implemented in the form of CO₂ emissions reduction in 2030 relative to the baseline CO₂ emissions. In these policy scenarios, emission targets can be reached in a variety of 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 the Appendix A and Appendix B).

4.3.1 Aggregate results

This section presents the results on the aggregate macroeconomic variables in the ME for cooperations presented in Table 5 and different NDCs. Figure 10 shows the percentage change in the total CO₂ emission in the ME for different cooperations and ambition levels. Figure 11 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. Figure 12 and Figure 13 depict the percentage change in aggregate welfare and aggregate Terms-of-Trade, respectively, for different levels of cooperation and NDCs. 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 cooperation levels and only differs with ambition levels (NDCs). The aggregate emission reduction in the Ref (and for all cooperations within the ME) is 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, 13.6 \$/tCO₂ and 290 \$/tCO₂. In addition, the results show that in the Ref scenario there is about 3.5% welfare reduction. This amount corresponds to the findings in the EMF36 Core results, where the ME is not disaggregated into regions. Welfare loss amounts to about 12.4% in NDC-1.5C. Regarding the ToT, results show that ToT drops to 0.967 and 0.89y, respectively for NDC and NDC-1.5C in the Reference scenario (Ref).

Comparing the results along the cooperation levels and ambition levels for the No_ME scenario and cooperations within the ME, several insights emerge: I) As expected, the results show that the higher the levels of ambition, the greater the carbon prices and welfare losses with the lower the ToT. II) There is a leakage of emission to the ME in No_ME scenario where the ME does not implement any climate policy. The leakages are about 0.77% and 3.7% of the emission in the baseline. However, such a leakage can only result in a partial elevation in welfare, compared to Ref, in high ambition levels. In fact, the ToT effect shows that much of the welfare loss in the ME is due to the climate policy in other regions as the cutback in importing fossil fuels from the ME is massive. And, III) when ambition levels are lower, the cooperations within the ME are notably neither welfare-increasing nor welfare-decreasing. One important reason for such behavior is that even though Saudi Arabia and XFE have the most expensive MACs, their ambition levels (NDC and NDC+) are so low that the carbon prices in Saudi Arabia and XFE may not increase to a high amount that bring about significant benefits from cooperations with regions such as Iran and XNE with lower MACs. IV) In higher ambition levels, however, even though the price differences may be in favor of a welfare-increasing cooperation, the ToT effect is dominant and prevents the overall region from gaining from collaboration within the ME. However, this does not preclude benefits for specific regions in the ME. The next section will elaborate on that, and will also present a short discussion on the regional results.

Comparing the results along the cooperation levels between the ME and regions outside the ME, several important insights emerge. I) In cooperations with China, India, and Russia, the ME is an emission permit demander in both low and high ambition levels. Considering both the MACs and NDCs in China, India, and Russia, one notices that the reason for taking a demander position by the ME in such cooperations that China and India have relatively lower MACs, whereas Russia promises comparably lower NDCs. While the common carbon price is lower in such cooperations, there are two effects preventing 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 ToT 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 level NDC-1.5C the emission payments are dominant and the welfare in the ME are slightly worsened compared to the Ref. II) The ME highly benefits from cooperation with Europe. Europe has comparably very high promises which results in higher carbon prices in the Ref scenario (about 200 \$/tCO₂ and 730 \$/tCO₂) than the average carbon prices in the ME. Europe is also a major destination for fossil fuel exports from the ME. Therefore, by the ME taking the position of emission permit supplier, there are massive payments from Europe to the ME and at the same time the ToT increase which consequently result in significant welfare gains by the ME—the welfare losses are almost one third of the welfare losses in the Ref scenario. And, III) the Global coalition is also beneficial for the ME. While the Global cooperation is beyond all cooperations discussed so far, it can be seen as the effect of all cooperations. In low ambition levels, similar to the cooperation with Europe, the ME is a supplier of emission permits and its ToT advances. However, the advancement in ToT in the Global cooperation is much more significant than the cooperation with Europe due to the more efficient redistribution of carbon permits worldwide which does not result in a significant cutback in fossil fuel exports from the ME. In higher ambition levels, the cheap MACs are dominant and the ME take the position of emission permit demander. Yet, the ToT effect is dominant and the outcome is an aggregate welfare increase in the ME.

Here we can also compare the results of the Ref (or IRN_SAU_XFE_XNE) and Global cooperations with

the corresponding EMF36 Core results in which the ME is not disaggregated. Although the aggregate emission reduction in the ME are slightly higher than in the EMF36 Core calculations (due to a higher NDC for Saudi Arabia in our scenarios), the welfare reduction in the Ref and Global cooperation are to a large extent similar to the welfare loss in when the ME is not disaggregated. This effect shows possible benefits, such as higher possibility for a more efficient reallocation of emission abatement, from further disaggregation.

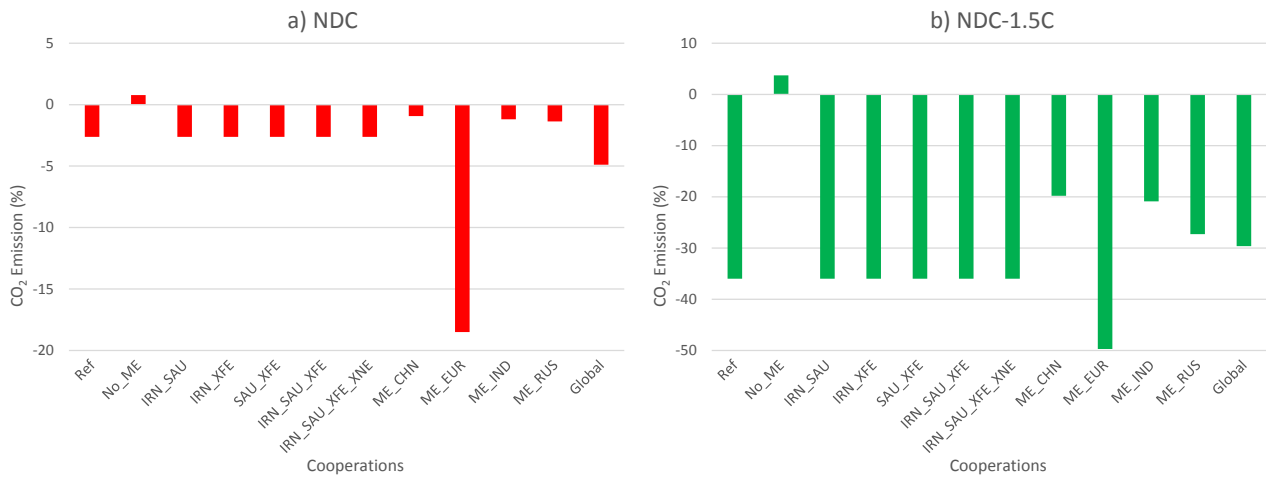


Figure 10: Percentage change in aggregate CO₂ emission in the Middle East for different levels of cooperation and NDCs.

