SOAS Department of Economics

An Empirical Analysis of the Influencing Factors of Renewable Energy Production in the Middle East and North Africa

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Student Working paper
No. 2

August 2021

The SOAS Department of Economics Student Working Paper Series is published electronically by SOAS University of London.

Suggested citation

Cole, S. P. (2021), "An Empirical Analysis of the Influencing Factors of Renewable Energy Production in the Middle East and North Africa", SOAS Department of Economics Student Working Paper No. 2, London: SOAS University of London.

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An Empirical Analysis of the Influencing Factors of Renewable Energy Production in the Middle East and North Africa.

Sarah Pudney Cole[1]

Abstract

The region of the Middle East and North Africa (MENA) continually performs relatively poorly in international renewable energy transition rankings, despite promising renewable energy potential due to arid conditions. This study undertakes empirical research on the factors driving non-hydro renewable energy share in total energy production in MENA (SNHRE), as well as the drivers behind total renewable energy share in total energy production (SRE). This study utilises multiple imputation in order to include countries with persistent missingness as well as conduct an assessment into the existence of selection bias in both of the renewable energy variables. Due to missingness, meaningful results for SNHRE drivers were unable to be found, although a more democratic regime, increased conflict and an increase in energy distribution efficiency are found to have a positive impact on the probability of NHRE adoption. FDI inflows, EFI, polity and conflict have theoretically contradictory coefficient estimates although they are also unrobust. OPEC has a robust significant positive effect on SRE, an outcome which is unexpected. Further research into this relationship is necessary as this finding coupled with the positive impact of energy distribution system maturity may highlight the importance of MENA interconnectedness in supporting the expansion of RE.

Keywords: Middle East and North Africa; Renewable Energy; Solar; Wind; Oil; Rentier State; Conflict; OPEC; Climate Change.

JEL classification: C31, C32, C5, C8, N45, N47, N55, N57, N75, N77, P48, Q00, Q42

Acknowledgements: I would like to thank my dissertation supervisor, Dr Risa Morimoto, for her support during the conception and writing of this dissertation, as well as for her ongoing support during the difficult circumstances of the academic year. I would also like to thank Dr Sophie Van Huellen for her extensive empirical help, without which I would not have been able to conduct the investigation I have. I could not have completed my Masters without my friends efforts to keep me sane, so I would to thank Ben, Isha, Juliet and Rehana for looking out for me. Finally, I would like to thank my family for always supporting me in my academic endeavours.

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Acronyms

CO2	Carbon Dioxide
CCS	Complete Case Scenario, CCS
REC	Consumption Of Renewable Energy
COP	Convention Of The Parties
DESERTEC	Deserts- Technology
EMB	Expectation Maximisation With Bootstrapping
FDI	Foreign Direct Investment
GHGs	Greenhouse Gases
GPD	Gross Domestic Product
GFCF	Gross Fixed Capital Formation
GCC	Gulf Cooperation Council
MENA	Middle East And North Africa
MAR	Missing At Random
MCAR	Missing Completely At Random
MNAR	Missing Not At Random
MI	Multiple Imputation
NHREP	Non-Hydro Renewable Energy Participation
OLS	Ordinary-Least-Squares Regression
OECD	Organisation For Economic Co-Operation And Development
OPEC	Organisation Of The Petroleum Exporting Countries
RE	Renewable Energy
REO	Renewable Energy Output
REP	Renewable Energy Participation
RET	Renewable Energy Transition
SB	Selection Bias
SA	Sensitivity Analysis
SNHRE	Share Of Non-Hydro Renewable Energy
SRE	Share Of Renewable Energy
EFI	The Economic Freedom Index
TO	Trade Openness
UAE	United Arab Emirates
UNFCC	United Nations Framework On Climate Change
WEF	World Economic Forum

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1. Introduction

Global warming is caused by greenhouse gases (GHGs) creating an insulating layer around the planet, preventing sun rays from exiting the atmosphere, leading to a rise in global temperature and climate disruption (Lashof and Ahuja, 1990). Carbon dioxide (CO_2) is the most significant greenhouse gas released accounting for 77% of total greenhouse gases, and has been rising exponentially due to the burning of fossil fuels for energy, accounting for 75% of CO_2 releases (Kaygusuz, 2007). In 1980, global atmospheric CO_2 levels were at 18.4 billion metric tonnes, compared to 32.7 in 2012, an increase of 77.5% (Lin and Omoju, 2017). Whilst countries in the Organisation for Economic Co-operation and Development (OECD) will continue to be responsible for a large amount of CO_2 emissions, 97% of CO2 increases from 2008 were from non-OECD countries, including the Middle East (Birol, 2008). Development pathways frequently rely on high-energy industries, thus the contribution of developing and emerging economies to CO_2 emissions is a serious threat to increasing global temperatures (Corbridge, 1986; Szirmai, 2012). As energy demands continue to rise with population growth, the Sustainable Development Goals include "access to affordable, reliable, sustainable and modern energy for all" as the seventh goal, signifying the importance of energy access for development whilst simultaneously raising concerns over the impact of climate change (SDG, 2015, pg.157).

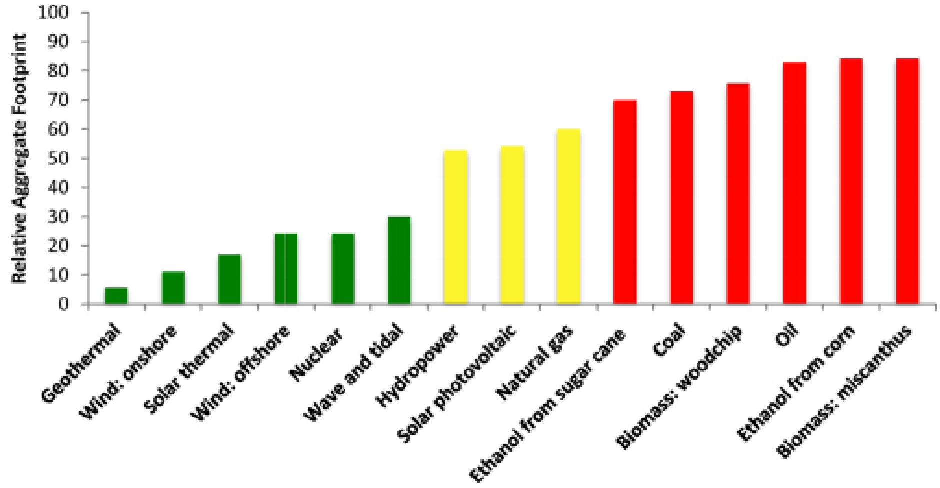
In response to the threat of climate change towards human life, the international community has devised various agreements. The United Nations Framework on Climate Change (UNFCC) was ratified in 1992 by 197 countries and became the first international legislation acting against climate change (UNFCCCa, 1992). This established the Convention of the Parties (COP) who are responsible for important international legislation. One of the most significant international agreements is the Kyoto Protocol adopted in 1997. This agreement was ratified in 2005 and includes binding GHG reduction targets (UNFCCCb, 1998). The Paris Agreement was ratified by 196 countries in 2015 at COP21, with countries agreeing to keep warming to below 2 degrees Celsius (Tagliapatietra, 2019; Paris Agreement, 2015). The success of climate agreements is debated, but clearly signals an international consensus that climate change must be addressed (Maizland, 2021).

1.1 Renewable Energy Transition

As hydrocarbon energies are the primary cause of climate change, alternative fewer polluting fuels are a key solution. A structural change away from traditional reliance on fossil fuels is known as The Renewable Energy Transition (RET) (Murhsed, 2018). Although some argue the RET is not a true transition, due the amount of fossil fuels in the total energy mix having not decreased, the RET has gained traction in policy making as the solution to mitigating climate change (York and Bell, 2019; Kemp *et al.,* 2007; Brand and Fink, 2014).

Renewable Energy (RE) is defined as energy generated continually from nature, a resource which has no finite end. It includes solar (Photovaltaic, Solar heating and Concentrating solar power), wind, marine (also known as tidal), hydro, geothermal and bioenergy (Boyle, 2012; Alrikabi, 2014; Giani *et al.,* 2020; Brunnschweiler, 2010). Not all RE should be treated equally, as Figure 1 below indicates biomass has a higher relative aggregate footprint than oil and coal (Hadian and Madani, 2015). Hydropower is also a controversial RE as it has been shown to disrupt river flow and ecosystems. A notable case includes the Giant Three Gorges Dam on the Yangtze River in China where since 2007 there exists “growing threats from landslides, pollution and flooding, as well as growing social and political unrest… associated with relocating millions of people” (Oster, 2007; Yardley, 2007; Gleick, 2013). Hydropower is also reliant on necessary levels of water flow, vulnerable to water shortages as a result of global warming (Schmidt *et al.* 2016*).* Finally, since hydropower is a cheaper energy source than conventional fossil fuels, countries which can exploit this do so without concerns for global warming, so hydropower production is not representative of climate change avoidance (Lin and Omoju, 2017).

Figure 1: Relative aggregate footprint of different energy sources (Hadian and Madani, 2015)



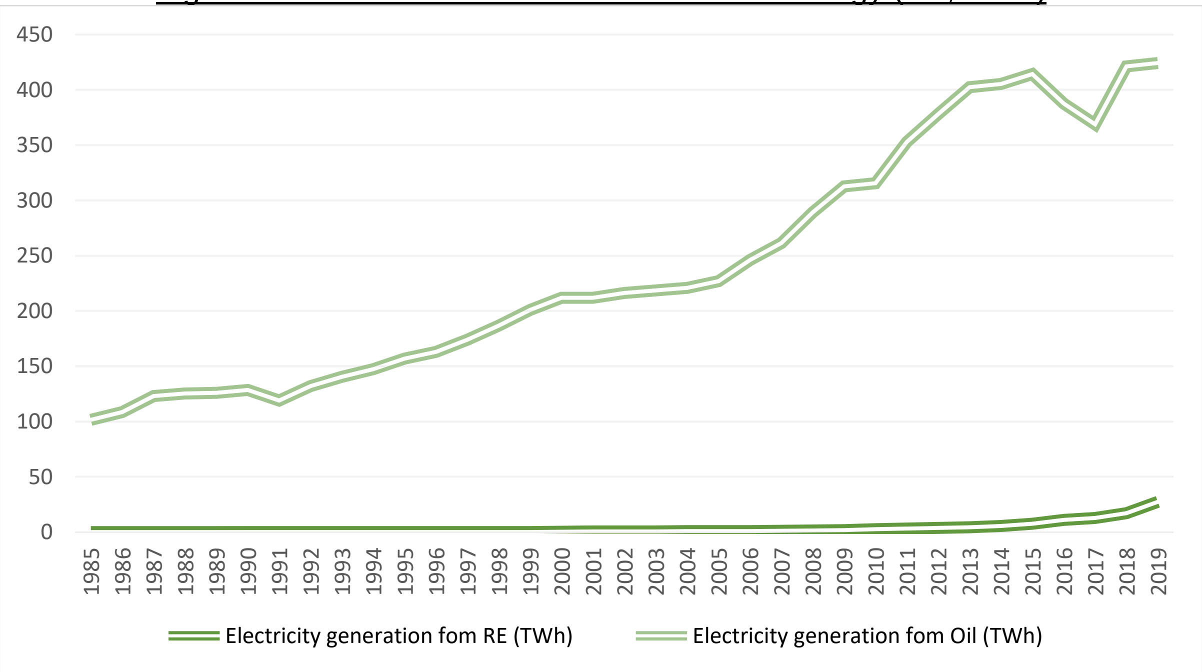
The Advanced Energy [R]evolution scenario reports that the whole world is capable of being 100% renewable powered by 2030 (Teske *et al.,* 2015). The US, South Korea, Japan, Costa Rica and the EU have been early success stories in the uptake of RE (Lin and Omoju, 2017). As of the turn of 2019, the countries with the highest percent of RE in their primary energy production were Iceland (79%), Norway (66%), Brazil (45%) and Sweden (42%) (Richie and Roser, 2020). Despite these successes, the 0.7% annual increase in RE production needs to double in growth in order to meet the goal of global energy sector decarbonisation by 2050 (Gielen *et al.,* 2019). Attempts have been made to construct composite indices to express environmental quality and more recently indices which measure the RET, such as: Environmental Quality Index (EQI, 2014), Environmental Performance Index (Hsu and Zomer, 2016), Energy Transition Index (World Economic Forum, 2021) and the Arab future energy index (RCREEE, 2019). The region of the Middle East and North Africa (MENA) continually performs relatively poorly in these rankings despite promising RE potential.

1.2 Renewable production capacity in MENA

Aghahosseini *et al.* (2020) analysed the feasibility of MENA reaching 100% renewable energy in total energy share by 2030, finding not only that MENA has the capacity to reach this goal, but also that a RE based power system is 55-69% cheaper than a business-as-usual scenario. Due to MENA being arid, wind and solar are the best energy sources, providing 90% of generation capacity (Ibid). One of the weaknesses of RE is its dependence on conditions out of human control, i.e. the weather. Hence, it is vitally important to implement multiple sources that work in tandem, which MENA is well endowed to do. See Jahangiri *et al.* (2016) for a regional capacities study in MENA for hybrid solar-wind power plants.

Within MENA, Morocco has the most ambitious target at 42% of installed capacity and 52% of energy supply for 2030, followed by Algeria with 27% by 2030 (Brand, 2016). Ibid find the greatest physical restriction to producing RE is suitable land availability, listing the United Arab Emirates (UAE), Bahrain, Qatar, Kuwait, Israel, Lebanon, Iraq, Syria and Tunisia as future net importers of RE from neighbouring MENA countries whilst Saudi Arabia, Egypt, Iran and Libya as future net exporters. Ibid emphasise the importance of interconnected electricity grids, electricity infrastructure and storage in order to facilitate large capacity renewable producers to supply to net importers. Excluding hydroelectricity, Jordan and the UAE rank highest for RE production in MENA (RCREE, 2019). The UAE has the capacity to move to 100% renewable energy, inclusive of the cost of scrapping energy subsidies by 2030, and it would cost less than 1 USD per gigajoule (Sgouridis *et al.,* 2016). The IPCC (2018) cites MENA as being critically positioned to endure rising heat waves, droughts and decreasing precipitation due to global warming. Paired with being a water-stressed region which relies heavily on water desalination and air conditioning, this combination is a real social and economic threat (Zyadin, 2013). Research questioning why MENA countries have not embraced the RET provide oil dependence as the primary answer. Figure 2 below shows the slow growth in production of RE compared to oil production alone in listed MENA countries between 1985 and 2019.

Figure 2: Production Of Oil And Renewable Energy (BP, 2019)



Notes: Renewable electricity generated in Terawatt Hours, oil production can be quantified as TWh for comparison purposes.

2. Literature Review

Bhattacharyya and Blake (2010) recognise that although the knowledge surrounding the amount of resources available in MENA and its potential for renewables has been researched, understanding of the factors which drive RE production in these states is only theoretical. First, this section will review the literature on oil dependence in MENA. It will discuss the potential gains for a RET in MENA and highlight the key restrictions preventing MENA from transitioning, including rising energy demand, lack of infrastructure, risky investment landscape and ongoing conflicts. Finally, it will summarise the previous empirical energy studies on energy consumption, energy production and RE production, highlighting the recurring factors.

2.1 Oil dependence in MENA

MENA is rich in fossil fuels, primarily oil, as it holds 56% of the world's oil reserves (Nematollahi *et al.,* 2016). This natural resource abundance is used for satisfying domestic energy needs and gaining income from trade. Studies identify oil resource abundance as providing a cheap energy source, making RE more expensive relatively and highlight how extractive industries are used to fund social and economic development (Pfeiffer and Mulder, 2013; Popp *et al.,* 2011). For example, growth of industries leads to employment and economic growth which provide downward pressure on poverty (Hertog, 2010; Olawuyi, 2020). Oil export dependency is a consequence of the resource curse where countries with abundant natural resources tend to have worse economic growth (Mahdavy, 1970); focus on low-skill intensive extraction industries; and a lower development level with a negative effect on GDP per capita in the long run (Auty, 1993; Karl, 1997; Kakanov *et al.,* 2018). The resource curse appears to hold true for MENA rentier states as they have weak institutional quality, relatively small manufacturing sectors and frequent conflict (Ross *et al.,* 2011). Another key pinnacle of the resource curse is sensitivity to volatile oil prices and the so-called Dutch Disease. This phenomenon describes how an increase in oil price leads to either dramatic appreciation in the currency of the exporter and falling exports in other commodity areas, or lower interest rates and inflation in the case of a fixed exchange rate (Corden and Neary, 1982; Corden, 1984).

Export dependency is characterised by the derivation of more than 60% of merchandise exports from primary commodities (UNCTAD, 2019a), whilst the World Economic Forum (WEF) defines a country as being dependent on oil (which includes natural gas, coal and other oil products) when fuel accounts for over 90% of export merchandise value (Hutt, 2016). A rentier state is similar; however, the key difference is that the majority of government revenue must be from foreign sources, most commonly through the sales of natural resources (Ross, 2012). The term rentier state was coined by Mahdavy in 1970, though a minimum of government income is not specified. For example, natural resources in the six MENA countries in the Gulf Cooperation Council (GCC) are owned by the ruling monarchy, who profit from their extraction and sale. In return, citizens are almost entirely untaxed and have access to free healthcare, education and subsidised energy (Reiche, 2010). In employing the established multi-level perspective on social technical transitions whilst researching the RET in Nigeria, Osunmuyiaw *et al* (2018) found more attention needs to be given to the role of political forces and their vested interests in energy transition research. As Nigeria is a developing rentier state, their findings highlight that rentier export dependence is more than an economic reliance but also a political necessity. Beblawi and Luciani (1987) proposed a rentier state theoretical framework, composed of three criteria, all of which commodity dependent countries in MENA satisfy. Please see Tagliapietra (2019) for a detailed discussion of hydrocarbon rentierism in MENA and its impacts.

