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Essays on Energy and Behavioral Financial Economics

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Abstracts

Chapter 1 - An analysis of Turkey's solar PV auction scheme: What can Turkey learn from Brazil and South Africa?

As global investments continue in renewable energy technologies, investment costs have declined significantly. Meanwhile, many governments have shifted from pre-set renewable support schemes to auction schemes in order to introduce competition in price setting. Turkey has initiated Renewable Energy Resource Zone (RERZ) auctions to promote solar photovoltaic (PV) and wind technologies. We examine the first of these auctions, Solar PV RERZ, which has ambitious targets in terms of increasing solar PV capacity and enhancing domestic competence in solar technologies. Despite the auction being hailed as a success in terms of low prices, we utilize the Levelized Cost of Electricity generation (LCOE) analysis to demonstrate that the project is vulnerable to macroeconomic shocks and financial risks. Model results show that the capacity factor is the most prominent factor in costs, and a 10% change in the capacity factor affects the LCOE about the same rate. Investment cost and interest rate are the other major factors affecting the LCOE. Based on these results, we make recommendations by discussing how Turkey can improve its auction design by incorporating some of the elements used by Brazil and South Africa.

Chapter 2 - How do macroeconomic dynamics affect small and medium-sized enterprises (SMEs) in the power sector in developing economies: Evidence from Turkey

Developing economies are currently projected to hold a major share of the global energy demand in the upcoming decades, giving them a key role in addressing climate change. However, new renewable energy investments in these countries have so far been relatively slow. A specific set of challenges dominate the investment environment in developing countries, including higher exposure to macroeconomic and political risks, uncertainties due to climate change, limited domestic manufacturing capabilities, and heavy reliance on foreign debt in capital investments. These factors tend to disproportionately affect small and medium-sized enterprises (SMEs) which currently hold a sizeable share of renewable and distributed energy technology investments. Not only does this impact the viability of energy transition, but also has important energy justice and local economic development implications – an overlooked subject in literature. Using a rich, novel dataset and panel data methods, this paper estimates the effect of a set of key macroeconomic variables on the capital structure and investment outcomes of SMEs within the Turkish power sector. Our results indicate that unfavorable macroeconomic conditions, which lead to a significant growth in liabilities and increased risk of bankruptcy, can cause a slowdown in power sector SME investments despite the prevalence of subsidies.

Chapter 3 - Should Children Listen to their Parents' Investment Advice?

This study investigates the impact of intergenerational advice on investment behavior in an experimental setting. We explore the effects of positive and negative advice from one generation to the next on asset allocation decisions. Results indicate that the transmission

of advice can significantly influence investment behavior, as participants who received positive advice allocated a higher proportion of their portfolio to risky assets. The transmission of advice to allocations appears to be through participants forming more optimistic beliefs about future returns rather than any change in their risk preferences. Even when challenged by a significant downturn, the group that received positive advice continued to hold optimistic beliefs. The study also challenges the assumptions of modern portfolio theory and suggests that inexperienced investors may be more influenced by the advice of previous generations.

Dedication

To my beloved parents, who have always believed in me, cheered me on, and sacrificed so much to ensure that I have the best opportunities in life, and to my loving husband, whose encouragement and support sustained me throughout this journey, this dissertation is dedicated to you with boundless appreciation and love.

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Abstract

As global investments continue in renewable energy technologies, investment costs have declined significantly. Meanwhile, many governments have shifted from pre-set renewable support schemes to auction schemes in order to introduce competition in price setting. Turkey has initiated Renewable Energy Resource Zone (RERZ) auctions to promote solar photovoltaic (PV) and wind technologies. We examine the first of these auctions, Solar PV RERZ, which has ambitious targets in terms of increasing solar PV capacity and enhancing domestic competence in solar technologies. Despite the auction being hailed as a success in terms of low prices, we utilize the Levelized Cost of Electricity generation (LCOE) analysis to demonstrate that the project is vulnerable to macroeconomic shocks and financial risks. Model results show that the capacity factor is the most prominent factor in costs, and a 10% change in the capacity factor affects the LCOE about the same rate. Investment cost and interest rate are the other major factors affecting the LCOE. Based on these results, we make recommendations by discussing how Turkey can improve its auction design by incorporating some of the elements used by Brazil and South Africa.

1.1 Introduction

Energy systems are currently undergoing a major transformation driven by renewable energy technologies and energy efficiency measures which play a vital role in overcoming environmental, economic, and social problems due to intensive use of fossil fuels (Grubb, 2004; Negro et al., 2012; OECD/IEA, 2016a, 2008; Reddy, 2002). On the other hand, the growing costs of renewable support mechanisms and decline in unit costs has forced governments to replace pre-set tariffs with competitive-bidding schemes as the primary support mechanism for large-scale wind and solar energy projects. Following the international experience, the Turkish government has initiated the "Renewable Energy Resource Zone" (RERZ) auction scheme as a cost-effective mechanism to support renewable energy technologies and has conducted the first solar photovoltaics (PV) RERZ auction in 2017. In addition to the construction of a large-scale power plant, this scheme requires the construction of a solar PV module factory and a research center to conduct research, development, and demonstration (RD&D) activities in solar technologies.