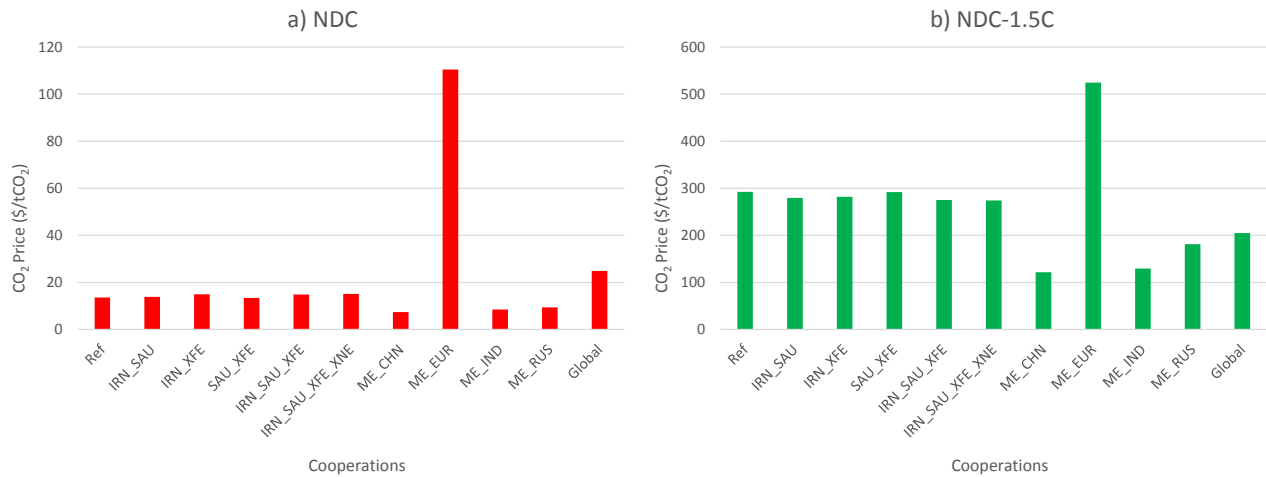


Figure 11: Average CO₂ price in the Middle East in USD per tCO₂ for different levels of cooperation and NDCs.

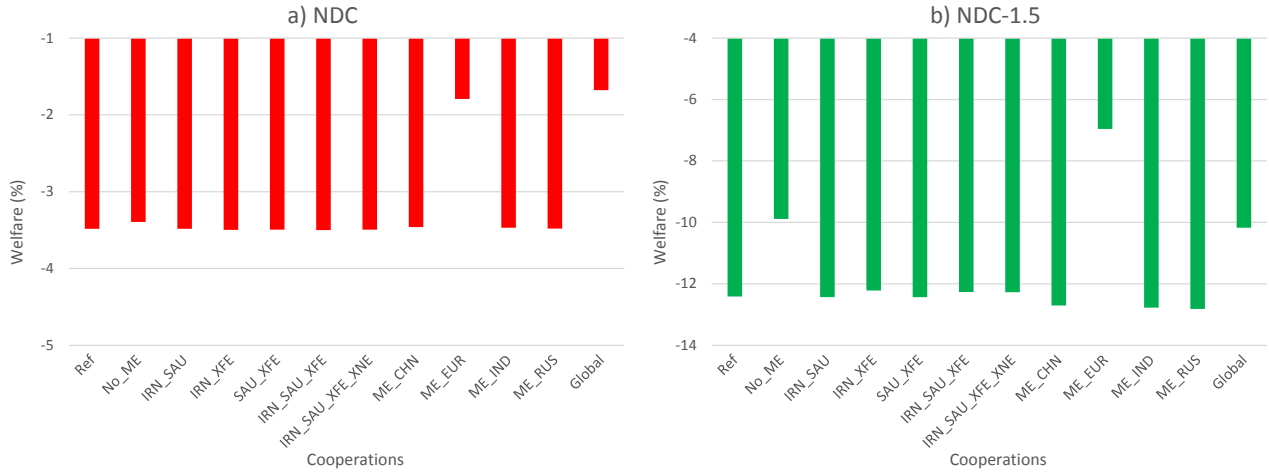


Figure 12: Percentage change in aggregate welfare in the Middle East for different levels of cooperation and NDCs.