2.2 Potential gains from a RET in MENA

In 2018, at least one quarter of EU crude oil imports came from MENA (Eurostat, 2020). Due to the RET, this market is forecasted to shrink as the EU emphasises RE over fossil fuels. Overland *et al.* (2019) develop an index which measures the gains and losses predicted for countries after a RET and explicitly discuss the potential losses faced by oil exporters when their leverage over importing countries decreases. MENA is in a prime position to take advantage of this shift and export renewables to the EU, a fact already internationally recognised. DESERTEC (DESERts-TEChnology) developed by trans-Mediterranean RE cooperation TREC network, envisions a renewables super grid pairing the solar power of MENA with the technology of Europe (Mason, 2009). Zickfeld and Wieland (2012) also propose an interconnected system between Europe and Gulf states called Desert Power 2050, highlighting the potential for the relationship to be secure and stable due to interdependency from both sides. Renewable resources are more difficult to monopolise thus are "less likely to lead to foreign interventions to secure their supply and more likely to foster international cooperation" (Sweijs, 2014, p.57). The Mediterranean solar plan has gained 750 million USD in development bank investments in recent years, a project MENA should take advantage of learning from (Carafa *et al.,* 2016). These projects are clear indicators of the capacity and attractiveness of the region for RE.

2.3 Energy consumption

Energy consumption in MENA is growing at a greater rate than the rest of the world due to population growth, heavy subsidies and rising living standards. Pro-poor growth is widely regarded to increase both CO_2 emissions and energy consumption, hence policies to raise the standard of living in MENA will likely contribute to emissions (Gertler *et al.,* 2016; Wolfram *et al.,* 2012). Furthermore, growing consumption of energy in MENA is concerning for oil export dependent countries, as it reduces potential exportable goods, and the government loses revenue. Thus, low oil dependency to support domestic energy needs is good for exports, hence why efficiency of domestic energy consumption is so important (Bhattacharyya and Blake, 2010). Rising energy consumption is also a consequence of increasing standards of living. As the middle class grows, demand for welfare, civil participation and public goods grows, potentially diverting funds away from renewable technology investments (Brand and Fink, 2014). However, Barbier (2009) and Renner *et al.* (2008) discuss extensively the economic, social and environmental benefits of producing RE such as increases in local employment and knowledge transfer, of which MENA could benefit. Producing RE does not hinder economic growth and development, but helps it (Ferroukhi *et al.*, 2016).

2.4 Infrastructure and foreign direct investment

Poor energy infrastructure (such as electricity transmissions lines, advanced electrical metering and smart distribution systems) will prevent efficient rollout and transmission (Murshed, 2018). Energy infrastructure investments are predicted to fall short of 2050 targets by 739 billion USD (Carafa *et al.,* 2016). Energy projects demand high financing which is linked to financial sector development and RE technology investments require long term loans and even greater investor confidence. In developing countries, the domestic banking sector is chief provider of external financing and access to bank credit is difficult, thus RE projects are hard to fund (Sonntag-O'Brien and Usher, 2004). Renewable projects also compete for financing with non-renewable projects, which are more established, therefore creating underinvestment in RE (Brunnschweiler, 2010). MENA countries are considered developing despite the UAE, Saudi Arabia, Qatar, Kuwait and Bahrain having current Gross Domestic Product (GPD) per capita of over 20,000 USD (WDI, 2020). Qatar has the highest with 62,000 USD and Yemen has the lowest with 774 USD. Their developing status suggests there does not exist the funds in the general public to finance large RE investments, despite some countries have very high GDP per capita. On top of this, renewable investment in MENA is considered very risky due to war, political instability, threats to personal and business safety, financial instability and changes in investment regime (Komendantova et al., 2012; MIGA, 2013). Significant effort must be made to derisk investment, spreading the impact of negative events, with attempts to do so primarily through regulatory requirements and policies (Carafa *et al.,* 2016).

2.5 Conflict

Brand and Fink (2014) identify the main barriers to RE production in MENA as being linked to political factors including, weak institutions, mistrust, civil wars, political instability and wider conflict. For the majority of the twentieth and twenty first century, MENA has been an outlier in otherwise generally peaceful times (Ahram, 2020). Both intra-state and inter-state violence has been persistent in the region, notably the Yemen civil war (1962-1970), Iraq-Iran war (1980-1988), Gulf war (1990-1991), 1991

Iraq uprising, Algerian civil war (1992-2002), Iraq war (2003-2011), Libyan crisis (2011-present) and Syrian civil war (2011-present) (Ibid). Conflict causes delays in adjustment of fiscal policies and a diversion of resources away from their most productive locations towards the war effort (Rodrik, 1998). Furthermore, Rodrik (1998) credits the development strategy in the middle east in the 1970's being exposed to external shocks as a fault of weak institutional handling of conflict. Thus, it is not only direct impacts of conflict that disrupt the economy but also weak institutions which struggle to both prevent and deal with conflict which amplifies the negative effects. Prevalent conflict is widely recognised as a symptom of the resource-curse as abundant resources are both a motive and opportunity for conflict (Wick and Bulte, 2006). Resource conflicts are widespread and varied from the diamond mines in Sierra Leone (Maconachie and Binns, 2007) and Cocoa farming in Colombia (Angrist and Kugler, 2008) to Columbite-Tantalum mining in the Democratic Republic of the Congo (Lalji, 2007). The theory of the rentier state however suggests a paradox theory, as the ruling elites who solely collect resource rents are able to "buy off opposition or suppress armed rebellion, thereby contributing to political stability and preventing armed conflict" (Basedau and Lay, 2009, p.758). Ibid in an empirical analysis finds rentier states with very high oil dependence to be more peaceful (at least internally) than those with less autocratic governments.

2.6 Empirical energy studies

An assessment of previous empirical studies on the production and consumption of RE gives a better indication of regional disparities as well as pointing to factors which have already been proven important in the plight for RE. Table 1 below gives an overview of the relevant empirical studies.

Table 1: Previous econometrics studies on the production and consumption of renewable energy.

Study	Scope	Variables	Method	Findings
Shakouri and Yazdi (2017)	South Africa 1971-2015	TO REC OEC	ARDL GC	Bi-directional causality found between TO and REC, and REC to economic growth (feedback hypothesis)
Murshed (2018)	5 south Asian emerging economies (BNG, IND, PAK, SRI, NEP) 2000-2017	REC, RES, EI. GDP, CO2, OP, FDI, GDPC, REO, GFC, CPI	UR Cointegration 2SLS GC	Rise in TO increases REC and increases EI. Does not increase RES (share).
Brunnsch-weiler, (2010)	119 Non-OECD developing and transition countries 1980-2006	REO, HO, non-Hydro RE. FSD, CFIPS, FD, power sector reform, Kyoto, EFI, GDPC, FDI, OP, CP, NGP, WP	GLS Arellano-Bond GMM	FSD positive impact on REO. Even bigger impact on non-Hydro RE.
Lin et al. (2016)	China 1980-2011	SREC, FSD GDP, TO, FDI, Fossil Fuel lobby effect	Johansen's Cointegration and ECM	FSD and GDP enhance SREC while TO, FDI and fossil fuel lobby effect undermine it
Salim and Rafiq (2012)	Turkey, Indonesia, IND, Brazil, China, Philippines, 1980-2005	REC, GDP, OP, CO2	Fully modified OLS, Dynamic OLS and GC. Cointegration and ECM.	GDPPC significant impact on REC in all countries. CO2 effects REC in Brazil, China, IND and Indonesia
Lin and Omoju (2017)	46 developed an developing inc. Jordan and Turkey 1980-2011	Share of non-hydro REO. FDI, TO, GDPPC, FSD, OP, policy commitments/ institutions, GFC, NRD	UR, Cointegration, Fully modified OLS, Dynamic OLS, panel ECM,	FSD, OP, TO, positive impact on share of no-hydro REC in long run. Economic growth negative impact on share of REO.
Sadorsky (2009)	G7 countries, 1980-2005	REC, GDPPC, OP, CO2, population	Panel cointegration and VECM	GDPPC and CO2 increases lead to positive effect on REC.
Pfeiffer and Mulder (2013)	108 developing countries, 1980-2010	Non-hydro REO per capita, HO. CP, GP, policy support, Kyoto, GDPC, EDU, OEC, DEM, TO, Aid, OEC growth, FDI, Assets, economic and regulatory instruments	Two stage estimation	Regulatory instruments, GDP, EDU and DEM promote REC. TP, aid, OEC and fossil fuel abundance delay REC.
Popp *et al*. (2011)	26 OECD countries, 1991-2004	Capacity Non-hydro RE, renewables investment, RE electricity supply, GDPC, OEC, nuclear electricity production, hydro electricity production, Kyoto, GP, CP, OP, energy imports, tariffs, RE certificate, RE policy	PATSTAT database on patents	Energy security, fossil fuel production, future electricity demand and national renewable policies have no effect, ratification of Kyoto and deployment of low carbon subs enhance REO
Chang *et al*. (2009)	OECD	REO, GDP, CPI	Panel Threshold Regression Model	Richer countries have capacity to adopt renewable energy, others cant.

Rafiq *et al.* (2014)	China and India, 1992-2011	REO. GDP, CO2	MULTIVARIATE VECM. GC	India- unidirectional short run between CO2 to REO and GDP. In LR bidirectional between all variables, suggesting inherent interdependence. For China, in SR unidirectional from GDP to REO and CO2 to REO. In LR, unidirectional from GDP to REO and bidirectional between CO2 and REO.
Marques *et al.* (2010)	23 European countries, 1990-2006	SREO. Member of the EU, energy import dependency, OP, GP, CP, CO2, fossil fuel contribution to electricity, OEC, GDP, REP	Fixed effect vector decomposition (FEVD) technique	Goal of energy independence enhances RE while traditional energy sources and CO2 emissions impede RE (LOBBY EFFECT). Energy import dependence positive impact on SREO.
Omri and Nguyen (2014)	64 countries, 1990-2011. Split sample into high, middle and low income.	REC. C02, OP, TO, GDPC	Dynamic GMM	Trade openness and increase in CO2 emissions are the major drivers of REC
Akar (2016)	12 Balkan countries, 1998-2011	REC. CO2, GDPC, TO, OR, NGR	Dynamic GMM	GDP negative effect on REC, TO and NGR positive effect
Ackah and Kizys (2015)	Algeria, Angola, Cameroon, Congo, Democratic Republic of Congo, Côte d'Ivoire, Egypt, Gabon, Ghana, Nigeria, South Africa, Sudan and Tunisia 1985-2010	REC. GDP, CPI, capital, population, energy depletion, energy price	One-way random effects model, one-way fixed effects model and dynamic GMM. Sargan test	Energy resource depletion and CO2 drivers of REC, as well as GDP. Energy price negative correlation.

Notes: Variable acronyms: Trade Openness (TO), Renewable Energy Consumption (REC), Share of REC (SREC), Renewable Energy Potential (REN), Overall Energy Consumption (OEC), CO2 emissions (CO2), Gross Domestic Product (GDP), International price of crude oil (OP), Foreign Direct Investment inflows (FDI), GDP per Capita (GDPC), Renewable Energy Output (REO), Share of REO (SREO), Wind Potential (WP), Gross Fixed Capital Formation (GFC), Consumer Price Index (CPI), Hydropower Output (HO), Financial Sector Development (FSD), credit from financial institutions to private sector as share of GDP (CFIPS), Financial Depth (FD), Economic Freedom Index (EFI), Coal Price, (CP), Natural Gas Price (NGP), Natural Gas Rent (NGR), Education (EDU), Democracy (DEM), Natural Resource Dependence (NRD), Oil Rent (OR). Country acronyms: Bangladesh (BNG), India (IND), Pakistan (PAK), Sri Lanka (SRI), Nepal (NEP). Method Acronyms: Auto Regressive Distributed Lag model (ARDL), Granger Causality (GC), Unit Root (UR), two Stage Least Squares (2SLS), Generalised Least Squares (GLS), Ordinary Least Squares (OLS),Generalised Method-of-Moments (GMM), Error Correction Model (ECM)

2.6.1 Energy consumption and trade

Energy models have long been used to determine the factors driving energy consumption within economies to assist with demand forecasting. The interconnectedness between trade liberalisation and energy consumption is initiated in the Heckscher-Ohlin theory of trade. This suggests developing countries produce relatively more goods that require relatively more intense use of natural resources and labour (Heckscher, 1919; Ohlin, 1933). This production leads to a scale effect increase and composite effect increase in energy consumption (as the country moves away from agriculture and towards industry) and a technique effect reduction in energy consumption as efficiency gains are revealed. Trade openness therefore causes an increase in energy consumption, which for the countries of focus in this study is likely to mean an increase in the extraction of fossil fuels for consumption rather than renewable energy increase, as fossil fuels are a more reliable source. Sadorsky (2011) tested the relationship for eight MENA countries between 1980 and 2007, finding feedback between energy consumption with income, a bi-directional relationship between imports and consumption and a uni-directional relationship between exports to energy consumption. Furthermore, in the long run “a one percent increase in exports increases energy consumption by 0.11% while a 1% increase in exports increases energy consumption by 0.04%” (Sadorsky, 2011, p.748). These findings support the theory that trade and energy consumption are interconnected but also that MENA countries can be confident that energy conservations policies will not impact exports, an important policy finding.

With the rise in renewables, research has been undertaken widely on modelling the demand and consumption of renewable energy (REC), initiating a new branch of energy models. REC models have primarily focused on trade (Omri and Mguyen, 2014; Murshed, 2018; Wang *et al.,* 2021; Sadorsky, 2009; Salim and Rafiq, 2012), income (Shakouri and Yazdi, 2017; Akar, 2016), oil prices (Shahbaz *et al*., 2014), CO_2 emissions, financial indicators (Lin *et al*., 2016), energy depletion (Ackah and Kizys, 2015) and social factors (Guidolin and Guseo, 2016; Yazdanpanah *et al.,* 2015).

2.6.2 Renewable energy output

Whilst a majority of studies use REC as the variable of investigation, as is typical in energy consumption models generally, this study uses renewable energy output (REO). This is because the countries of focus are rentier states which by definition extract, sell and consume fossil fuels, implying a dependence on their natural resources. As MENA countries rely heavily on exports of fossil fuels (primarily oil), they are disincentivised from moving towards renewable production.

Oil price is one variable in the assessment of REO which may have a different effect in rentier states. Lin and Omoju (2017) in a study on 46 developed and developing countries between 1980 and 2011 using panel cointegration find economic growth to reduce REO as a share of total energy, whilst oil price, economic development and financial development have positive correlation with REO share. The positive effect of oil price is indicative of the effect of oil as a substitute for RE, such that as oil becomes more expensive, RE is cheaper by comparison. This finding is unlikely to hold for rentier states who rely on the sale of oil, thus an increase in oil prices creates a more lucrative good.

Other variables common in the assessment of REC are also assessed against REO. Rafiq *et al.* (2014) use variance decomposition to further explain the strength of impacts from shocks on the dependent variable. In an assessment of China and India between 1972 and 2011 they find bidirectional causality between GDP, CO2 and REO in India, supporting their inherit interdependence, and in China a long run bidirectional causality between REO and CO2, suggesting not enough is yet being done to curb emissions.

Marques *et al.* (2010) conducted a study on the share of renewables in primary energy supply (SREO) in 23 European countries between 1990 and 2006. Notably, they assessed energy import dependency as a proxy for energy security and find it to be significant. This implies countries with higher energy import dependencies (measured by sum of energy imports) will be more likely to have a higher SREO. Likewise, the lower the share of imports, the lower the dependency (which is the case for MENA). They found the effects of GDP to be unstable which falls in line with a wider consensus but is still surprising, and also found the greater the proportion of coal and oil in the energy supply the lower the SREO, supporting the lobby effect. Murshed (2018) regressed various RE variables against trade openness and found trade openness lead an increase in REO, but no significant effect on SREO.

Another important factor to facilitate REO, as discussed in section 2.4, is the role of the financial system. Brunnchweiler (2010) conducted the most thorough analysis on 119 non-OECD countries between 1980 and 2006, focusing on financial sector development as underdeveloped financial institutions and markets prevent effective channelling of loans for REO. Regulation variables were inconclusive due to weak indexes, and at the time of writing this dissertation, regulation indexes are still too weak for use. Brunnchweiler finds two of the three financial sector variables to be significant while financial depth was deemed too broad a variable to capture robust results. Other studies assess the impact of FDI inflows on REO hypothesising greater greenfield investment to provide technological transfer.

Pfieffer and Mulder (2013) find the opposite to be true in a study on 108 developing countries between 1980-2010. Economic and regulatory instruments, GDP, education and democratic regime have a positive relationship with SREO. Increasing trade intensity, energy consumption, fossil fuel abundance, FDI inflows and aid all reduce SREO. Policy support programmes having a negative correlation to SREO is believed to be the symptom of weak institutions and government as these support programmes, along with aid, are usually directed towards the poorest counties with the smallest capacity to implement renewable diffusion.

Popp *et al.* (2011) take a very different set of explanatory variables when conducting analysis of the factors driving investment in renewables in 26 OECD countries between 1991 and 2004. They include share of electricity supply by renewable source, GDP per capita, nuclear electricity production, electricity from hydro, energy imports, tariffs, renewable energy certificates and renewable energy policy and most significantly, knowledge stock (four different patent counts). Although the impact of research and development is significant, it has less effect on RE investment than ratifying the Kyoto protocol or an increase in the use of nuclear and hydro power, which suggests the drive to reduce carbon emissions is the most significant plight.

As the gap between capacity to produce renewable energy and actual output is considerable in MENA, it is vital to ask which of these restrictions has the greatest impact and what factors could most increase RE production in this region. The literature investigating the factors which influence energy demand is plentiful (Sadorsky, 2011; Shahbaz *et al.,* 2014), whereas traditional energy supply is assumed to be based entirely on natural resources and not a decision factor. In recent years REC and REO has been researched extensively due to the growing trend of sustainability, but there is still a shortage of robust studies focusing on energy production in developing countries. Critically, there are no studies empirically researching the factors influencing REO specifically in MENA. The main contributions of this paper are fourfold.

1. A focus on specifically rentier states in the Middle East and North Africa.
2. The exclusion of hydroelectricity from the renewable production measure as hydropower sources are cloaked in controversy, providing a meaningful measure of effective steps away from fossil fuels.
3. Using the share of non-hydro renewable energy (SNHRE) instead of total production. As a RET relates specifically to structural change, REO is only accurately measured relative to energy from fossil fuels.
4. A unique methodology for data analysis as multiple imputation allows the inclusion of countries with greater missingness (Iraq in particular). Due to the prevalence of zero values in the dependent variable, sensitivity analysis has been conducted to test for selection bias. Thus, this study is able to identify the factors which most influence the adoption of RE and the factors which influence how much is produced.

3. Data

According to UN DESA (2020) and UNCTAD (2019) a commodity dependent developing country is one which 60% or more of its merchandise exports is from primary commodities. UNCTAD (2019) lists Algeria, Bahrain, Iran, Iraq, Kuwait, Libya, Oman, Qatar, Saudi Arabia, Sudan, the UAE and Yemen as commodity dependent (thus by extrapolation- rentier states), although Sudan is not included as part of MENA in the World Bank's classification of countries, therefore it will not be included as part of this study. Due to limited data availability for Bahrain, Libya and Yemen are also not included in this study.

A range of variables were considered for this research based on previous literature and data availability.

The World Economic Forum (WEF, 2020) publishes an annual index on the RET, assigning every country a percent transitioned. This would have been a valuable indicator as it assesses many different aspects of transitioning, however the index only began in 2015, thus providing too few data points for regression analysis.

The dependent variable, total REO, is controversial as this would include energy production from hydroelectricity. Studies have used renewable energy production minus hydroelectricity instead to quantify less controversial methods of renewable energy sources which includes solar, wind, biofuel and geothermal (Brunnschweiler, 2010; Pfeiffer and Mulder, 2018; Popp *et al.,* 2011). Data was taken from Our World In Data which uses data from the BP statistical review and Ember, adjusting for any measurement discrepancies. The dependent variable will be the Share of Non-

Hydro Renewable Energy output (SNHRE) in the total energy supply. This will indicate the growth in renewable capacity relative to hydrocarbon production, essential for measuring a transition away from fossil fuels. Data collection for SNHRE began in 1985, so the earliest data used in this study will be from this year.

Trade openness (TO) has been widely researched in tandem with energy consumption, as previously discussed. The significance of TO on REO in theory is threefold. First, as the EU is a significant consumer of MENA oil, the less open a country is to trade, the more sensitive the country will be to the changing energy consumption trends. Second, TO promotes technological transfer, providing MENA countries with RE expertise. Technology transfer is a key objective of the UNFCCC (1992) for combating climate change whilst supporting industrialisation in developing countries. Thirdly, the economic theory of trade as previously discussed ties trade and energy consumption closely together, with higher trade leading to greater energy use for production purposes. Customs procedures, order compliance and import duties were considered as proxies to measure trade openness. The share of import and export trade as a percent of GDP has be chosen instead, aligning with other energy models (Omri and Nguyen, 2014).

Fuel exports and imports as a percent of merchandise exports and imports are also included as two separate variables. This is due to the importance of an interconnected energy system within MENA in supporting the RE transition (Aghahosseini *et al.,* 2020).

Kaygusuz (2007) states 75% of CO_2 emissions are produced in the generation of energy from fossil fuels. Development strategies and industrialisation will lead to increased energy consumption from the most dependable resource, which in the case of MENA, is fossil fuels. Thus, increases in energy consumption and CO_2 production are likely to reduce the share of REO. Energy consumption is measured as primary energy per capita and is used in various studies (Popp *et al.,* 201; Marques *et al.,* 2010), showing an important link between the demand for electricity in a country and its dependence on proven sources of electricity creation such as oil. Energy efficiency is included using the energy transmission and distribution losses from total energy output as a proxy. Higher energy efficiency means less energy wasted, so less energy needed for domestic consumption and more exported (Bhattacharyya and Blake, 2010). Promoting efficiency effectively reduces hydrocarbon consumption, so is a widely promoted strategy (Zillman et al., 2018). The inclusion of CO_2 emissions can also act as a proxy for environmental degradation, testing to see if REO is responsive to the level of emissions in the region. Ideally, the measure of environmental degradation in a country would have wider scope than just emissions output (CO_2) and would include factors like biodiversity and deforestation. The Environmental Performance Index would have been useful to include however the oldest observations were taken in 2006, therefore it is too recent (Hsu and Zomer, 2016).

The lobby effect is the impact of large hydrocarbon organisations minimising competition. Consumption of fossil fuels in total energy consumption has been used to describe the lobby effect, however this study will instead use the share of oil rents as a percent of GDP in line with Lin and Omoju (2017). The lobby effect is expected to have a negative correlation with REO as governments see alternative energy sources as threats to the potential of their natural endowments. This is especially relevant for this study as rentier states are inherently dependent on natural resource rents. Another variable significant for the study of rentier states is oil price, as energy from oil is a direct substitute for renewable energy electricity. Contrary to oil importers, an increase in the price of oil will encourage a rentier state to extract more oil to profit from the sales, creating a disincentive for investing in renewables. This study predicts to find an opposite effect for oil price compared to renewable energy consumption studies.

Whether a country is a member of the Organisation of the Petroleum Exporting Countries (OPEC) is included, as the mission of OPEC is to coordinate petroleum policies and stabilise oil markets, therefore members will face pressure to promote and support their petroleum industry (OPEC, 2012).

GDP per capita is assessed to test the theory that higher levels of income cause a shift in preferences towards environmental protection. Based on the theory of the Environmental Kuznets Curve, as incomes increase, environmental degradation first increases, then decreases once a tipping point is reached. A negative GDP coefficient could signify that the region has not yet reached the tipping point. Marques *et al.* (2010) point to GDP as a better measure of income in relation to REO than GDP per capita as they find it is the size of the economy, not the standard of living that correlates with investment in renewables. For this study, GDP per capita will be used as the relationship being tested is between the level of development and REO.

Foreign Direct Investment (FDI) inflows are essential to raise capital for the creation or expansion of renewable energy firms or firms linked via upstream or downstream production chains. FDI is essential in developing countries where cash is less available, however rentier states make billions in earnings from the sale of fossil fuels, so have greater access to capital in theory. The role of FDI inflows for rentier states is likely just as significant as in non-rentier states as governments would need to redirect investments away from reliable high carbon technologies.

On the other hand, developing REO in MENA is a significant investment risk (Komendantova et al., 2012; MIGA, 2013). Financial sector development is an important contributor to facilitating investment in a country through risk reduction. Renewable energy projects require long term loans, primarily achieved from domestic bank credit or international financing. Both of these pathways require a competent financial system to manage the processing of loans and repayments. The WDI provides data on domestic credit to the private sector and it is used in this study as it is in Lin and Omoju (2017).

The level of energy system infrastructure and assets in a country is measured using Gross Fixed Capital Formation (GFCF) which has been used in previous studies (Murshed, 2018; Lin and Omoju, 2017). The higher the level of GFCF, the easier and quicker a country may be able to develop a renewable energy system. For example, a pre-existing extensive national grid with high carrying capacity will provide a country with a strong electricity transportation framework on which to add electricity generated from renewables.

The Economic Freedom Index (EFI) is a variable created under the Economic Freedom of the World which ranks countries and gives an overall score out of 10 according to 5 categories of economic freedom (which themselves are averages of many subsections). These include size of government, legal systems and property rights, access to sound money, freedom to trade internationally and regulation of credit, labour and business. The EFI is compiled by the Fraser Institute (2018) and has been used in Brunschweiler's (2010) study on the role of finance in facilitating the RET as a proxy for institutional strength. It is expected that a higher EFI score correlates with high REO.

Political variables considered include the Kyoto Index and democracy index. The Kyoto index indicates which countries have ratified the Kyoto Protocol and is used in other studies, however the protocol entered into force in 1992 which is too recent for any significance in a regression study (UNFCCCb, 1998). Instead, Polity is used, named as POLITY2 from the POLITY5 annual time series dataset (Marshall and Gurr, 2020). Polity gives a combined annual score between -10 and 10 measuring regime authority spectrum from hereditary monarchy to consolidated democracy. This variable was used in Pfeiffer and Mulder (2013) as an important determinant of renewable production adoption.

A measure of conflict is vitally important in this study as MENA has suffered with domestic and international conflicts consistently through the 21st century such as the Arab Spring, which weakens institutional strength due to political instability (Simons, 2004). Governments must reprioritise when conflict break outs, thus the support of new industry (such as renewable energy creation) is no longer as important. The Global Peace Index (GPI, 2020) began in 2008, so it is too recent to use and the Global Conflict Risk Index (Halkia *et al.,* 2017) is inaccessible as an open source. Hess (2003) uses household consumption difference during years of conflict as an indicator of the impact of conflict on economic growth, however this proxy could signal many other factors such as recession, natural disasters or other causes not linked to conflict and is thus not appropriate for this study. The proxy chosen for conflict is the number of individual incidents of conflict in a country retrieved from the Uppsala Data Conflict Program (UDCP) (Stina, 2020). This proxy includes all incidents of conflict between two or more distinct groups occurring on home soil.

Furthermore, variables that would indicate the level of risk countries face due to climate change were also considered, as a larger proportion of the population at risk of rising sea levels or drought would incentivise government to invest more in renewables in order to avoid internal displacement. The data for these variables were young and sparse therefore they are not used. For example, “Land where elevation is below 5 meters”, which can be found in the WDI.

The final independent variables chosen based on availability for the countries selected and free online access are shown in Table 2 below.

Table 2: Variables used in regression analysis, source and unit of measurement.

Variable code	Long Name	Source	Measure/unit
SRE	Renewables total	Our world in data	Percent of renewable energy production as share of total electricity production
SNHRE	Renewables minus hydro	Our world in data (2020)	Percent of renewable energy production minus contribution from hydropower as share of total electricity production
OPEC	Opec Member	BP (2019)	Dichotomous, 0= not member, 1=member
Oilres	Oil reserves	BP (2019)	Thousand million barrels
Energycons	Primary energy consumption	BP (2019)	Giga joules per capita
Energyloss	Electric power transmission and distribution losses	WDI	% of output
C02	C02 emissions	BP (2019)	Million tonnes
Oilpr	Crude oil price	BP (2019)	Dollars, changes, see data doc
Trade	Trade openness	WDI (2020)	Imports add exports as percent of GDP
FDI	Net FDI inflows	WDI (2020)	Foreign direct investment, net inflows (% of GDP)
GDP	GDP per capita	WDI (2020)	GDP per capita (constant 2010 us$)
EFI	Economic freedom index	Fraser Institute (2018)	Index, 0-10, 10 is highest freedom rank
Oilrent	Oil rents	WDI (2020)	Oil rents (% of GDP) revenue minus costs
GFCF	Infrastructure	WDI (2020)	Gross fixed capital formation (% of GDP)
Fuelexport	Fuel exports	WDI (2020)	Fuel exports (% of merchandise exports)
Fuelimport	Fuel imports	WDI (2020)	Fuel imports (% of merchandise imports)
Findev	Financial development	WDI (2020)	Domestic credit to private sector (% of GDP)
Conflict	Conflict	UCDP (2020)	Number of individual incidents of violence
Polity	Polity2 Index	Marshall and Gurr (2020)	Measure of regime from -10 to 10, where 10 is democracy

Table 3: Summary statistics for each variable altogether (not separated by country)

Variable	Maximum	Minimum	Mean	NA
Year	2019	1985	2002	0
Country	-	-	-	-
SRE	26.869	0	2.78	129
SNHRE	3.025	0	0.05242	196
OPEC	1	0	0.75	0
Oilres	297.671	2.993	90.174	0
Energycons	1142.2	30.86	300.14	0
Energyloss	50.632	1.564	11.721	40
C02	670.712	7.037	149.238	0
Oilpr	126.45	19.94	58.02	0
Trade	734.922	0.021	132.768	27
FDI	8.49635	-4.33687	1.07937	17
GDP	80886	1432	23166	27
EFI	7.49	0	4.648	92
Oilrent	64.078	3.868	29.514	24
GFCF	43.074	2.918	23.423	98
Fuelexport	99.9865	0.1927	84.1133	75
Fuelimport	65.67176	0.01491	2.67874	82
Findev	105.187	1.267	36.714	59
Conflict	797	0	51	37
Polity	6	-10	-6.913	16

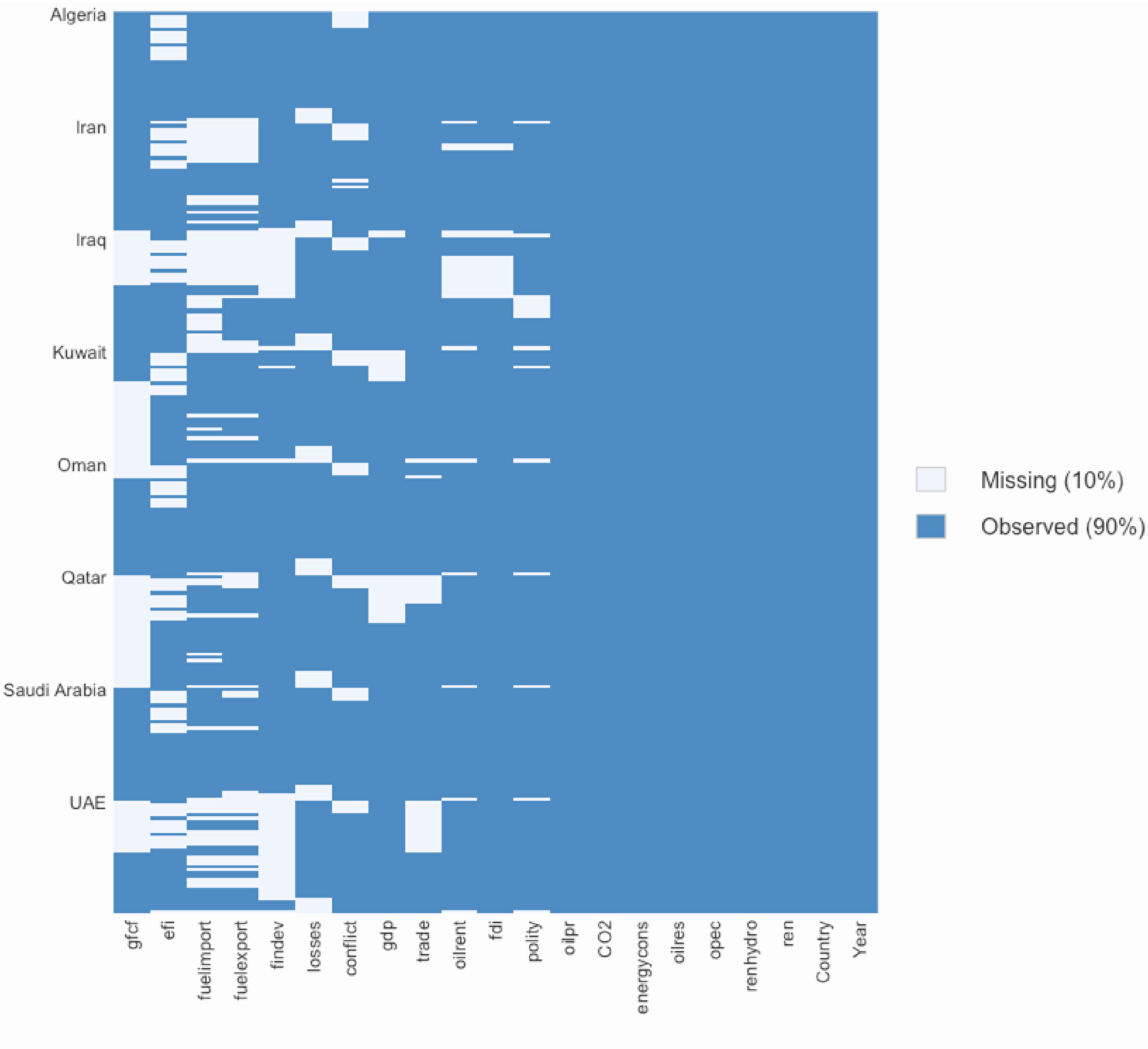
4. Methodology

The data analysis conducted in this study involves three main stages; multiple imputation, selection bias analysis of SNHRE through sensitivity analysis, and analysis of SRE driving factors. An initial key issue that arose is the potential existence of selection bias in the data, which is discussed in section 4.2.