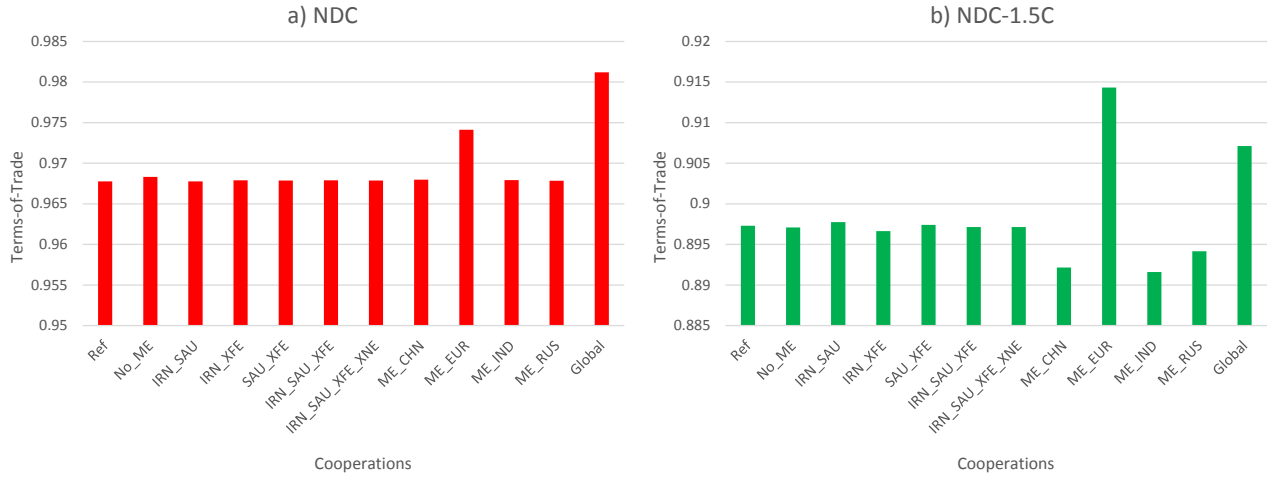


Figure 13: Percentage change in aggregate Terms-of-Trade for the Middle East for different levels of cooperation and NDCs.

4.3.2 Regional results

This section presents the regional results in the ME. Figure 14 and Figure 15 show the percentage change in regional CO₂ emission and the corresponding regional CO₂ price in USD per tCO₂, respectively, for different levels of cooperation and ambition levels. Also, Figure 16 and Figure 17 show the percentage change in regional welfare and ToT, respectively, for different cooperation and ambition levels in the ME. In the Ref scenarios, as there is no cooperation possibility, the regions are bounded to their promised ambition levels, and the carbon prices in the respective regions reflect the astringency of the ambition level and availability of domestic abatement potentials. Note that, as stated in Section 4.2, the reallocation of international trade has an influence on the outcomes, and the carbon prices in the Ref may not exactly match with the respective point on the MACs.

Comparing the results in the Ref and No_ME scenarios among the regions and along the ambition levels, several insights emerge. I) In the Ref cooperation, even though Saudi Arabia and XFE have relatively the most expensive MACs, their promises for NDC and NDC+ are so low that the required carbon prices to meet their promises are lower than the levels required in Iran and XNE whose MACs are cheaper.¹² Under the Ref, the carbon prices in XNE and Iran are respectively about 19.3 \$/tCO₂ and 17.0 \$/tCO₂ in NDC, while the carbon

¹²Please note that we have used NDC and NDC+ for Saudi Arabia that is higher than what were used in EMF36 Core scenarios. Yet, the carbon prices in Saudi Arabia is lower than in Iran. Therefore, our chosen NDCs would not affect the results much if otherwise we followed EMF36 Core NDCs.

prices in Saudi Arabia and XFE are about 14.6 \$/tCO₂ and 2.5 \$/tCO₂, respectively. However, despite the fact that Iran and XNE generally have the highest ambition levels and cheapest MACs, the emission reductions needed for higher ambition levels in NDC-1.5 in Saudi Arabia and XFE are high enough to increase their carbon prices in the Ref cooperation to a level greater than what are required in Iran and XNE. The carbon prices in the NDC-1.5C for the Ref in Saudi Arabia, XFE, XNE, and Iran are approximately 370, 350, 265, and 215 \$/tCO₂. II) Saudi Arabia has the highest welfare loss with -6.5% and -20.6%, respectively, for NDC and NDC-1.5C ambitions levels, whereas XNE has the lowest welfare loss with -1.7% and -6.6%, respectively, for NDC and NDC-1.5C. Iran and XFE are in the middle between Saudi Arabia and XNE regarding the welfare loss. Among other reasons (such as the MACs and the diversity in the mitigation options), one important reason is the ToT effects. Indeed, III) Saudi Arabia has the lowest ToT with 0.95 and 0.83, respectively, for NDC and NDC-1.5C ambitions levels, whereas XNE has the highest ToT with 0.98 and 0.96, respectively, for NDC and NDC-1.5C. Iran and XFE, again, place in the middle between Saudi Arabia and XNE regarding the ToT. Saudi Arabia's economy is most dependent on oil exports and oil usage (for power generation). Therefore, even a quite low reductions in its oil export and oil usage would be costly. On the other hand, XNE has relatively more diverse possibilities for power generation (XNE has the highest share of renewable in its energy basket) and is less dependent on fossil fuel exports than other regions in the ME. While Iran has a cheap MAC too, the drawbacks in its fossil fuel export due to climate policy in other regions make it more vulnerable than XNE in terms of both welfare loss and reduction in ToT. IV) In the No_ME scenario, where the ME regions do not implement any climate policy, there is leakage of emissions to Iran, XNE, XFE, but not to Saudi Arabia. That can be explained as the substitutability between export of fossil fuels and their domestic use in all regions in Iran, XNE, and XFE. However, in Saudi Arabia, such a substitutability is harder. V) While the ToT effect dominates in the lower NDCs, and hence there are no significant welfare improvements, under higher ambition levels, No_ME scenario is more welfare improving in all regions.