4.1 Multiple imputation

It is necessary to conduct multiple imputation (MI) for two reasons. Firstly, there are certain observations scattered throughout the data for which no data is available. This is referred to as missing data- and is a problem because regressions cannot be undertaken with any missing data. To avoid this issue, listwise deletion is commonly undertaken in social-sciences where all cases are deleted which contain at least one missing variable (Little and Rubin, 1987). In this case, 10% of all observations are missing and listwise deletion would result in 205 cases out of a potential 281 and exclusion of Iraq, Kuwait, Qatar and the UAE, as for every year these countries have at least one observation missing. Please see the summary table (Table 3) for note of missing observations (NA) for each variable, and Figure 3 below for the missingness map. Such a reduction in observations result in a much smaller dataset from which less valid inferences can be drawn. MI is widely accepted as a preferable treatment of missingness (Baraldi and Enders, 2010; Cheema, 2014).

Figure 3: Missingness Map for dataset.



4.1.2 EMB

The MI method used is expectation maximisation with bootstrapping (EMB). Traditional methods of imputation are not suited to endemic missingness found in political variables especially considering the worsened rate of missingness experienced by developing countries (Honaker and King, 2010). A description of the MI method can be found in the Appendix 1.

To avoid computational difficulties common in standard posterior imputation methods, EMB instead uses a bootstrapping algorithm, which uses “the original sample units to impute the missing observations in their original positions” (Honaker and King, 2010). Bootstrapping instead of posterior estimates is still proper imputation as it incorporates between-imputation variability, so despite EMB being a relatively new algorithm, it can be used with confidence (Rubin, 1987). After imputation, the observed data remains the same, but the imputed data differs having been imputed using the density function of the observed data to reflect the uncertainty of the missing data. A final step is required to combine the imputations. Rubin’s rule developed by Rubin (1987) enables the imputed datasets to be combined through averaging the point estimates and employing a more complex process for deriving standard errors.

4.1.3 Working through Amelia II

Using the Amelia II package in the software R provides an EMB MI application. Other packages in R such as Sbgcop (Hoff, 2007), imputeTS (Moritz and Bartz-Beielstein, 2017) and MICE (van Buuren and Groothuis-Oudshoorn, 2011) were attempted, however Amelia II proved best for use with cross-sectional time-series data (Hollenbach *et al.,* 2014). A detailed description of the AMELIA II imputation process can be found in Appendix 2. After evaluating the best MI method after assessing diagnostics (shown in the Appendix 3), if there was no missingness in the dependent variable, an OLS regression could be undertaken and inferred from. In this case, since the dependent variable has been imputed and because SB is hypothesised, further tests must be undertaken.

4.2 Selection bias assessment through sensitivity analysis

In addition to undertaking MI for the purpose of filling in missing values in the explanatory variables, MI has been utilised due to the prevalence of zero values in the dependent variable. 70% of the SNHRE observations are zero, meaning between 1985 and 2019, there was a 30% chance one of the MENA countries in this study produced any NHRE. Due to research suggesting MENA has a great capacity for producing NHRE, these zero values are questionable. The zero values may be zero because of omitted data, such as off-grid NHRE not being included in the variable, or due to a bias in the selection mechanism (Pfeiffer and Mulder, 2013). Assuming (SB), an ordinary-least-squares regression (OLS) on the dataset only for observations that are not zero in the dependent (a complete case scenario, CCS), would result in bias coefficient estimates giving invalid inferences (White and Carlin, 2008; Nakagawa, 2015). Thus, MI of SNHRE has been undertaken, setting the zero values as missing and using an imputation mechanism to predict them. A comparison of the SNHRE output regression in a CCS and imputed NHRE case can show SB. If SB does exist, inferences are more valid from the imputed NHRE.

Murray (2018) identifies three different types of missing data. Missing Completely At Random (MCAR), where a comparison of a MCAR MI regression output with a complete case scenario (CCS) shows no statistical differences. Missing at Random (MAR) is the assumed case in all MI and specifies that the missingness is conditional on certain explanatory variables, thus the missing mechanism can be identified. Missing Not At Random (MNAR) specifies that the mechanism for which missingness occurs is conditional on the imputed variable itself. Selection bias is dependent on a MNAR case, but proof of MNAR is not proof of SB (Qin et al, 2020).

The decision to assess SB through MI and not through the use of Heckman's two step procedure is deliberate (Heckman, 1976). Despite the wide use of the two-step procedure (Deb and Trivedi, 2002; Mroz, 1987), it has been heavily criticised for an overreliance on the normality assumption and its susceptibility to collinearity issues (Bushway *et al.,* 2007; Puhani, 2000). For these reasons, an assessment of selection bias will instead follow the method of sensitivity analysis (SA) proposed by Qin *et al.* (2020).

The first step in SA is to stochastically impute NHRE under the assumption of MAR, then manually adjust the imputations under MNAR. Equation (1) is the NHRE production equation. Equation (2) is where only positive values of NHRE are included in the regression, treating all zero values as 'missing', thus when the decision equation *d* (the NHRE participation binary variable) is equal to 1. Equation (2) is equivalent to a CCS or listwise deletion of the dependent. In these equations, b is the intercept, β is the coefficients vector, *X* is the independent variable vector and ε is the error term.

$$SNHRE_i = b + \beta X_i + \varepsilon_i \quad (1)$$

$$SNHRE_{i,1}^{obs} = b_1 + \beta_1 X_{i,1} + \varepsilon_{i,1} \quad \text{when } d = 1 \quad (2)$$

It is widely accepted that $\beta \neq \beta_1$ in cases of selection bias. A multivariate model is then used to represent the selection behaviour of NHRE production. A NHRE binary variable is created which is 1 when the observed NHRE is positive and 0 if the observed NHRE is 0. This way, the NHRE participation (NHREP) binary variable created will demonstrate a probability increase or decrease in the chance of producing NHRE after a change in an explanatory variable. A logit regression with NHREP as the dependent is called the decision equation, as it illustrates the factors which influence the decision to produce NHRE. Theoretically, NHREP should be dependent on the potential amount of NHRE production, just as the choice of whether or not to work a particular job depends on the wage. The logit decision equation is equation (3) below, where the dependent is binary NHREP participation which is dependent on imputed values of NHRE under the MAR assumption. An insignificant NHRE in equation (3) indicates MAR bias and this is where SA is utilised to assess if the SB is MAR or MNAR.

$$NHREP_i = \alpha SNHRE_{i,0+1}^{MAR} + \varphi X_i + \theta Z_i + e_i \qquad \text{where } \alpha = 0, NHRE_{i,0+1}^{MAR} \qquad (3)$$

$$NHREP_i = \alpha SNHRE_{i,0+1}^{MNAR} + \varphi' X_i + \theta' Z_i + e'_i \qquad \text{where } \alpha \neq 0, NHRE_{i,0+1}^{MNAR} \qquad (4)$$

Sensitivity Analysis is the process by which MNAR is simulated through imposing systematic shifts on the imputed SNHRE via delta adjustments and assessing how this impacts the significance of the variable in the decision equation (Qin *et al.,* 2020). Tipping point analysis enables examination of the sensitivity of SB but only at a marginal level, where the MAR assumption is only just being rejected. An insignificant $SNHRE_{i,0+1}^{MAR}$ in equation (3) would confirm the MAR assumption. Imputed SNHRE observations were reduced by 1% increments from 90% until the variable becomes significant in the NHREP logit model (4). At this stage, $NHRE_{i,0+1}^{MNAR}$ is then used as the dependent variable in an OLS regression (5), and compared to equation (2), the CCS. In comparing the regressions, significant changes in the coefficient estimates β would indicate the severity of SB. If there exists no overlap in the confidence interval of an explanatory variable, this is significant evidence to support selection bias MNAR, and the MNAR imputed NHRE variable is deemed more appropriate to draw inferences from in an OLS.

$$NHRE_{i,0+1}^{MAR} = b + \beta_{0+1}^{MAR} X_i + \varepsilon'_i \quad (5)$$

$$NHRE_{i,0+1}^{MNAR} = b + \beta_{0+1}^{MNAR} X_i + \varepsilon'_i \quad (6)$$

4.3 Modelling Non-Hydro Renewable Energy Production Share in Total Energy

Once the tipping point for MNAR significance was found, the output regression from equation (5) is uninterpretable due to no significant explanatory variables. Regression outputs for equation (5) can be found in Appendix 5. This is discussed further in the results section. Due to this outcome, adjustments were made in order to attempt to reduce the standard errors of the imputed NHRE, including increasing the number of imputations to 20 and 50, increasing the confidence of the observational priors from 95% to 99.99%, increasing the polynomial function from 2 to 3 and reducing the explanatory variables to variables with strong correlation only. These efforts were futile, providing very little improvement to the significance of β_{0+1}^{MAR}. Further regression outputs can be found in Table 13 in the appendix. As there is no usable interpretable OLS regression as equations 2 and 5 have no significant β_{0+1}^{MAR}, no inferences can be made about the factors which drive the amount of NHRE produced in the selected countries. The same process is repeated for total renewable energy in energy share.

4.4 Modelling Renewable Energy Production Share in Total Energy

As an investigation into the factors driving SNHRE produced no interpretable OLS results, an investigation into the factors driving the share of total renewable energy (inclusive of hydropower energy) (SRE) is also carried out. As SRE has a lower proportion of missingness, the results should provide significant explanatory variables in equation (5’ and 6’). The process of MI was repeated alongside OLS and logit regressions. Diagnostics of the SRE imputation can be found in the Appendix 4, where the best method is clearly shown.

$$SRE_i = b + \beta X_i + \varepsilon_i \quad (1')$$

$$SRE_{i,1}^{obs} = b_1 + \beta_1 X_{i,1} + \varepsilon_{i,1} \quad \text{when } d = 1 \quad (2')$$

$$REP_i = \alpha SRE_{i,0+1}^{MAR} + \varphi X_i + \theta Z_i + e_i \quad \text{where } \alpha = 0, NHRE_{i,0+1}^{MAR} \quad (3')$$

$$REP_i = \alpha SRE_{i,0+1}^{MNAR} + \varphi' X_i + \theta' Z_i + e'_i \quad \text{where } \alpha \neq 0, NHRE_{i,0+1}^{MNAR} \quad (4')$$

$$SRE_{i,0+1}^{MAR} = b + \beta_{0+1}^{MAR} X_i + \varepsilon'_i \quad (5')$$

$$SRE_{i,0+1}^{MNAR} = b + \beta_{0+1}^{MNAR} X_i + \varepsilon'_i \quad (6')$$

The MAR imputed SRE variable was significant in the logit equation (3’), thus assessing the degree of SB through SA is not necessary. A comparison of β_1 and β_{0+1}^{MAR} will support the SB hypothesis if there are differing confidence intervals for explanatory variables. Finally, as $SRE_{i,0+1}^{MAR}$ is the most appropriate to use, equation (5’) will then be used for making interpretations about which factors drive RE in MENA. For robustness checks, various models of the OLS regressions on $SRE_{i,0+1}^{MAR}$ are carried out.

Analysis of the driving factors for SRE production consists of developing a baseline set of results which captures control variables. As it may be important to control for other effects to see how this impacts the coefficient estimates, four additional models are created on top of the baseline variables, namely; financial environment, trade openness, conflict and energy industry maturity. A comparison of the baseline coefficients to coefficients in additional models can highlight robustness of the coefficient estimates.

5. Results and Discussion

5.1 Results of Modelling Non-Hydro Renewable Energy Production Share in Total Energy

A logit regression with NHREP as the dependent shows the original SNHRE data as significant. This makes sense as the potential SNHRE a country could produce should influence whether or not they chose to produce any. A second logit regression is then undertaken replacing the original NHRE variable with imputed NHRE (equation 3). $\alpha SNHRE_{i,0+1}^{MAR}$ is insignificant in this regression which confirms the MAR assumption, as the significance of the variable has changed after imputation, confirming there exists a missingness mechanism. The missingness mechanism could be captured in the explanatory variables X_i, or the mechanism could be captured by SNHRE itself, but this would require SNHRE potential to play a significant role in NHREP.

In order to investigate further if the missingness mechanism is MAR or MNAR, SA was conducted delta-adjusting the imputed SNHRE so that the MNAR condition is met. At which point imputed SNHRE becomes significant in equation (4) can show how plausible MNAR is, and by extrapolation, the plausibility of SB. The significant MNAR random scenario is a large departure from the MAR imputations, a 63% reduction. As this reduction is very large, it indicates that a MNAR scenario is unlikely to be plausible. Had the significance of the variable been more sensitive, say at 3-5% reduction, the MNAR scenario would be more credible. Since SA simulates scenarios under which SB *could* arise, this scenario being so drastic suggests SB is unlikely. The density distributions for an imputed MAR SNHRE and imputed MNAR SNHRE can be found in Appendix 5.

Further support of SB would have involved a comparison of $\beta_{0+1}^{MNAR}$and β_1, and assessing any significant changes. Final interpretations would then have been made from equation (6). As none of the β_{0+1}^{MNAR} were significant, this comparison is meaningless and there is nothing to interpret from (6) (See Appendix 5 for OLS output tables). It is most likely that the insignificance of OLS regressions with any of the three SNHRE variables is due to little variance in SNHRE (due to 70% being zero), leading to a large proportion of missingness in the imputed SNHRE (Garson, 2015). Thus, the OLS regressions with MNAR imputed SNHRE as the dependent may include data which truly doesn't show any relationship with the explanatory variables.

The dataset does include the variable for SRE which has less missingness. After repeating MI for zero-value SRE observations, imputed SRE was found significant in equation (3'). This finding means SA is not necessary. Table 4 below shows a comparison of equation (4), a logit regression of NHREP including MNAR imputed SNHRE and equation (3'), the logit regression of REP including MAR imputed SRE. Table 4 illustrates that OPEC and polity impact the chance of a country participating in NHRE but does not affect RE participation. This suggests being a member of OPEC reduces the probability and an increase in democracy increases the probability of solar and wind production, although neither have any impact on the probability of REP. As REP captures traditional renewable energy production methods such as hydropower and biomass, these are not likely to be impacted by the same factors as modern more technologically intense methods such as solar and wind. In line with this explanation, CO2, oil rents and fuel export effect the possibility of REP but not NHREP. For both logit regressions, the negative intercept suggests rentier states in MENA, all factors held constant, would not produce any RE or NHRE.

Table 4: Comparison between total renewable energy participation (REP) and non-hydro renewable energy participation (NHREP) logit regressions.

	REP logit (4)	NHREP logit (3')
(Intercept)	-1.48*** (0.257)	-0.986*** (0.257)
RE (MAR)/NHRE (MNAR)	0.0236** (0.0072)	0.219*** (0.111)
OPEC	-0.0531 (0.0755)	-0.506*** (0.0802)
Oil Reserves	-0.0021** (0.0006)	0.0026*** (0.0006)
Energy Consumption	0.0002 (0.0002)	0.0004 (0.0002)
Energy Losses	-0.0153* (0.0061)	-0.0193*** (0.007)
CO2	0.296*** (0.0459)	0.0818 (0.0483)
Oil Price	0.216*** (0.0519)	0.265*** (0.0538)
Trade Openness	-0.0004* (0.0002)	0.0004*** (0.0002)
FDI	-0.005 (0.0098)	-0.0187 (0.0098)
GDP	0*** (0)	0*** (0)
EFI	0.0264* (0.0104)	0.0512*** (0.0102)
GFCF	-0.004 (0.0034)	0.0067 (0.0038)
Oil Rents	-0.0117*** (0.0028)	-0.0046 (0.0028)
Fuel Exports	0.0066*** (0.0014)	0.0003 (0.0014)
Fuel Imports	0.0054 (0.0041)	0.0015 (0.0043)
Financial Sector Development	0.0048*** (0.001)	0.0073*** (0.0011)
Conflict	0.0013*** (0.0002)	0.0011*** (0.0003)
Polity	0.0162 (0.0088)	0.0518*** (0.0092)

*Notes: *** significance <0.001, ** significance <0.01, * significance <0.05. Standard error in brackets beneath the coefficient estimate*

5.2 Results of Modelling Renewable Energy Production Share in Total Energy

As $\alpha SRE_{i,0+1}^{MAR}$ was significant, there is evidence for SB. A comparison of the CCS SRE OLS and MAR SRE OLS shows many changes in the significance of variables as well as two non-overlapping confidence intervals (Appendix 6). For this reason, the equation (5') OLS is the most robust. An investigation of the factors driving the SRE produced consisted of modelling OLS regressions, beginning with a baseline set of explanatory variables and expanding the model against other control groups. The baseline results in Table 5 show a highly significant intercept, highlighting that all variables controlled for, MENA countries have the potential to have an 11% SRE, although the probability of adopting RE is initially negative, meaning a greater potential amount of RE will decrease the chance of RE being produced at all. Being a member of OPEC increase potential SRE by 5.37% whilst an increase in GDP per capita and a one-unit step closer towards democracy both reduce the potential SRE.

Extended results give further scrutiny into how SRE production in MENA is influenced by the financial environment, economic openness, conflict and energy industry maturity, as well as assessing the robustness of the baseline indicators against different control groups.

Surprisingly, none of the financial environment indicators are significant, suggesting neither financial sector development, GFCF or FDI have any effect on the potential SRE produced. This is in contrast to previous studies which have found positive effects for all three variables. The logit regression does however show both FDI and financial development to be significant in determining the adoption of RE. Table 5 shows a 1% increase in FDI has a negative impact on RE adoption, contrary to economic theory, although in line with the findings from Pfieffer and Mulder (2013) who assess SNHRE drivers in developing countries, though they don't offer an explanation. A simple explanation is simply that the FDI inflows towards brown industries is less established and less risky than investment in RE. Garin *êt al*. (2018) found between 2003-2015 the two largest sectors of FDI for each MENA country to be coal, oil and natural gas and real estate, with investment in renewables peaking at 4% of total investment in Egypt, which is not a rentier state. Additionally, financial sector development although insignificant in impacting the potential SRE, has a positive effect on the adoption of RE. The inclusion of these financial variables in the OLS regression does impact the predicted intercept, increasing it from 11% to 13.1%. Furthermore, the effect of membership to OPEC falls to 3.9% increase in RE production when the financial environment is held constant. This suggests the effects of membership to the trade block is easily dissipated amongst the financial variables as OPEC is less important in driving RE production when the financial environment is considered. The polity variable becomes insignificant after financial environment is controlled for. Finally, the impact of GDP per capita remains unchanged.

An assessment of the impact of controlling for economic openness reveals two of the three additional variables to have a significant impact on the share of RE. Whilst an increase in the rank in the EFI index and a 1% increase in trade openness leads to a 1% decrease and a 0.01% increase in SRE respectively. The effect of an increase in the EFI is contradictory to the hypothesis in section 2.1 and theory of the resource curse. As the EFI is a proxy for institutional strength it is expected that a higher EFI score means better institutions facilitating market interactions. In a study of 119 developing and non-OECD countries, Brunnschweiler (2010) found a positive relationship between the EFI and RE electricity generation, directly opposed to the results found here. A clear explanation of this relationship is difficult, although it could potentially be explained by uncorrelated improvements in corruption at the same time as growing fossil fuel energy use, crowding out the share of RE. Otherwise, one of the contributing indicators to the EFI is the size of government, since government interventions are considered interference in the free hand of the market. This measure may juxtapose the rentier state. For example, better institutions in a taxed economy would facilitate the free market, whereas in a rentier state, better institutions could mean strengthened ideals and a more streamlined institutional system for exploiting fossil fuels. The RE industry in countries more successful in the RET have been supported by socialist, long- sighted governments (McKinnon, 2010; Sawin, 2001), and such countries would rank more poorly in the EFI due to increased government intervention and regulations. Further investigation into this relationship is needed.

Table 5: Baseline, Financial Environment, Economic Openness, Conflict and Energy Industry OLS and Logit models.

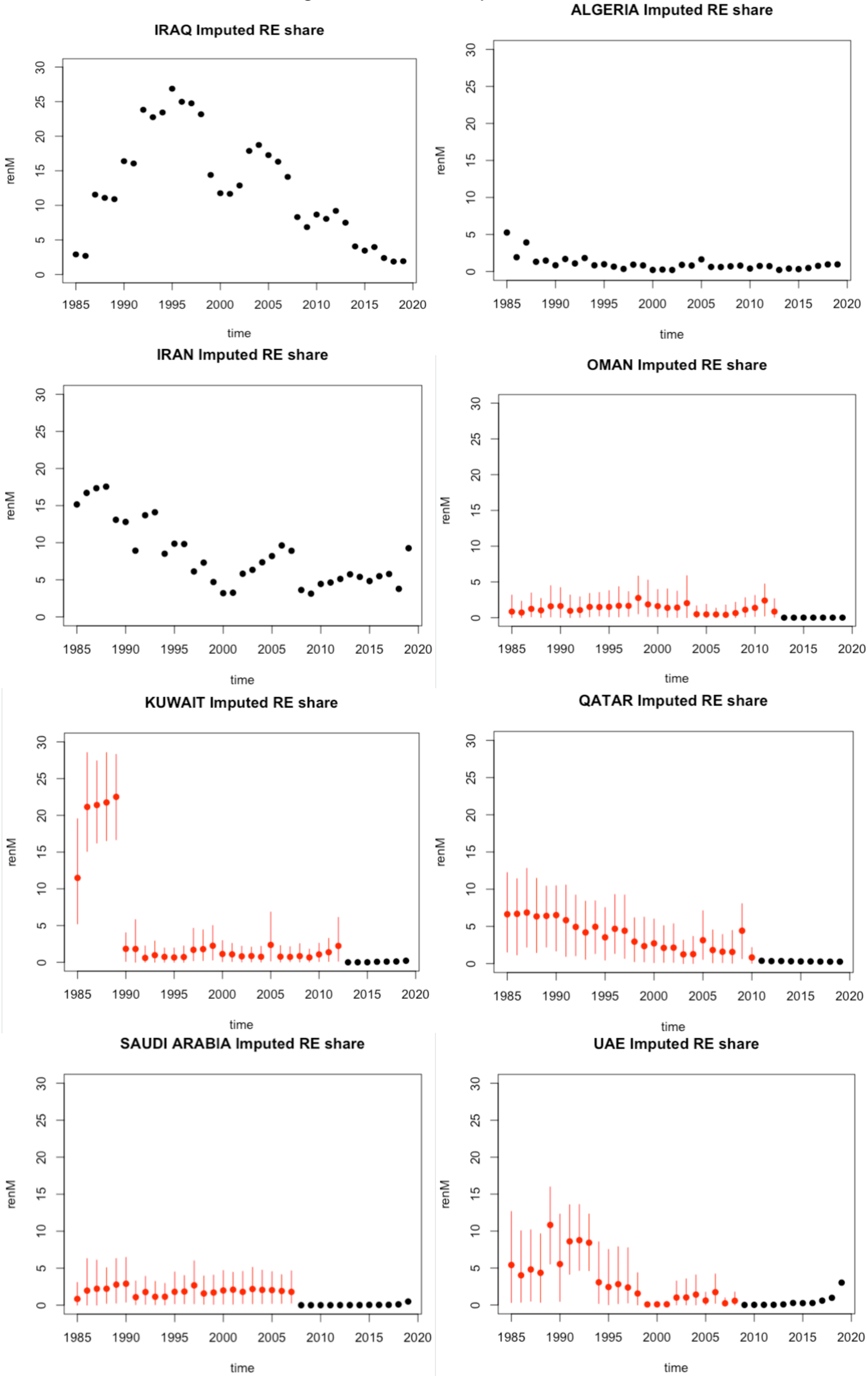
	Baseline		Financial Environment		Economic Openness		Conflict		Energy industry		All	
	Logit	OLS	Logit	OLS	Logit	OLS	Logit	OLS	Logit	OLS	Logit	OLS
Intercept	-0.879***	11***	-0.767***	13.1***	-1.22***	7.71*	-1.14***	8.83*	-1.51***	25.1***	-1.48***	23.8***
	(0.187	3.94	0.207	4.27	0.198	3.67	0.189	4.14	0.262	5.03	0.257	3.97
RE share in total energy	0.012**		0.0097***		0.0154**		0.0101*		0.0197***		0.0236**	
	0.0043		0.0049		0.0048		0.0041		0.0058		0.0072	
OPEC	(0.0669	5.37***	-0.0034	3.9*	0.0047	4.56***	0.0746	5.35***	0.0909	3.58**	-0.0531	0.813
	0.0724	1.31	0.0762	1.58	0.0708	1.27	0.0701	1.31	0.0812	1.34	0.0755	1.23
Oil Reserves	-0.0020***	-0.003	-0.0018***	-0.0027	-0.0025***	-0.029*	-0.0026***	-0.00756	-0.0027***	-0.00585	-0.0021***	-0.0309**
	(0.0005	0.0141	0.0005	0.0144	0.0006	0.014	0.0005	0.0142	0.0006	0.0139	0.0006	0.0102
Energy Consumption	0.0001	0.0079	0.0001	0.009	0.0002	-0.0064	0.0001	0.0075	0.0001	0.00626	0.0002	-0.0088*
	(0.0002	0.0052	0.0002	0.0051	0.0002	0.0043	0.0002	0.0052	0.0002	0.0048	0.0002	0.0037
Oil Price (log)	0.286***	-1.33	0.279***	-1.05	0.296***	-1.14	0.258***	-1.52	0.267***	-1.49	0.216***	-1.24
	0.0535	1.41	0.0543	1.28	0.0517	1.24	0.0521	1.4	0.0551	1.34	0.0519	0.877
GDP per capita (log)	-0.0000***	-0.0002**	-0.0000***	-0.0002***	-0.0000***	0	-0.0000***	-0.0002**	-0.0000**	-0.0002***	-0.0000***	0
	0.0000	0.0001	0	0.0001	0	0	0	0.0001	0	0.0001	0.0000	0
Oil Rents	-0.0102***	0.00497	-0.0105***	-0.0234	-0.0093***	0.0517	-0.0098***	0.0081	-0.0129***	0.0869	-0.0117***	0.122*
	0.0024	0.0818	0.0025	0.0776	0.0023	0.0738	0.0024	0.0808	0.0027	0.0857	0.0028	0.0558
Polity (2)	0.0143*	-0.284*	0.0227**	-0.16	0.0088	-0.347**	-0.0046	-0.428**	0.0057	-0.0839	0.0162	0.0248
	0.0063	0.122	0.0079	0.185	0.0064	0.109	0.0074	0.141	0.01	0.171	0.0088	0.141
CO2 (log)	0.214***	-1.24	0.212***	-0.97	0.306***	0.222	0.265***	-0.826	0.275***	-1.06	0.296***	0.975
	0.042	1.09	0.0416	1.04	0.0509	1.21	0.0421	1.11	0.0424	1.06	0.0459	0.869
Financial Development			0.0032**	0.0227							0.0048***	0.0364
			0.0012	0.0287							0.0010	0.0198
GFCF			-0.0028	-0.114					-0.0047	0.0312	-0.0038	-0.0407
			0.0032	0.0631					0.0034	0.0728	0.0034	0.0546
FDI			-0.0233*	-0.153	-0.0298**	-0.303					-0.005	-0.283
			0.0105	0.208	0.0105	0.191					0.0098	0.164
EFI					0.0072	-1.07***					0.0264*	-1.13***
					0.01	0.228					0.0104	0.189
Trade Openness					-0.0007***	0.0103***					-0.0004*	0.0061**
					0.0002	0.0028					0.0002	0.0022
Conflict							0.0009***	0.0071			0.0013***	0.0055
							0.0002	0.0036			0.0002	0.0039
Energy Losses									-0.0031	-0.28**	-0.0153*	-0.263**
									0.0067	0.107	0.0061	0.0943
Fuel Exports									0.0063***	-0.136***	0.0066***	-0.144***
									0.0012	0.0218	0.0014	0.0238
Fuel Imports									0.0074	0.313**	0.0054	0.18*
									0.0053	0.103	0.0041	0.0841

*Notes: *** significance <0.001, ** significance <0.01. * significance <0.05*

The empirical results for TO are as expected, since more trade will mean more opportunity for technology transfer. Though the impact is only small at a 0.01% increase in SRE, it is highly significant. FDI is insignificant again, so it can be confidently assumed that FDI does not impact SRE in MENA rentier states. Holding these economic openness factors constant causes a reduction in the intercept from the baseline prediction from 11% to 7.71% (though the confidence intervals of the coefficient estimates overlap, so it is not a significant change). Whilst oil reserves become significant (and negative), GDP per capita becomes insignificant. A -0.029 coefficient estimate for oil reserves is in line with previous theory, suggesting an increase in oil reserves leads to a decrease in potential SRE. For this variable to not have been significant in the baseline results may simply imply the variation in oil reserves was too narrow for it to be important in SRE, but holding economic openness factors constant reveals the significance of oil reserves in disincentivising support for RE.

The third model includes conflict, a highly regarded factor in determining productivity of all kinds in afflicted countries. Though the variable itself appears to not impact potential SRE and holding conflict constant does not affect the significance of any baseline variables, it does significantly change the coefficient estimate for polity. A one unit increase in the political regime towards complete democracy causes a decrease in potential SRE by 0.428%. Polity is an index capturing the political regime of a country, from -10 (autocratic) to 10 (democratic). A negative relationship between polity and potential SRE goes against theory, which suggests a democratic government better represents the will of civil society (thus better representing the attitude shift towards renewables). There even exists a detailed explanation specific to MENA tying economic crisis to democratisation which would explain a rise in SRE. Ehteshami (1999) argues that MENA governments have historically responded to economic crisis by broadening their political bases, as economic prosperity underpins political stability (Nonneman, 1996). Hence, the political reform process in MENA has not been led by civil society unrest or human development needs, but instead “the ruling regime’s perceived strategy for survival” (Ibid, p.203). This democratisation phenomenon tied with the economic crisis caused by the Gulf War in 1990 (which caused currency devaluations and a falling oil price), would explain a *positive* relationship between institutional quality and SRE quite well. In direct contradiction, the opposite has been shown. The potential SRE for many countries in the sample show a drop off point of SRE in the dataset, which can be seen in Figure 3 below (Algeria: 1987, Iran: 1988, Iraq: 1996, Kuwait: 1989, UAE: 1994). This is evidence for a shock of some sort to the region. A longitudinal investigation into the relationship between SRE and EFI is needed, in order for the date of specific shocks to be identified, so that an evaluation of potential causes for this relationship can be carried out. The conflict variable itself is significant in the logit model, having a positive effect on RE adoption. Further investigation is needed to explain this relationship and tests its robustness.

Figure 3: MAR imputations for SRE.



Notes: Red dots are the imputed estimates with the red line representing the 95% confidence interval, black dots are the observed values.

Finally, the fourth model demonstrates the impact of controlling for energy industry maturity. Of the additional energy maturity variables, GFCF is insignificant, whilst energy losses and fuel exports are significant and negative, and fuel imports are significant and positive. The expectation of GFCF to have a positive effect on RE share has not been met, though the insignificant result is in line with the findings of Lin and Omoju (2017). Another model was run, dropping GFCF from the explanatory variables, but no significant changes were found. A 1% increase in fuel imports, fuel exports and energy losses leads to a 0.313% increase, 0.136% decrease and 0.28% decrease in the potential RE share respectively. These are all in line with theory which suggests dependence on traditional fuel imports encourages domestic RE production, strong fuel exports disincentivises RE production and energy losses from the national electricity distribution system hinders access to RE generated electricity.

Interestingly, despite fuel exports being negative in the OLS regression, is it positive in the logit, implying an increase in fuel exports increases the chance of RE being adopted. This could be explained by the profit motive. Transportable fossil fuels are easier to trade than the electricity generated by renewables in the context of poor infrastructure. Thus, there is incentive for a country to start generating RE to satisfy domestic demand following an increase in fuel exports. Controlling for energy maturity variables causes a significant increase in the intercept compared to the baseline result from 11% potential SRE to 25.1%. This implies MENA countries with zero energy losses from the national grid and no imports or exports of fuel could feasibly produce 25% of their energy needs through renewables, a very important finding. Table 5 also shows a significant decrease in the impact of OPEC membership from 5.37% to 3.58%, and the impact of polity loses significance suggesting the trade of fuel and efficiency of electricity systems have a greater impact on potential SRE than the political regime.

A direct comparison of these models against the baseline ensures which variables are robust against modelling disparities. Polity for example alternates between significant and insignificant, depending on the explanatory variables. Thus, the unexpected negative polity coefficient estimate in the conflict model carries less weight when drawing practical inferences. Membership to OPEC on the other hand, is consistently significant. Finally, due to persistent insignificance, it can be concluded that the share of RE in total energy demand is not affected by oil reserves, energy consumption, oil price, oil rent or CO2 emissions.

Further inferences can be made as to the factors which drive the initial adoption of RE through analysis of the logit regressions associated with each additional model. The baseline result reveals OPEC to have a significant impact in the share of RE but not in the probability of its adoption. Oil reserves, oil rent and CO2 emissions have no impact in the share of RE but have a consistent significant effect on the probability of RE adoption across the models, making these findings robust. Whilst CO2 emissions have no impact on SRE in any of the models, it is highly significant and positive in every logit model. The implication here is that an increase in environmental degradation causes an approximately 0.26-point increase in the probability of RE being adopted, but when SRE does become positive, the amount of CO2 emissions has no further impact on the share of RE produced. A policy implication of this finding is that the concern for the environment is only humoured by creation of RE generation, the reasons behind which are not taken seriously. As expected, oil reserves and oil rents are both consistently negative, implying an increase in either will lead to a decrease in potential SRE, with oil rent having a stronger negative impact. Similarly, oil price has no significant impact on SRE, but has a consistently positive impact on the adoption of RE, in line with previous studies that suggest an increase in the price of a substitute for RE makes RE more attractive. GDP per capita is highly significant but only slightly negative at -0.0002 in each OLS at most, simultaneously having a highly significant zero impact on the adoption of RE. This implies an increase in GDP per capita by one unit decreases potential SRE in MENA by 0.0002%, contrary to previous findings (Chang *et al.,* 2009), though the impact is so small it is negligible.

6. Conclusion

The fight against climate change primarily relies on the renewable energy transition to curb emissions. MENA countries, despite having huge potential to produce RE, have responded weakly to this challenge. This study empirically investigated the factors behind the decision to produce non-hydro renewable energy, as well as the factors driving the amount of overall renewable energy production in rentier MENA states. The high incidence of 70% missingness in SNHRE limited the inferences that could be made into the drivers behind NHRE in the region. Future studies will have to use a different indicator and actively avoid missingness in order to gain meaningful insights into NHRE drivers in MENA. For both SNHRE and SRE, multiple imputation, sensitivity analysis and additional final OLS regressions all contributed to the robustness of results. Empirical findings largely supported existing research with a few exceptions. Empirical results for FDI inflows, EFI, polity and conflict are counterintuitive, although also unrobust. Further research is necessary to decipher whether the findings here are indicative of a significant relationship or not, and investigate the policy implications these findings are supported. Surprisingly, membership to OPEC is consistently positive in contributing to potential SRE. OPEC is a body which seeks to unify petroleum policies, so it is unclear why this relationship exists. As the interconnectedness of MENA states is imperative to support energy distribution systems, OPEC may play an important role in facilitating the RET in MENA. The evidence supporting SB in SRE suggests micro-data on local solar and wind production may prove more appropriate for further data analysis, highlighting the localised energy system infrastructure in the region.