In addition, several insights emerge when comparing the results along the cooperations and ambition levels. I) In lower ambition levels, there are no significant welfare changes when cooperations form within the ME. One explanation for this observation is the low NDCs and small differences in the carbon prices in the Ref which leave no significant room for a beneficial cooperation. In addition, as an emission trading system only occurs when there is a common carbon price between the highest and lowest carbon prices in the collaborating regions, any collaboration in which Iran engages with Saudi Arabia or XFE will have a carbon price greater than Saudi Arabia's or XFE's carbon prices, and hence, forcing the regions with the most expensive MACs to further mitigate—which is obviously not efficient in terms of welfare gain. This also holds for cooperation between Saudi Arabia and XFE in low ambition levels. II) In higher ambition levels, Iran benefits from cooperations within the ME, whereas Saudi Arabia experiences welfare losses, which admits that the effects of payments in the emission market seem to be a dominant effect for Iran and Saudi Arabia, but in different directions (note that Saudi Arabia enters the emission trading market as a demander of emission permits, whereas Iran acts as a supplier of emission permits). The welfares of XFE and XNE mainly do not change, which implies that ToT is the dominant effect in these regions. III) In lower ambition levels, the carbon price difference between the average price in the ME and common carbon price in cooperations with China, India, or Russia is not significant, and hence these cooperations do not considerably affect the regions in the ME. However, IV) in the high ambition levels, the cooperation between the ME and China, India, or Russia are welfare-decreasing evidently for Saudi Arabia and slightly for Iran, whereas XFE slightly benefits from these cooperations. XNE is indifferent. In these cooperations, the regions in the ME take the position of emission permit demander, and hence they pay to the other regions. This effect seems to be dominant and worsens the welfare in Saudi Arabia. In addition, China and India are great destinations for fossil fuel exports from the ME. Therefore, the ToT of Saudi Arabia and Iran reduce more which consequently further decrease the welfare in the cooperations with China or India. Regarding the welfare in XFE, the common carbon price in cooperation with China, India, or Russia is lower than the carbon price in XFE, and hence the effects of outsourcing the abatement becomes dominant and welfare-increasing. Note that XFE has a lower average emission intensity than the ME. Therefore, for example, although XFE and Saudi Arabia have similar carbon prices in the Reference scenario, the emission intensity in XFE is lower than in Saudi Arabia, and consequently, less abatement by XFE is more cost-efficient than by Saudi Arabia. V) All the regions in the ME highly benefit from cooperations 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, when the regions in the ME take the position of emission permit supplier, they receive massive payments from Europe and simultaneously the ToTs improve. It consequently results in significant welfare gains by the ME. Iran's welfare increase even improves beyond the baseline, by about 0.6% in NDC and 3.2% in NDC-1.5C, which is well explained, in addition to Iran's enjoying a cheap MAC, through the significant increase in ToT in Iran, that is visibly higher than the increases for other regions. Finally, VI) the regions in the ME also benefit from the Global cooperation where all the model regions cooperate. While the regions in 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. In either case, their ToTs markedly improve because in the Global cooperation the global import of fossil fuel from the ME does

not fall as dramatically as it happen in other cooperations. Note that the advancement in Saudi Arabia's ToT in the Global cooperation is much more significant than the cooperation with Europe due to the more efficient redistribution of carbon permits worldwide which results in a cutback in fossil fuel exports from the regions in the ME and especially Saudi Arabia. However, comparing the Global cooperation along the ambition levels, one realizes that the regions in the ME enjoy more from a supplying emission permits than demanding them, as the increase in welfares is more visible in the lower ambition levels.

Four further points are important: Firstly, while we mostly rely on the NDC targets calculated by the EMF36 Core project, there are different interpretations of NDCs of some regions in the ME than those used in this study. Some regions' NDC commitments also provide emission baselines within the commitment that differs from the IEO used in the EMF36 Core project. Therefore, applying this different NDC interpretation 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), its baseline emissions are projected to be around 1000 Mt in 2030, therefore NDC would result in emissions reduction 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 lowest range calculated in Chepeliev and van der Mensbrugghe (2020). This 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. Secondly, the main reason why different types of collaboration within the regions in ME are not welfare-increasing can be high heterogeneity in mitigation efforts. Although in the EMF36 Core project some specific interpretations of the NDC targets are analyzed, some other estimates of NDC targets by countries are also available (e.g. du Pont et al. (2017) and Climate Action Tracker (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 welfare increasing for the ME as a whole. Thirdly, as stated before, the technological representations in the 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 have an impact on the results as well. Finally, other policy mechanisms, like fossil fuel subsidies reform, could potentially be combined with carbon pricing and affect the results.

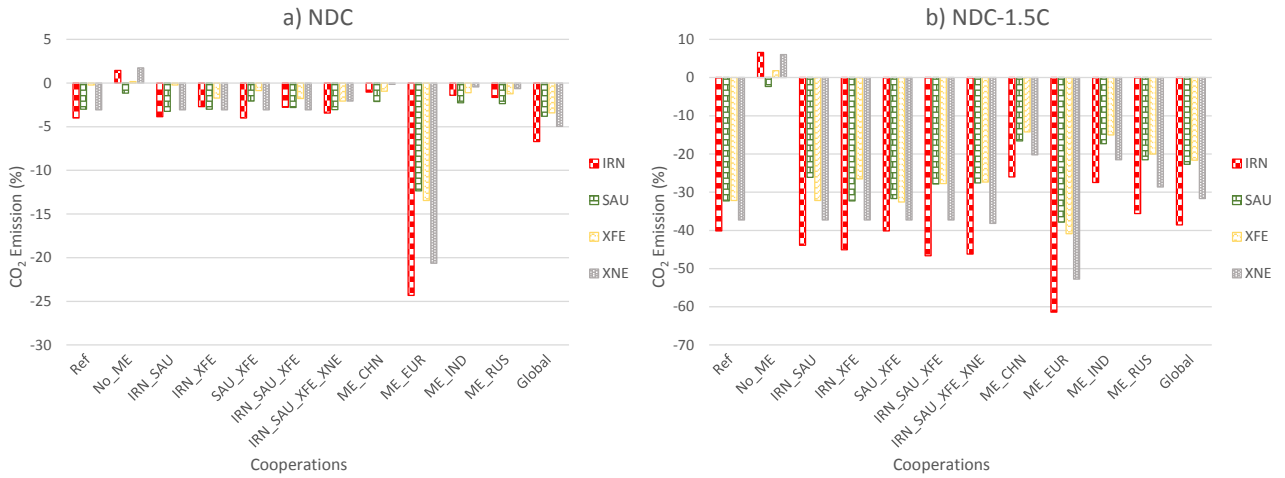


Figure 14: Percentage change in regional CO₂ emission in the Middle East for different levels of cooperation and NDCs.