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Appendix

Appendix 1: A description of multiple imputation.

If the MI method used produced just one set of imputations for the missing data, a single imputation, the algorithm would fit missing observations exactly on the least squares plane, which generates the same beta when regressed and gives heteroskedastic imputed observations. Correcting for this, multiple imputation is undertaken which adds “noise” to the imputed variables so their density function more closely resembles that of the observed data sample by using a Monte Carlo technique (Cameron and Trivedi, 2005). Thus, it is necessary to impute multiple sets of data so that each prediction of missing observations varies slightly and this variation is represented in the confidence intervals. The expectation maximisation algorithm repeats four prediction, estimation and augmentation steps until the changes in the revised estimate of the estimate become arbitrarily small (Iwasaki, 2002; Takahashi, 2015).

Data is assumed to be distributed normally. Although the normality assumption is strong and may not hold for all variables, there is research to suggest it still works well under non-normal conditions, and variables can be transformed prior to imputation to make them adhere to this assumption (Schafer, 1997; Schafer and Olsen, 1998).

$$D \sim \mathcal{N}_k(\mu, \Sigma)$$

$$\begin{aligned}\widehat{\boldsymbol{\beta}}_A &= \left[\mathbf{X}_1'\mathbf{X}_1 + \mathbf{X}_2'\mathbf{X}_2\right]^{-1}\left[\mathbf{X}_1'\mathbf{y}_1 + \mathbf{X}_2'\widehat{\mathbf{y}}_{\text{mis}}\right] \\ &= \left[\mathbf{X}_1'\mathbf{X}_1 + \mathbf{X}_2'\mathbf{X}_2\right]^{-1}\left[\mathbf{X}_1'\mathbf{X}_1\widehat{\boldsymbol{\beta}} + \mathbf{X}_2'\mathbf{X}_2\widehat{\boldsymbol{\beta}}\right] \\ &= \widehat{\boldsymbol{\beta}}.\end{aligned}$$

Appendix 2: AMELIA II imputation process and functional decisions to improve accuracy of imputations.

Many different functions within AMELIA enable a more accurate imputation. The first includes expanding the dataset to include auxiliary variables, The nature of MI is to impute data based on an assumption that the missing observations are missing at random (MAR). That is to say there may be a mechanism that underpins which observations are missing, but as long as the mechanism is captured by the explanatory variables, there will exist no bias in the imputations. For example, if there a strong correlation between which NHRE observations are missing and a high incidence of conflict, the missingness mechanism is captured, and the MAR assumption holds. Including additional auxiliary variables can contribute towards this assumption. These variables are listed in Table # below and have been sourced from the WDI. Secondly the number of imputations has been set at 5 for initial exploration, then raised to 20 and 50, as the number of imputations does not need to be very high for imputation to be efficient. Schafer (1997) emphasizes this point showing how even with 50% of the data missing, 20 imputations can achieve 97.5% efficiency. At this stage, there is no indication of a problematic imputation. Thirdly, using a polynomial time function uses trendedness of longitudinal variables to smooth imputations. When polynomials are included in the MI function, the imputation method can become unstable.

Table 6: Multiple Imputation Variables

Variable Name	**Description**
Agriland	Agricultural land (% of land area)
Arable	Arable land (% of land area)
Coalrent	Coal rents (% of GDP)
domcreditbanks	Domestic credit to private sector by banks (% of GDP)
electricpower	Electric power consumption (kWh per capita)
forest	Forest area (% of land area)
popden	Population density (people per sq. km of land area)
renenergy	Renewable energy consumption (% of total final energy consumption)
greenhouse	Total greenhouse gas emissions (% change from 1990)
urban.pop	Urban population (% of total population)

The fourth function improves this instability by adding ridge priors can be added which essentially shrink covariances and improve the stability of the EM. A very important imputation assistance tool is the inclusion of Bayesian observational priors. As a large proportion of missingness exists for some variables (and in specific countries), there is a larger margin for error. For example, Table # below shows import and export data for the UAE is missing consecutively between 1985 and 2000. Observational priors are essentially an indication of what the missing value could be, based on expert opinion or in the below cases, predictions from other data sources Table # below shows the variables with significant missingness (determined as those variables in countries for which blocks of 8 consecutive values of data are missing). The confidence matrix used for these priors can be found in the appendix (A#). For example, oil rent for Iraq is missing between 1991-2003 due to the Gulf war and then a military coup. It is expected that oil rent for 1991 was near 0%, but it is unclear how rapidly oil production recovered (Alnasrawi, 1992).

Table 7: Significant Missingness in the Data

Variable	**Country**	**Missing**	**Source**
Trade openness:	Qatar UAE	85-93 85-2000	FRED (2021) FRED (2021)
Gdp:	Kuwait Qatar	85-94 85-99	FRED (2021) FRED (2021)
Oil rent:	Iraq	91-2003	Alnasrawi, 1992
GFCF	Iraq Kuwait Qatar UAE	85-99 95-2019 1985-2019 1985-2000	No data Ceic (2021) Ceic (2021) Trading Economics (2019)
Fuel export:	Iraq Iran UAE	86-99 85-99 1985-2011 patch	No data No data No data
Fuel import:	Iraq Iran	1985-2019 patch 85-96	
Fin dev:	Iraq UAE	-2003 1985-2016	No data FRED (2021)

Table 8: Matrix of confidence intervals used for observational priors.

[,1]	[,2]	[,3]	[,4]	[,5]	
[1,]	14	10	71.5455	75.2145	0.999
[2,]	22	10	71.5455	75.2145	0.999
[3,]	30	10	63.98925	67.27075	0.999
[4,]	38	10	69.069	72.611	0.999
[5,]	46	10	83.43075	87.70925	0.999
[6,]	54	10	78.975	83.025	0.999
[7,]	62	10	84.435	88.765	0.999
[8,]	70	10	78.78	82.82	0.999
[9,]	16	10	84.95175	89.30825	0.999
[10,]	24	10	91.87425	96.58575	0.999
[11,]	32	10	96.954	101.926	0.999
[12,]	40	10	100.96125	106.13875	0.999
[13,]	48	10	103.57425	108.88575	0.999
[14,]	56	10	112.359	118.121	0.999
[15,]	64	10	122.70375	128.99625	0.999
[16,]	72	10	137.2215	144.2585	0.999
[17,]	80	10	135.55425	142.50575	0.999
[18,]	88	10	128.7	135.3	0.999
[19,]	96	10	147.64425	155.21575	0.999
[20,]	104	10	152.34375	160.15625	0.999
[21,]	112	10	145.38225	152.83775	0.999
[22,]	120	10	131.625	138.375	0.999
[23,]	128	10	126.36	132.84	0.999
[24,]	6	12	37329.75	45625.25	0.999
[25,]	14	12	28584	34936	0.999
[26,]	22	12	29029.5	35480.5	0.999
[27,]	30	12	30627	37433	0.999
[28,]	38	12	31619.25	38645.75	0.999
[29,]	46	12	34771.5	42498.5	0.999
[30,]	54	12	31779	38841	0.999
[31,]	62	12	34726.5	42443.5	0.999
[32,]	70	12	32109.75	39245.25	0.999
[33,]	78	12	32724	39996	0.999
[34,]	86	12	35662.5	43587.5	0.999
[35,]	94	12	39008.25	47676.75	0.999
[36,]	102	12	47486.25	58038.75	0.999
[37,]	110	12	41836.5	51133.5	0.999
[38,]	118	12	48879	59741	0.999
[39,]	4	12	27803.25	33981.75	0.999
[40,]	12	12	21984.75	26870.25	0.999
[41,]	20	12	25953.75	31721.25	0.999
[42,]	28	12	22880.25	27964.75	0.999
[43,]	36	12	26138.25	31946.75	0.999
[44,]	44	12	19786.5	24183.5	0.999
[45,]	52	12	12186	14894	0.999
[46,]	51	14	0	3	0.999
[47,]	84	15	14.343509	15.079073	0.999
[48,]	92	15	15.481105	16.275008	0.999
[49,]	100	15	14.135091	14.859967	0.999
[50,]	108	15	18.793369	19.757132	0.999
[51,]	116	15	15.214143	15.994356	0.999
[52,]	124	15	11.376293	11.959692	0.999
[53,]	132	15	13.972485	14.689023	0.999
[54,]	140	15	13.114185	13.786707	0.999
[55,]	148	15	13.236216	13.914996	0.999
[56,]	156	15	13.122476	13.795424	0.999
[57,]	164	15	14.480198	15.222772	0.999
[58,]	172	15	15.361891	16.14968	0.999
[59,]	180	15	19.561235	20.564375	0.999
[60,]	188	15	17.1981	18.080054	0.999
[61,]	196	15	16.572238	17.422096	0.999
[62,]	204	15	16.894819	17.76122	0.999
[63,]	212	15	13.292865	13.97455	0.999
[64,]	220	15	12.602689	13.24898	0.999
[65,]	228	15	13.9477	14.662966	0.999
[66,]	236	15	16.18705	17.017156	0.999
[67,]	244	15	24.679235	25.944837	0.999
[68,]	252	15	28.959514	30.444617	0.999
[69,]	260	15	26.654792	28.021705	0.999
[70,]	268	15	24.262353	25.506577	0.999
[71,]	8	15	24.014778	25.246305	0.999
[72,]	16	15	22.981732	24.160283	0.999
[73,]	24	15	20.10033	21.131116	0.999
[74,]	32	15	20.961963	22.036935	0.999
[75,]	40	15	18.813314	19.778099	0.999
[76,]	48	15	15.130941	15.906887	0.999
[77,]	56	15	14.380531	15.117994	0.999
[78,]	64	15	15.773863	16.582779	0.999
[79,]	72	15	16.439049	17.282077	0.999
[80,]	80	15	17.797384	18.71007	0.999
[81,]	88	15	17.22849	18.112002	0.999
[82,]	96	15	17.313546	18.201421	0.999
[83,]	104	15	19.340122	20.331923	0.999
[84,]	112	15	18.472469	19.419775	0.999
[85,]	120	15	15.885566	16.700211	0.999
[86,]	128	15	1.581338	1.662432	0.999
[87,]	102	15	34.513274	36.283186	0.999
[88,]	110	15	33.260234	34.965887	0.999
[89,]	118	15	18.886199	19.854722	0.999
[90,]	126	15	13.732394	14.43662	0.999
[91,]	134	15	22.234892	23.375143	0.999
[92,]	142	15	30.216942	31.766529	0.999
[93,]	150	15	33.149171	34.849129	0.999
[94,]	158	15	30.728018	32.303813	0.999
[95,]	166	15	32.843027	34.527285	0.999
[96,]	174	15	40.037779	42.090999	0.999
[97,]	182	15	42.811441	45.0069	0.999
[98,]	190	15	40.089442	42.145311	0.999
[99,]	198	15	41.88911	44.03727	0.999
[100,]	206	15	30.495245	32.059103	0.999
[101,]	214	15	28.305102	29.756646	0.999
[102,]	222	15	26.465851	27.823074	0.999
[103,]	230	15	27.131523	28.522883	0.999
[104,]	238	15	30.996036	32.585576	0.999
[105,]	246	15	36.140225	37.99357	0.999
[106,]	254	15	47.64796	50.091445	0.999
[107,]	262	15	43.487465	45.717591	0.999
[108,]	270	15	41.785496	43.928342	0.999
[109,]	278	15	43.252439	45.470513	0.999
[110,]	96	18	28.275	29.725	0.999
[111,]	104	18	29.4255	30.9345	0.999
[112,]	112	18	34.788	36.572	0.999
[113,]	120	18	34.125	35.875	0.999
[114,]	128	18	29.39625	30.90375	0.999
[115,]	136	18	32.175	33.825	0.999
[116,]	144	18	33.384	35.096	0.999
[117,]	152	18	33.1695	34.8705	0.999
[118,]	160	18	33.2085	34.9115	0.999
[119,]	168	18	36.37725	38.24275	0.999
[120,]	176	18	46.10775	48.47225	0.999
[121,]	184	18	47.1705	49.5895	0.999
[122,]	192	18	57.057	59.983	0.999
[123,]	200	18	81.4515	85.6285	0.999
[124,]	208	18	72.15	75.85	0.999
[125,]	216	18	60.75225	63.86775	0.999

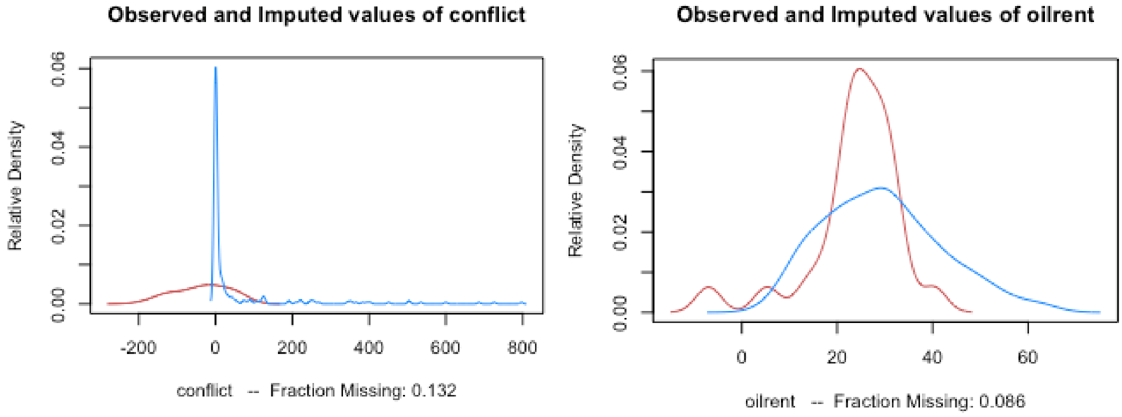
[126,]	224	18	58.5	61.5	0.999
[127,]	232	18	57.525	60.475	0.999
[128,]	240	18	59.87475	62.94525	0.999
[129,]	248	18	74.59725	78.42275	0.999
[130,]	256	18	78.975	83.025	0.999
[131,]	264	18	76.557	80.483	0.999

Table 9: Upper and lower bounds matrix for priors

[,1]	[,2]	[,3]	
[1,]	3	0	1.00E+05
[2,]	4	0	1.00E+05
[3,]	5	0	1.00E+05
[4,]	6	0	1.00E+05
[5,]	7	0	1.00E+05
[6,]	8	0	1.00E+05
[7,]	9	0	1.00E+05
[8,]	10	0	1.00E+05
[9,]	11	0	1.00E+05
[10,]	12	0	1.00E+05
[11,]	13	-10	1.00E+01
[12,]	14	0	1.00E+02
[13,]	15	0	1.00E+02
[14,]	16	0	1.00E+02
[15,]	17	0	1.00E+02
[16,]	18	0	1.00E+02
[17,]	19	0	1.00E+05
[18,]	20	-10	1.00E+01
[19,]	21	0	1.00E+02
[20,]	33	0	1.00E+02

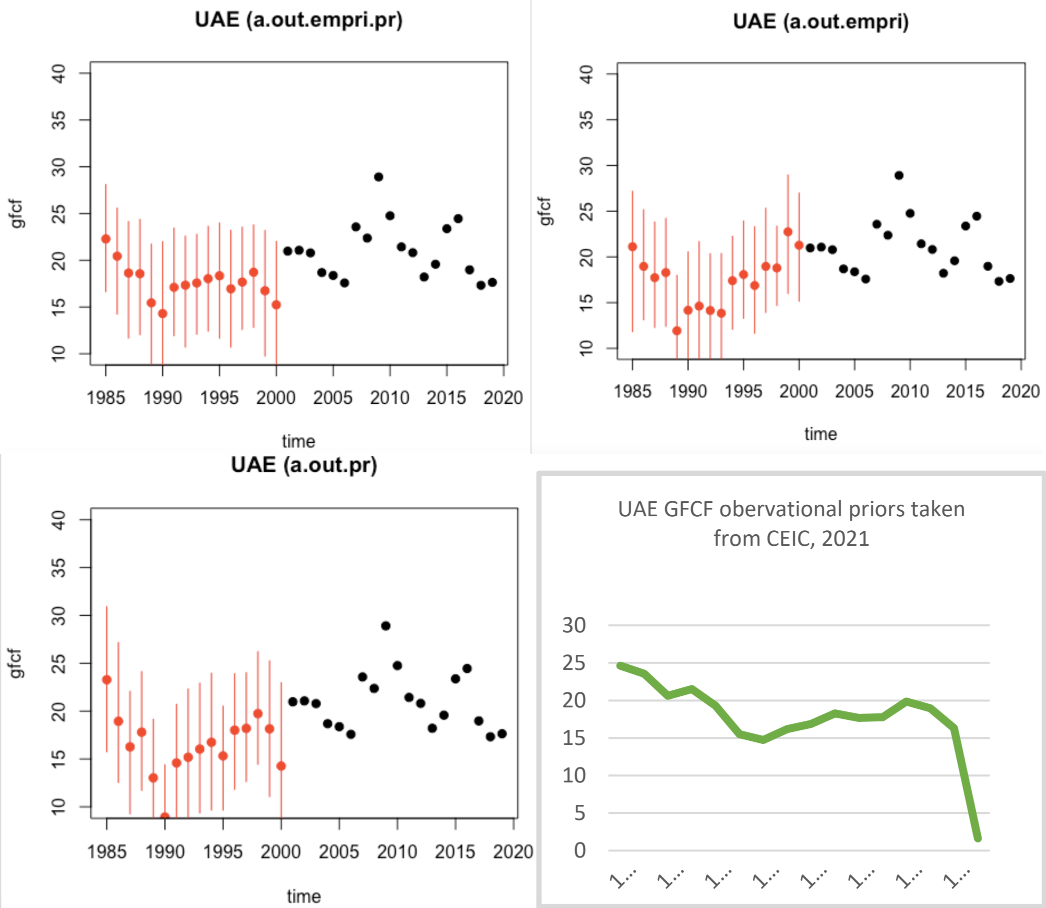
For example, oil rent for Iraq is missing between 1991-2003 due to the Gulf war and then a military coup. It is expected that oil rent for 1991 was near 0%, but it is unclear how rapidly oil production recovered (Alnasrawi, 1992). Fifth, upper and lower bounds are in place for every variable with missingness as checking density distributions of the imputations with observational priors revealed the density function to include negative values for variables which could not logically be negative (density distributions can be seen below in Fig #). Exceptions to this negative rule include EFI and polity, as they are indiexes with the lowest value of -10.

Fig 4: Observational priors with no general lower bounds. Conflict and oil rent are shown.



Appendix 3: Diagnostics of MI with AMELIA II

Figure 5: Comparisons between MI with just observation priors compared with observation priors and all other functions to enhance imputation for GFCF for the UAE.



A comparison of the effect of different functions in imputation reveals a combination of both ridge priors and observational priors to produce the imputed datapoints most similar. UAE ridge and observational priors have narrower confidence intervals and greater trendedness. For this reason, priors paired with all other observations can be confidently used for all variables.

Figure 6 below shows the density of the mean imputation in red with the density of observed values in blue. Comparing the two densities can reveal if the method of imputation needs improvement, which would be apparent if the densities are vastly different. As the variables with the significant missingness in GDP existed for Qatar and Kuwait, which have very high GDP per capita compared to other countries in MENA, explaining the skewed imputations density. Financial development would have a concerningly different imputed density function however the most significant imputation has been for UAE which used observational priors.

Figure 6: Comparing Density distributions between observed and imputed variables

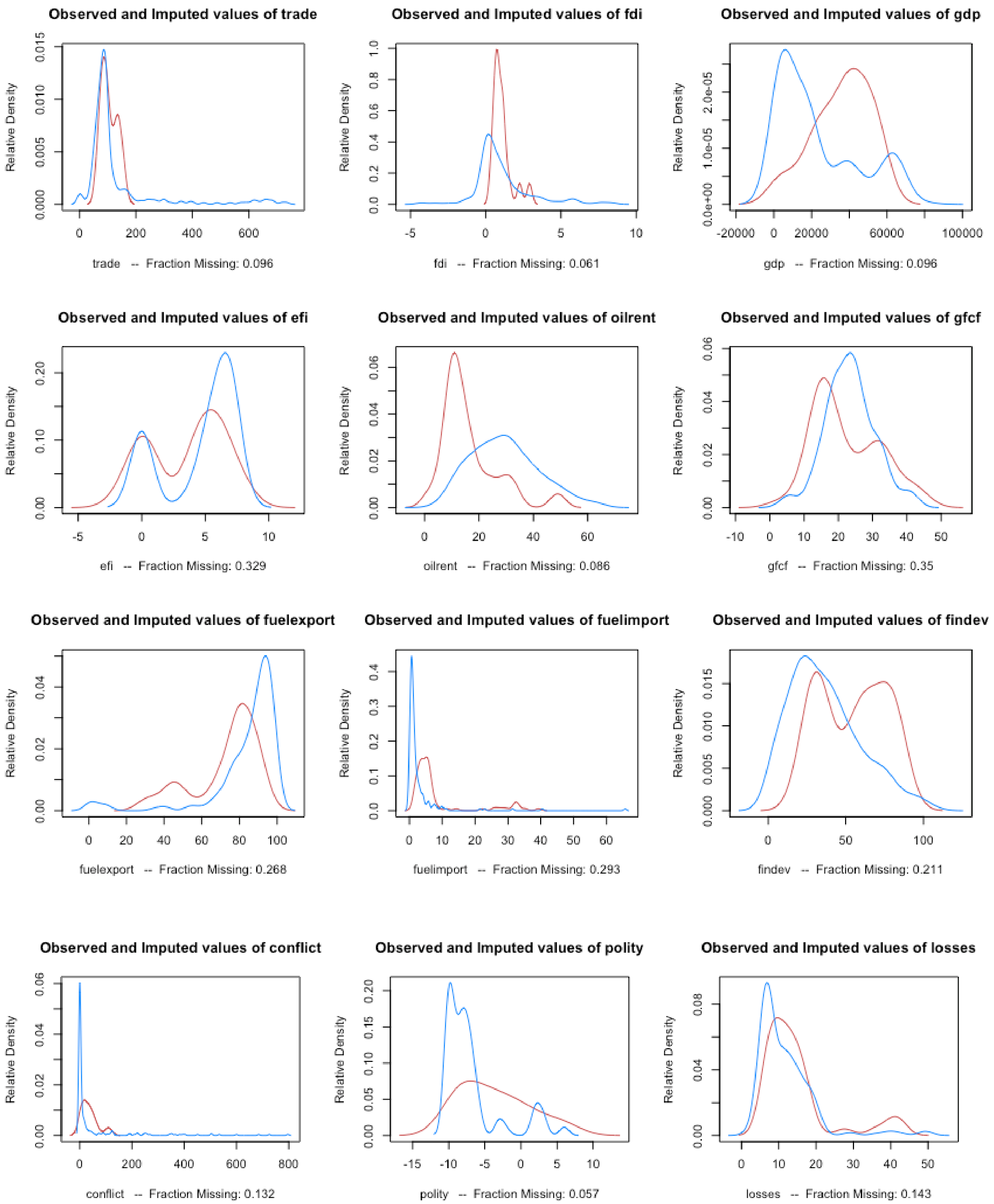
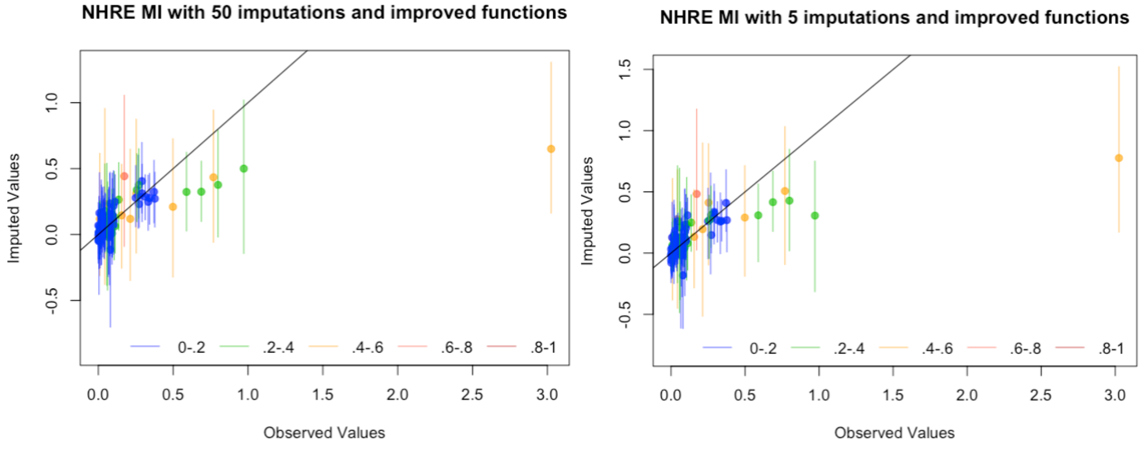


Figure 7: Overimputations measure. each observation is dropped iteratively and predicted using the remaining non-missing observations. The plot illustrates how many predictions fall within a 95% confidence intervals of the true observed value.



Appendix 4: MI of SRE.

Table 10: Observational priors matrix for renewable energy dataset imputations

	[,1]	[,2]	[,3]	[,4]	[,5]
[1,]	14	10	71.5455	75.2145	0.999
[2,]	22	10	71.5455	75.2145	0.999
[3,]	30	10	63.98925	67.27075	0.999
[4,]	38	10	69.069	72.611	0.999
[5,]	46	10	83.43075	87.70925	0.999
[6,]	54	10	78.975	83.025	0.999
[7,]	62	10	84.435	88.765	0.999
[8,]	70	10	78.78	82.82	0.999
[9,]	16	10	84.95175	89.30825	0.999
[10,]	24	10	91.87425	96.58575	0.999
[11,]	32	10	96.954	101.926	0.999
[12,]	40	10	100.96125	106.13875	0.999
[13,]	48	10	103.57425	108.88575	0.999
[14,]	56	10	112.359	118.121	0.999
[15,]	64	10	122.70375	128.99625	0.999
[16,]	72	10	137.2215	144.2585	0.999
[17,]	80	10	135.55425	142.50575	0.999
[18,]	88	10	128.7	135.3	0.999
[19,]	96	10	147.64425	155.21575	0.999
[20,]	104	10	152.34375	160.15625	0.999
[21,]	112	10	145.38225	152.83775	0.999
[22,]	120	10	131.625	138.375	0.999
[23,]	128	10	126.36	132.84	0.999
[24,]	6	12	37329.75	45625.25	0.999
[25,]	14	12	28584	34936	0.999
[26,]	22	12	29029.5	35480.5	0.999
[27,]	30	12	30627	37433	0.999
[28,]	38	12	31619.25	38645.75	0.999
[29,]	46	12	34771.5	42498.5	0.999
[30,]	54	12	31779	38841	0.999
[31,]	62	12	34726.5	42443.5	0.999
[32,]	70	12	32109.75	39245.25	0.999
[33,]	78	12	32724	39996	0.999
[34,]	86	12	35662.5	43587.5	0.999
[35,]	94	12	39008.25	47676.75	0.999
[36,]	102	12	47486.25	58038.75	0.999
[37,]	110	12	41836.5	51133.5	0.999
[38,]	118	12	48879	59741	0.999
[39,]	4	12	27803.25	33981.75	0.999
[40,]	12	12	21984.75	26870.25	0.999
[41,]	20	12	25953.75	31721.25	0.999
[42,]	28	12	22880.25	27964.75	0.999
[43,]	36	12	26138.25	31946.75	0.999
[44,]	44	12	19786.5	24183.5	0.999
[45,]	52	12	12186	14894	0.999
[46,]	51	14	0	3	0.999
[47,]	84	15	14.343509	15.079073	0.999
[48,]	92	15	15.481105	16.275008	0.999
[49,]	100	15	14.135091	14.859967	0.999
[50,]	108	15	18.793369	19.757132	0.999
[51,]	116	15	15.214143	15.994356	0.999
[52,]	124	15	11.376293	11.959692	0.999
[53,]	132	15	13.972485	14.689023	0.999

[54,]	140	15	13.114185	13.786707	0.999
[55,]	148	15	13.236216	13.914996	0.999
[56,]	156	15	13.122476	13.795424	0.999
[57,]	164	15	14.480198	15.222772	0.999
[58,]	172	15	15.361891	16.14968	0.999
[59,]	180	15	19.561235	20.564375	0.999
[60,]	188	15	17.1981	18.080054	0.999
[61,]	196	15	16.572238	17.422096	0.999
[62,]	204	15	16.894819	17.76122	0.999
[63,]	212	15	13.292865	13.97455	0.999
[64,]	220	15	12.602689	13.24898	0.999
[65,]	228	15	13.9477	14.662966	0.999
[66,]	236	15	16.18705	17.017156	0.999
[67,]	244	15	24.679235	25.944837	0.999
[68,]	252	15	28.959514	30.444617	0.999
[69,]	260	15	26.654792	28.021705	0.999
[70,]	268	15	24.262353	25.506577	0.999
[71,]	8	15	24.014778	25.246305	0.999
[72,]	16	15	22.981732	24.160283	0.999
[73,]	24	15	20.10033	21.131116	0.999
[74,]	32	15	20.961963	22.036935	0.999
[75,]	40	15	18.813314	19.778099	0.999
[76,]	48	15	15.130941	15.906887	0.999
[77,]	56	15	14.380531	15.117994	0.999
[78,]	64	15	15.773863	16.582779	0.999
[79,]	72	15	16.439049	17.282077	0.999
[80,]	80	15	17.797384	18.71007	0.999
[81,]	88	15	17.22849	18.112002	0.999
[82,]	96	15	17.313546	18.201421	0.999
[83,]	104	15	19.340122	20.331923	0.999
[84,]	112	15	18.472469	19.419775	0.999
[85,]	120	15	15.885566	16.700211	0.999
[86,]	128	15	1.581338	1.662432	0.999
[87,]	102	15	34.513274	36.283186	0.999
[88,]	110	15	33.260234	34.965887	0.999
[89,]	118	15	18.886199	19.854722	0.999
[90,]	126	15	13.732394	14.43662	0.999
[91,]	134	15	22.234892	23.375143	0.999
[92,]	142	15	30.216942	31.766529	0.999
[93,]	150	15	33.149171	34.849129	0.999
[94,]	158	15	30.728018	32.303813	0.999
[95,]	166	15	32.843027	34.527285	0.999

[96,]	174	15	40.037779	42.090999	0.999
[97,]	182	15	42.811441	45.0069	0.999
[98,]	190	15	40.089442	42.145311	0.999
[99,]	198	15	41.88911	44.03727	0.999
[100,]	206	15	30.495245	32.059103	0.999
[101,]	214	15	28.305102	29.756646	0.999
[102,]	222	15	26.465851	27.823074	0.999
[103,]	230	15	27.131523	28.522883	0.999
[104,]	238	15	30.996036	32.585576	0.999
[105,]	246	15	36.140225	37.99357	0.999
[106,]	254	15	47.64796	50.091445	0.999
[107,]	262	15	43.487465	45.717591	0.999
[108,]	270	15	41.785496	43.928342	0.999
[109,]	278	15	43.252439	45.470513	0.999
[110,]	96	18	28.275	29.725	0.999
[111,]	104	18	29.4255	30.9345	0.999
[112,]	112	18	34.788	36.572	0.999
[113,]	120	18	34.125	35.875	0.999
[114,]	128	18	29.39625	30.90375	0.999
[115,]	136	18	32.175	33.825	0.999
[116,]	144	18	33.384	35.096	0.999
[117,]	152	18	33.1695	34.8705	0.999
[118,]	160	18	33.2085	34.9115	0.999
[119,]	168	18	36.37725	38.24275	0.999
[120,]	176	18	46.10775	48.47225	0.999
[121,]	184	18	47.1705	49.5895	0.999
[122,]	192	18	57.057	59.983	0.999
[123,]	200	18	81.4515	85.6285	0.999
[124,]	208	18	72.15	75.85	0.999
[125,]	216	18	60.75225	63.86775	0.999
[126,]	224	18	58.5	61.5	0.999
[127,]	232	18	57.525	60.475	0.999
[128,]	240	18	59.87475	62.94525	0.999
[129,]	248	18	74.59725	78.42275	0.999
[130,]	256	18	78.975	83.025	0.999
[131,]	264	18	76.557	80.483	0.999

Table 11: Upper and lower bounds matrix for renewable energy dataset imputations

	[,1]	[,2]	[,3]
[1,]	3	0	1.00E+05
[2,]	4	0	1.00E+05
[3,]	5	0	1.00E+05
[4,]	6	0	1.00E+05
[5,]	7	0	1.00E+05
[6,]	8	0	1.00E+05
[7,]	9	0	1.00E+05
[8,]	10	0	1.00E+05
[9,]	11	0	1.00E+05
[10,]	12	0	1.00E+05
[11,]	13	-10	1.00E+01
[12,]	14	0	1.00E+02
[13,]	15	0	1.00E+02
[14,]	16	0	1.00E+02
[15,]	17	0	1.00E+02
[16,]	18	0	1.00E+02
[17,]	19	0	1.00E+05
[18,]	20	-10	1.00E+01
[19,]	21	0	1.00E+02
[20,]	33	0	1.00E+02

Figure 8: Comparison of the distributions of RE imputations with increasing number of imputations.