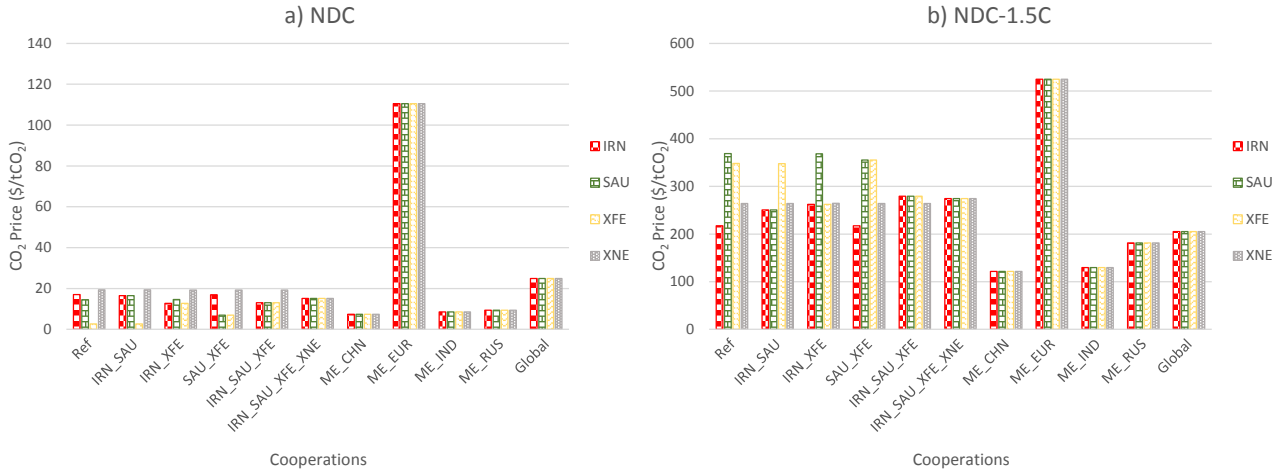


Figure 15: Regional CO₂ price in the Middle East in USD per tCO₂ for different levels of cooperation and NDCs.

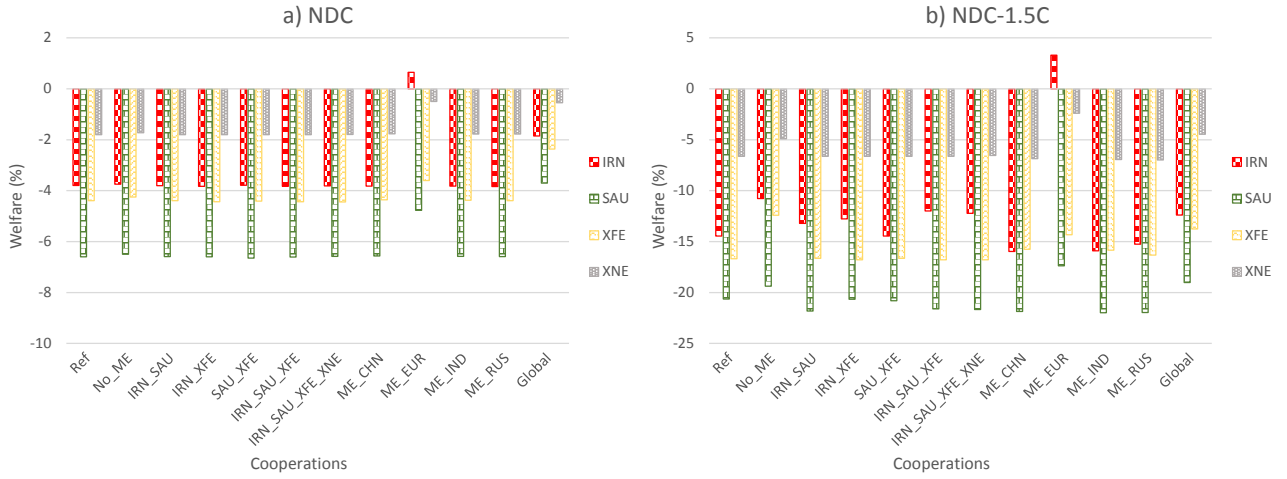


Figure 16: Percentage change in regional welfare in the Middle East for different levels of cooperation and NDCs.

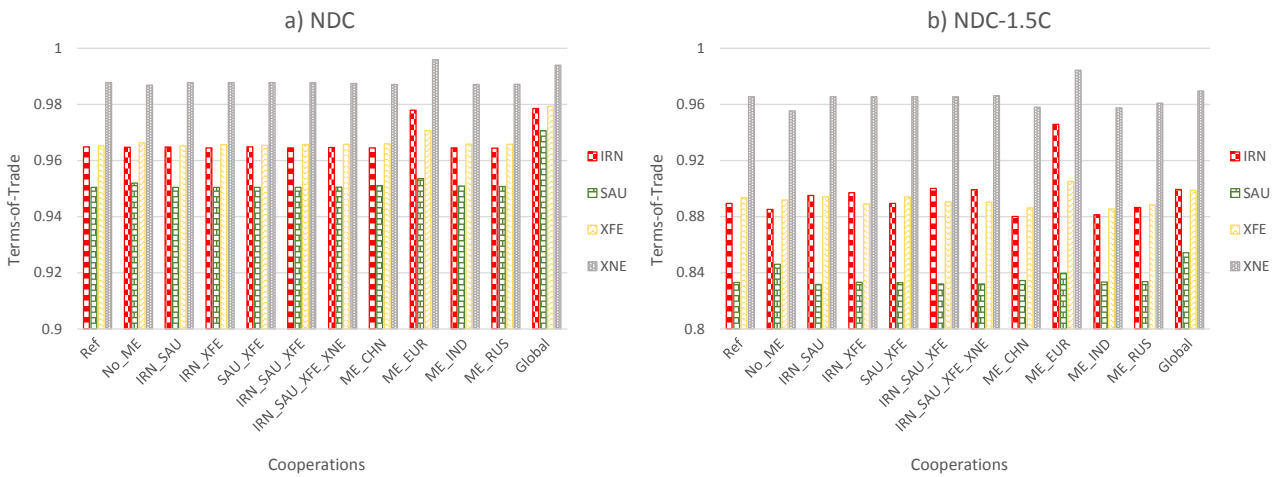


Figure 17: Percentage change in regional ToT in the Middle East for different levels of cooperation and NDCs.

5 Conclusion

Through the Paris agreement, individual countries have submitted national pledges of certain reductions in their carbon emissions by 2030, so-called Nationally Determined Contributions (NDCs), which can be met through different instruments. The 36th round of Energy Modeling Forum (EMF36) investigates various policy regimes to fulfill NDCs and the widespread economic impacts such regimes may bring about. 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 extraction required for the worldwide fulfillment of NDCs. The high cost of abatement in the ME is shown in the core EMF36 project.