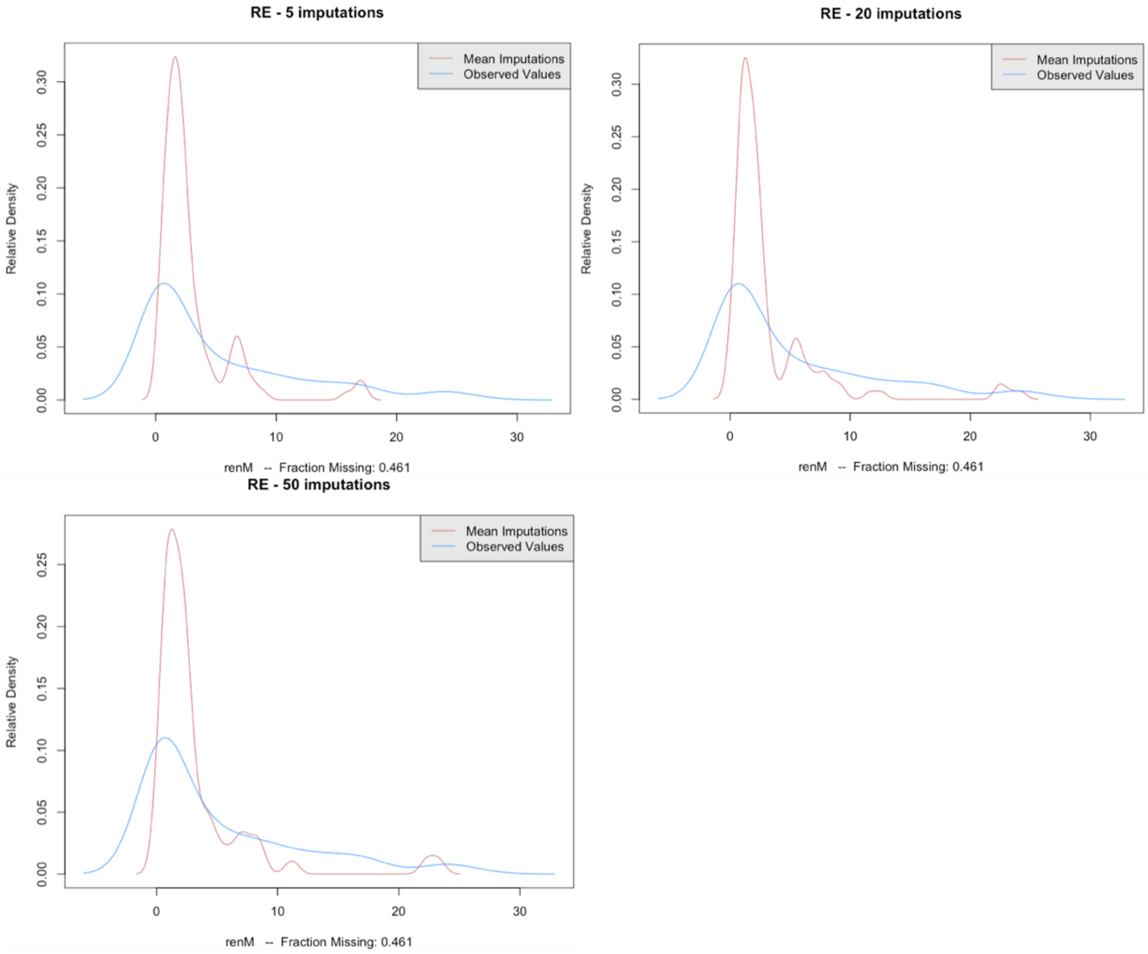
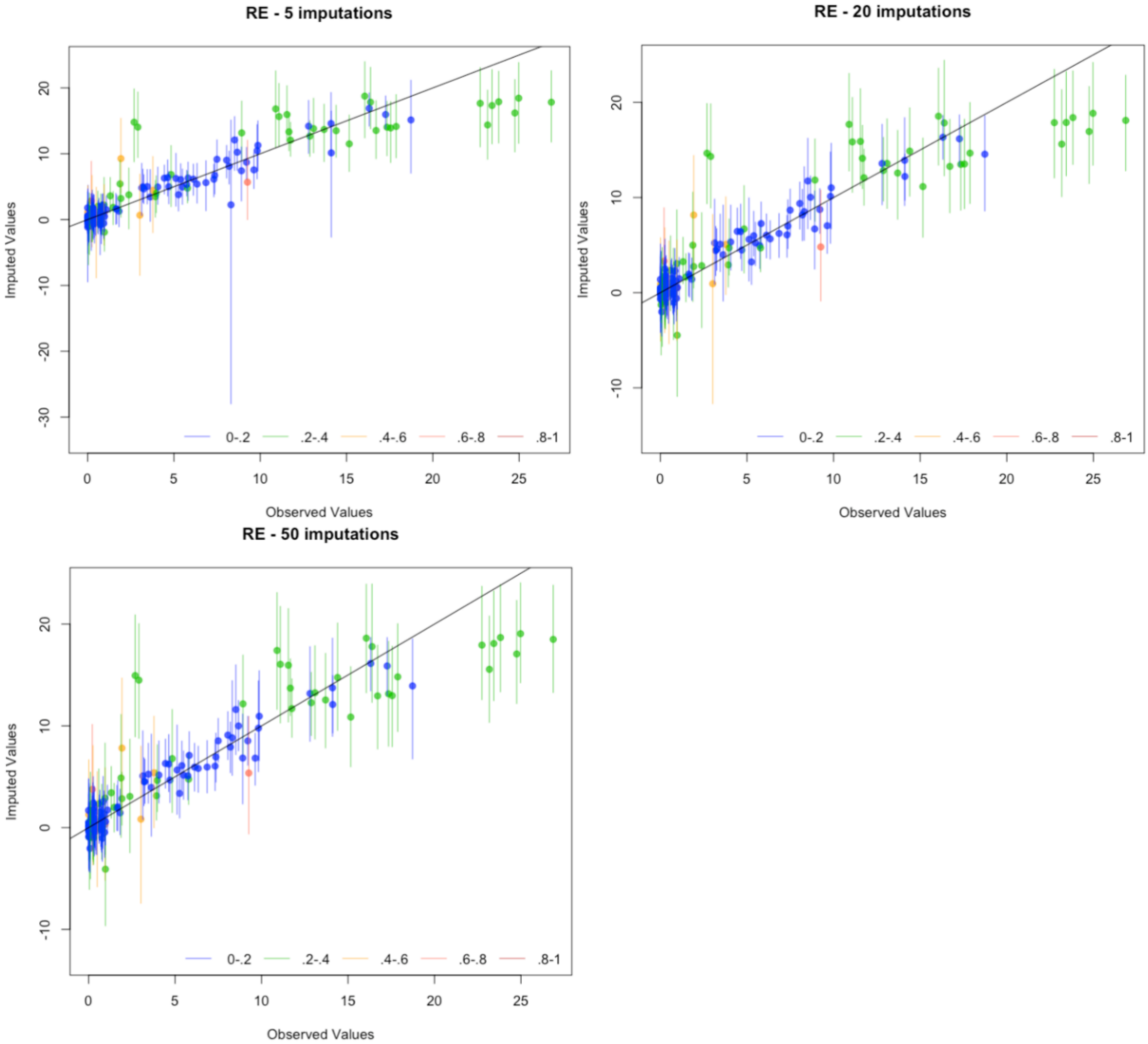


Figure 9: An overimputation assessment of RE imputations. The plot illustrates how many predictions fall within a 95% confidence intervals of the true observed value. A confidence interval crossing the line of best fit indicates the accuracy of imputations, and the length of the vertical line shows the confidence interval.



Appendix 5: Results of SNHRE

Figure 10: Density plots for NHRE in a CCS, MAR imputation and MNAR imputation at a 63% reduction.

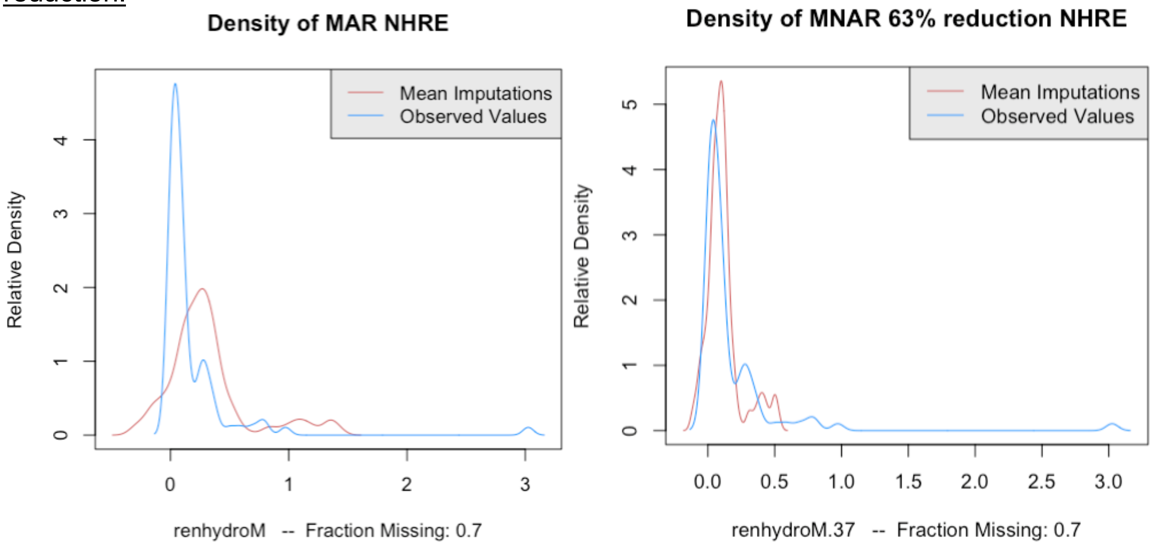


Table 12: Equation 5 OLS regression for NHRE CCS, NHRE with imputed explanatory variables and original NHRE, NHRE MAR imputed for when NHREP==1, NHRE imputed under MAR. These variables have all been imputed by the original method of imputations, which includes 5 imputations, polytime of 2 and lower confidence intervals for observational priors.

	Complete case scenario. OLS regression only include observations where renhydroD==1				NHRE imputed under MAR				NHRE under a 37% of original imputation scenario			
	β_1	CI		P	β_{0+1}^{MNAR}	CI		P	β_{0+1}^{MNAR}	CI		P
(Intercept)	-0.1240	-0.3450	0.0970	0.5750	0.5580	0.1610	0.9550	0.1600	0.2500	-0.1140	0.6140	0.4900
opec	-0.1110	-0.1906	-0.0314	0.1620	0.0248	-0.0892	0.1388	0.8280	-0.0605	-0.1365	0.0155	0.4300
oilres	0.0002	-0.0003	0.0006	0.6960	-0.0011	-0.0028	0.0005	0.4890	-0.0005	-0.0012	0.0003	0.5600
energycons	0.0000	-0.0002	0.0002	0.9820	-0.0002	-0.0006	0.0002	0.6580	0.0000	-0.0002	0.0002	0.8500
losses	-0.0130	-0.0223	-0.0037	0.1640	-0.0236	-0.0433	-0.0039	0.2300	-0.0161	-0.0276	-0.0046	0.1600
CO2	0.0327	-0.0050	0.0704	0.3860	0.0539	-0.0681	0.1759	0.6600	0.0416	-0.0069	0.0901	0.3900
oilpr	0.0574	0.0187	0.0961	0.1380	0.0260	-0.0655	0.1175	0.7760	0.0362	-0.0181	0.0905	0.5100
trade	0.0000	-0.0002	0.0002	0.9720	0.0001	-0.0001	0.0003	0.5470	0.0000	-0.0002	0.0001	0.9000
fdi	0.0020	-0.0056	0.0097	0.7930	0.0202	0.0099	0.0305	0.0500	0.0046	-0.0039	0.0130	0.5900
gdp	0.0000	0.0000	0.0000	0.6210	0.0000	0.0000	0.0000	0.1080	0.0000	0.0000	0.0000	0.4400
efi	0.0096	0.0000	0.0192	0.3170	-0.0219	-0.0472	0.0034	0.3880	-0.0042	-0.0158	0.0074	0.7200
gfcf	-0.0031	-0.0061	-0.0001	0.2960	-0.0227	-0.0378	-0.0076	0.1330	-0.0082	-0.0132	-0.0031	0.1100
oilrent	-0.0045	-0.0063	-0.0026	0.0160	-0.0127	-0.0230	-0.0024	0.2160	-0.0056	-0.0098	-0.0015	0.1800
fuelexport	0.0019	0.0010	0.0028	0.0270	0.0063	0.0027	0.0100	0.0840	0.0017	-0.0014	0.0048	0.5800
fuelimport	0.0060	0.0019	0.0102	0.1470	0.0178	0.0009	0.0347	0.2940	0.0071	0.0018	0.0124	0.1800
findev	0.0021	0.0010	0.0031	0.0470	0.0008	-0.0012	0.0029	0.6910	0.0016	0.0006	0.0025	0.1100
conflict	0.0003	-0.0001	0.0008	0.4610	0.0004	-0.0007	0.0016	0.6900	0.0004	-0.0001	0.0009	0.4400
polity	0.0173	0.0068	0.0278	0.1010	0.0122	0.0023	0.0221	0.2160	0.0133	0.0045	0.0221	0.1300

Notes: Headings are CI (confidence interval), P (p-value)

Table 13: NHRE MAR imputed, sensitivity analysis, NHRE MAR, NHRE MNAR These variables have all been imputed by the improved method of imputation, which includes 50 imputations, polytime of 3 and higher confidence intervals for observational priors.

	Complete case scenario. OLS regression only include observations where renhydroD==1				NHRE imputed under MAR				NHRE under a 37% of original imputation scenario			
	β_1	CI		P	β_{0+1}^{MNAR}	CI		P	β_{0+1}^{MNAR}	CI		P
(Intercept)	-0.1240	-0.3450	0.0970	0.5750	1.2200	0.4530	1.9870	0.1100	1.2200	0.8870	1.5530	0.1100
opec	-0.1110	-0.1906	-0.0314	0.1620	0.0754	-0.0706	0.2214	0.6100	0.0754	-0.0029	0.1537	0.6100
oilres	0.0002	-0.0003	0.0006	0.6960	-0.0019	-0.0034	-0.0004	0.2000	-0.0019	-0.0026	-0.0012	0.2000
energycons	0.0000	-0.0002	0.0002	0.9820	-0.0002	-0.0006	0.0002	0.6200	-0.0002	-0.0004	0.0000	0.6200
losses	-0.0130	-0.0223	-0.0037	0.1640	-0.0326	-0.0535	-0.0117	0.1200	-0.0326	-0.0435	-0.0217	0.1200

CO2	0.0327	-0.0050	0.0704	0.3860	0.0414	-0.0475	0.1303	0.6400	0.0414	-0.0039	0.0867	0.6400
oilpr	0.0574	0.0187	0.0961	0.1380	-0.0068	-0.1015	0.0879	0.9400	-0.0068	-0.0618	0.0482	0.9400
trade	0.0000	-0.0002	0.0002	0.9720	0.0000	-0.0002	0.0003	0.8500	0.0000	-0.0001	0.0002	0.8500
fdi	0.0020	-0.0056	0.0097	0.7930	0.0100	-0.0066	0.0265	0.5500	0.0100	0.0000	0.0199	0.5500
gdp	0.0000	0.0000	0.0000	0.6210	0.0000	0.0000	0.0000	0.4200	0.0000	0.0000	0.0000	0.4200
efi	0.0096	0.0000	0.0192	0.3170	-0.0393	-0.0662	-0.0124	0.1400	-0.0393	-0.0520	-0.0266	0.1400
gfcf	-0.0031	-0.0061	-0.0001	0.2960	-0.0200	-0.0358	-0.0042	0.2100	-0.0200	-0.0267	-0.0133	0.2100
oilrent	-0.0045	-0.0063	-0.0026	0.0160	-0.0085	-0.0184	0.0014	0.3900	-0.0085	-0.0137	-0.0034	0.3900
fuelexport	0.0019	0.0010	0.0028	0.0270	0.0022	-0.0062	0.0107	0.7900	0.0022	-0.0021	0.0065	0.7900
fuelimport	0.0060	0.0019	0.0102	0.1470	0.0120	0.0028	0.0212	0.1900	0.0120	0.0072	0.0168	0.1900
findev	0.0021	0.0010	0.0031	0.0470	0.0011	-0.0007	0.0030	0.5500	0.0011	0.0001	0.0022	0.5500
conflict	0.0003	-0.0001	0.0008	0.4610	0.0009	0.0000	0.0017	0.3200	0.0009	0.0004	0.0014	0.3200
Polity	0.0173	0.0068	0.0278	0.1010	0.0049	-0.0106	0.0204	0.7500	0.0049	-0.0035	0.0132	0.7500

Appendix 6: Results of SRE

Table 14: OLS regression for SRE CCS and SRE MAR. These variables have all been imputed by the improved method of imputation, which includes 50 imputations, polytime of 3 and higher confidence intervals for observational priors.

	SRE MAR imputed				SRE CCS			
	β_{0+1}^{MAR}	Confidence	Interval	P-Value	β_1	Confidence	Interval	P-Value
(Intercept)	21.9000	17.5500	26.2500	0.0000	39.781594	30.1380	49.4252	0.0000
opec	1.0700	-0.2300	2.3700	0.4090	-5.675639	-7.9319	-3.4194	0.0119
oilres	-0.0329	-0.0425	-0.0233	0.0006	0.003015	-0.0121	0.0181	0.8420
energycons	-0.0088	-0.0121	-0.0055	0.0080	-0.063704	-0.0834	-0.0440	0.0012
oilpr	-1.2700	-2.1350	-0.4050	0.1422	-3.280038	-4.1154	-2.4446	0.2999
gdp	0.0000	0.0000	0.0000	0.8128	0.000556	0.0004	0.0007	0.5164
oilrent	0.1310	0.0723	0.1897	0.0258	0.176952	0.1239	0.2300	0.0001
polity	-0.0252	-0.1692	0.1188	0.8610	-0.180033	-0.3248	-0.0353	0.6574
CO2	1.1600	0.4020	1.9180	0.1262	1.204061	-0.6513	3.0595	0.0197
findev	0.0309	0.0115	0.0503	0.1103	-0.009189	-0.0330	0.0146	0.0022
gfcf	-0.0279	-0.0957	0.0399	0.6809	0.028995	-0.0464	0.1044	0.0000
fdi	-0.3870	-0.5880	-0.1860	0.0542	-0.576974	-0.8243	-0.3296	0.7004
efi	-1.0200	-1.2000	-0.8400	0.0000	-1.20091	-1.4551	-0.9467	0.0009
trade	0.0055	0.0031	0.0078	0.0192	0.001518	-0.0019	0.0049	0.0001
conflict	0.0048	0.0003	0.0093	0.2850	-0.005753	-0.0100	-0.0015	0.1683

losses	-0.2470	-0.3510	-0.1430	0.0176	-0.127915	-0.2513	-0.0045	0.6997
fuelexport	-0.1450	-0.1804	-0.1096	0.0000	-0.209216	-0.2621	-0.1564	0.1719
fuelimport	0.1840	0.0898	0.2782	0.0509	0.132549	0.0363	0.2288	0.2136

Notes: P-Values highlighted in red show significance