The ME is not only the world's largest producer and exporter of oil but also 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. However, the countries in the ME are very diverse. While, for example, Iran and Saudi Arabia are among the top 10 emitters in the world, there are countries such as Bahrain and Jordan 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.

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 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 (comprising hydro, solar, and wind technologies), nuclear, fossil, and others (including geothermal and bio fuel technologies). 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. NDC, conditional NDC (NDC+), NDC to meet the 2-degree global average temperature target (NDC-2C), and NDC to meet the 1.5-degree 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 that goes beyond the cooperation options examined in EMF36 Core scenarios and Coalition Subgroup.

The baseline results show that Iran has the lowest baseline carbon price to meet its projected GDP and CO₂ emission growth presented in the IEO projections. In addition, Saudi Arabia has the highest baseline carbon price while XFE and XNE have the next highest places. Emission shares of fuels in the ME suggest that oil is the main source of emission in Saudi Arabia, XNE, and Iran, whereas XFE emits mostly by burning natural gas. Besides, XNE is the only regions that has a sizable amount of coal in its energy mix. The results suggest that Iran, XNE, and XFE have the lowest MACs in order, whereas Saudi Arabia has the highest MAC. While Iran and XFE mainly mitigate by firstly less use of natural gas, and secondly less use of oil, it is more cost-efficient for Saudi Arabia and XNE to mitigate by consuming firstly less oil, and secondly less natural gas. Yet, XNE can mitigate significantly by less use of coal.

The results on policy scenarios show that much of the effects on the ME comes from the terms-of-trade due to the drawbacks in fossil fuel importations from the rest of the world even if the ME does not implement any climate policy. In addition, in case of the no climate policy in the ME, there will be a leakage of emission to all the regions in the ME, except for Saudi Arabia. Nonetheless, such a leakage, only under high ambition levels, can partly moderate the welfare loss. The results also show that, under low ambition levels, in the Ref scenario (that is, without any cooperations), the highest carbon prices will occur for XNE, Iran, Saudi Arabia, and XFE. However, for the same scenario under high ambition levels, the highest carbon prices will emerge for Saudi Arabia, XFE, XNE, and Iran. Nevertheless, the cooperations within the regions in the ME are not welfare increasing if aggregate welfare is considered. Yet, under high ambition levels, Iran mostly enjoys from cooperations within the ME, whereas Saudi Arabia experiences a welfare loss. The regions in the ME will demand emission permits and do not benefit under cooperations with China, India, or Russia, mostly because the ToT exacerbates and its effect dominates such that in the higher ambition levels the regions may even experience slight welfare losses. On the contrary, the regions in the ME highly benefit from a cooperation with Europe where these regions act as suppliers of emission permits and receive massive payments from Europe. Iran's welfare exceptionally increases beyond its baseline welfare when the ME cooperates with Europe. The Global cooperation is also highly beneficial to the regions in the ME as the fossil fuel importations by the rest of the world significantly elevates in the Global scenario. Nevertheless, 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.

Several caveats are noteworthy: Firstly, while we mostly rely on the NDC targets calculated by EMF36 Core project, there are different baselines as well as interpretations of NDCs of some regions in the ME than those used in this study. Therefore, a possible research question for future studies can be further investigation of cooperation efficiencies under other baseline and NDCs for the region. Secondly, the technological representations in the model strictly follow the presentations in the GTAP 9a Power data set, and there are no backstop technologies activated in the forward calibration of the model or counterfactual scenarios. More renewable options can potentially reduce the carbon prices. Thirdly, other policy mechanisms, like fossil fuel subsidies reform, could potentially be employed together with carbon pricing, and this process can potentially affect the results. As the Middle East is characterized by high fossil fuel subsidies, assessment of various policy mechanisms are promising research questions. Finally, the effects of policy scenarios on the specific sectors are not fully covered in this paper. Such studies with a focus on specific sectors in the ME countries can deepen our understanding of underlying mechanisms of policy options. We leave these research paths for future.

Competing interests

The authors declare that they have no conflicts of interest.

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

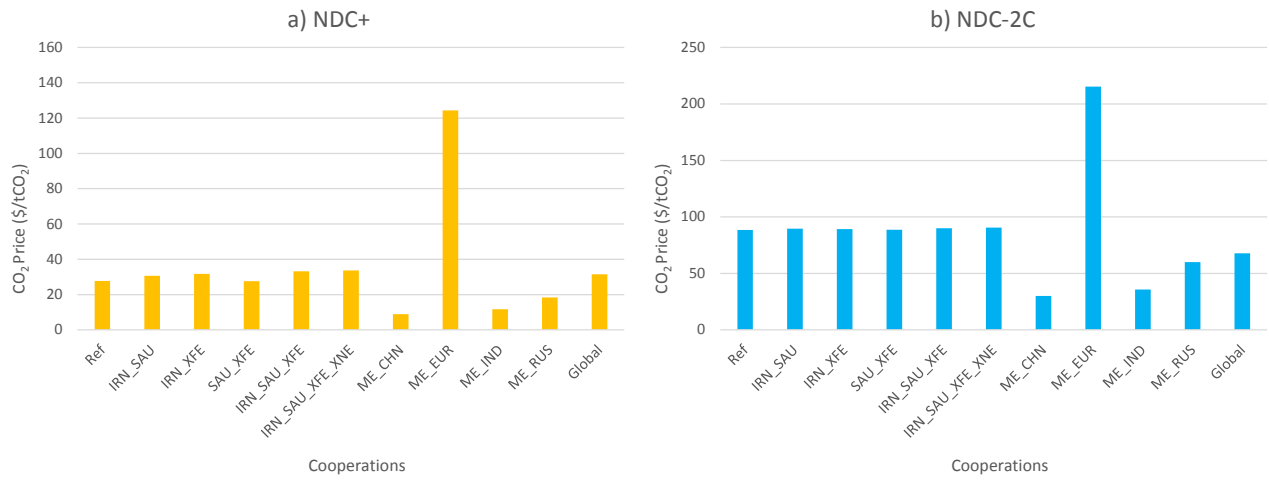


Figure 18: Average CO₂ price in the ME in USD per tCO₂ for different levels of cooperation and NDCs.

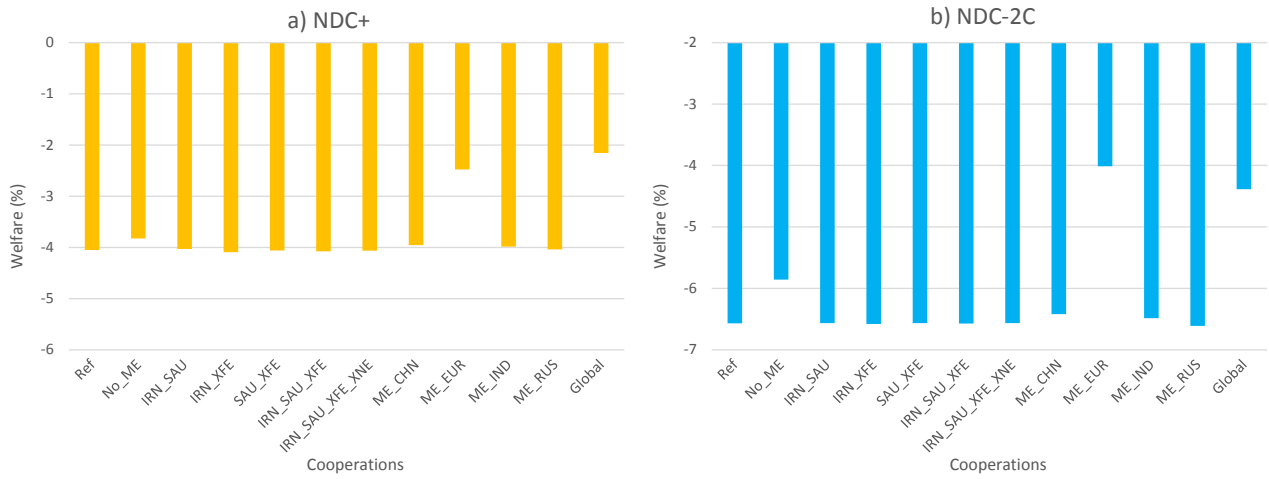


Figure 19: Percentage change in aggregate welfare in the ME for different levels of cooperation and NDCs.

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

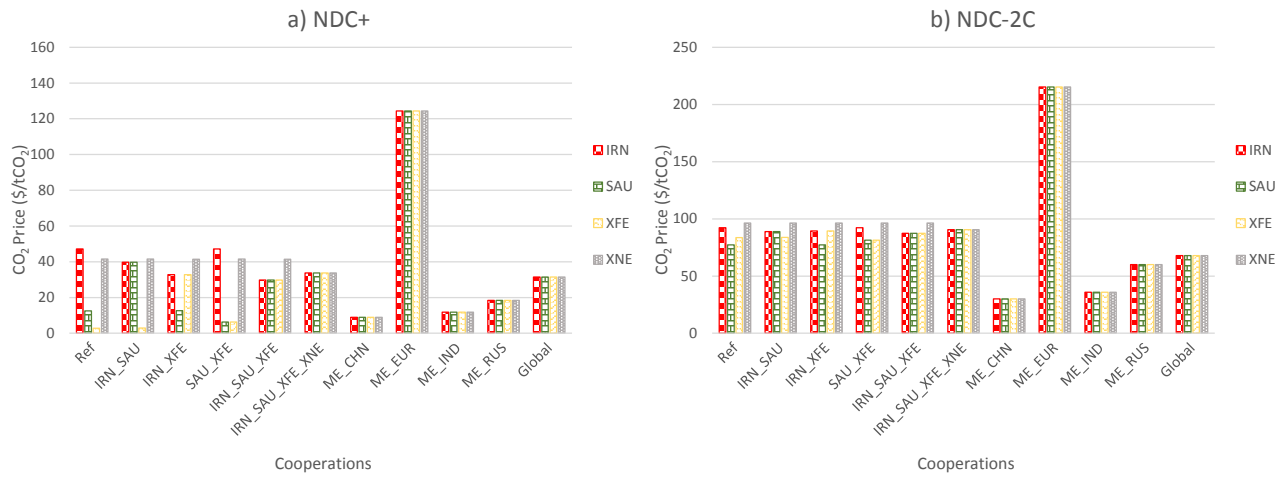


Figure 20: Regional CO₂ price in the ME in USD per tCO₂ for different levels of cooperation and NDCs.

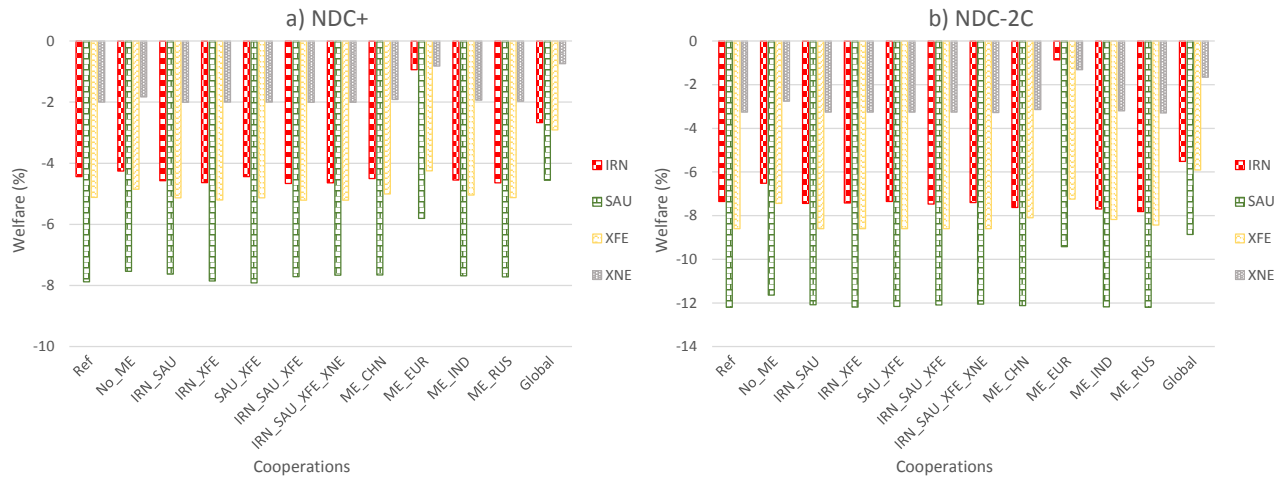


Figure 21: Percentage change in regional welfare in the ME for different levels of cooperation and NDCs.

Appendix C: Sensitivity analyses

As all models, CGE models, too, are sensitive to key assumptions. In our study, there are many assumptions that can be the focus on a thorough sensitivity analysis. Armington elasticity values in multi-regional trade models seem to be promising candidate 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 common 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, elasticity of substitution between electricity produced by different technologies (renewable, nuclear, fossil, and others)) in the electricity sector as a promising candidate for affecting the results. Note that, for the sensitivity analyses, it is essential to re-calibrate the model as these assumption will affect the baseline too. For this reason, we present the results on the welfare and CO₂ revenues as a percentage change against the absolute values for the cooperations as well as baseline.¹³ For the sensitivity analyses, we deviate from the main values by $\pm 20\%$. Also for the brevity of the analyses, we only present the results on the ME.

Figure 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 0.025% in both directions. However, for higher ambition levels, the changes in welfare are slightly more pronounced such that the fluctuations may raise to 0.5%. 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 while CO₂ revenue in the ME is affected by the changes in assumptions, the fluctuations are generally below 10%. Nonetheless, CO₂ revenues are affected more by the assumptions about the composite electricity that the values of Armington elasticity. Finally, the effects of changes in substitution elasticity in electricity composite on CO₂ revenue is larger under higher ambition levels, whereas the effects of Armington elasticity is more pronounced under lower ambition levels.

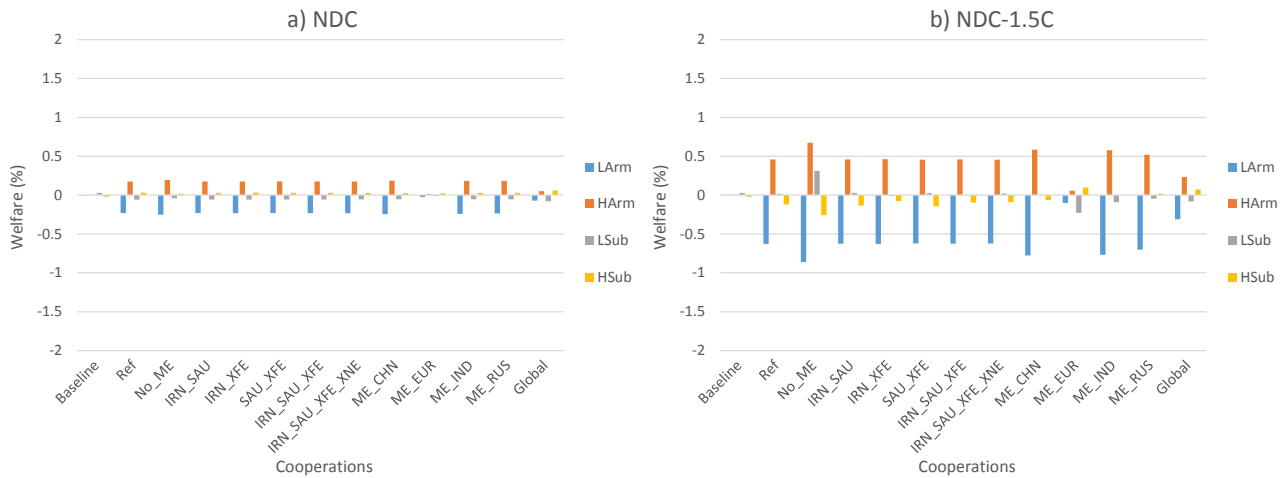


Figure 22: Percentage changes in welfare of the Middle East in baseline and different cooperation levels and for different NDCs.

¹³Note that in the previous sections, we did not present the absolute values of welfare, 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. In addition, as the carbon prices are calculated in relation to the baseline carbon prices, we present the CO₂ revenues to include the changes in baseline values too.

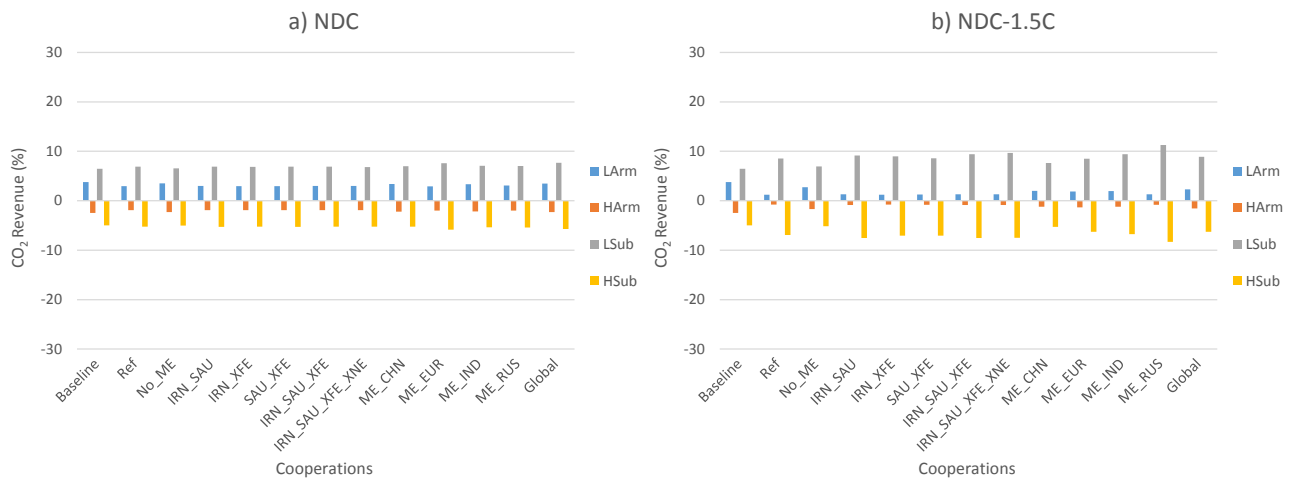


Figure 23: Percentage changes in CO₂ revenue of the Middle East in baseline and different cooperation levels and for different NDCs.