The literature has underlined that there are many uncertainties that affect the success of such auctions - mostly due to different macroeconomic conditions, funding and financing schemes and regulatory structures. These uncertainties create more risks for investors in developing economies; however, studies on renewable auctions are mostly conducted on developed economies or major developing economies such as China, India, or Brazil (Eberhard et al., 2018; Rego and Parente, 2013). To the best knowledge of the authors, there is only one study evaluating the design of the RERZ scheme in Turkey – see SHURA (2019), and only Karaveli et al. (2015) discussed the economics of a large-scale solar power plant built in Karapinar region where the RERZ project will be constructed. However, this study only compared a prospective 4800 MW capacity project and did not evaluate the actual RERZ project. In this respect, this article aims to contribute to the literature on renewable energy auctions by analyzing Turkey's first solar RERZ auction and comparing it with Brazilian and South African auctions. In addition, the major contribution of this paper is the comparison of different approaches in renewable support auction designs in developing economies and discuss their implications for electricity markets and energy policies. In the first part of the study paper, project characteristics and the effects of different factors in such investments will be analyzed by using the Levelized Cost of Electricity generation (LCOE) approach and sensitivity analysis. In the second part of the paper, the design of the RERZ support scheme will be discussed under the light of South African and Brazilian experiences in renewable energy auctions. Besides being one of the first studies on Turkish RERZ auctions, this article also contributes to the literature on renewable energy auction design in developing economies. The article starts with an overview of the renewable energy support schemes and Turkey's renewable energy policy in Section 2. Section 3 presents the methodology and results with sensitivity analysis. Section 4 compares the Turkish case with South African and Brazilian cases and examines the strengths and weaknesses of the RERZ scheme in line with the experiences of these countries. Finally, Section 5 concludes the article.

1.2 Renewable energy policies and support mechanisms in Turkey

1.2.1 Literature review on renewable energy support mechanisms

Renewable energy technologies are hailed as a means to successfully transform fossil-fuel intensive energy systems into cleaner and sustainable ones. However, power supply systems are prone to lock-in effects and institutional inertia; demand for new innovations in the power sector cannot be easily formed; and a very long-time span is required for the diffusion of new innovations (Karakosta et al., 2010; Polzin et al., 2015). Hence, governments have initiated major support schemes to create a level-playing field for renewable energy technologies. In retrospect, these schemes can be grouped under two major categories: (1) Supply-push measures which aim to stimulate technological innovations by focusing on the early stages of RD&D; and (2) Demand-pull measures which aim to create demand for new technological innovations by stimulating deployment and diffusion (Grubb, 2004; Lund, 2009). The first category includes government RD&D expenditures, government sponsored pilot plants and scale-ups, incentives for private RD&D expenditures (e.g., grants, subsidies, and tax breaks), public-private partnerships for energy research and training programs, etc. The second category mainly affects private investment decisions in favor of renewable energy technologies. Governments mostly prefer demand-pull measures (notably economic instruments) since investors favor these schemes for revenue stability, predictability, and risk-reduction (Burer, 2009; Ritzenhofen and Spinler, 2016). Among demand-pull measures, most countries have favored feed-in tariffs (FiTs) over auctions and feed-in premiums (FiPs), because FiTs are more effective in reducing risks and encourage renewable energy investments in the short-term (Becker and Fischer, 2013; Blazquez et al., 2018; Shrimali et al., 2016; Couture et al., 2010). However, as renewable energy investments increase, new hybrid schemes (such as the *spot market gap model*) that combine FiTs and FiPs are developed to reduce exposure to market risks and reduce financial costs (OECD/IEA, 2016a; Couture et al., 2010). At the early stages of renewable energy investments, feed-in tariffs were determined by the government, and generous payments were made to investors in some countries such as Germany and Spain. Although this approach has had merits and has fostered renewable energy investments in the short-term, a number of problems have emerged in its design: (1) how to determine the optimal tariff that maximizes social welfare; (2) how to incorporate learning economies and cost reductions in prices; and (3) how to control investments at a level that does not jeopardize overall system reliability. Therefore, earlier periods in renewable energy support schemes were also learning periods; countries have tried to develop effective schemes to back deployment and technological diversity in these technologies. Over time, renewable technologies' share in electricity supply has increased significantly, and the costs of financial incentives have created problems in some electricity markets (Kreiss et al., 2017; Ritzenhofen and Spinler, 2016). As a result, governments have started to include market forces by introducing auctions in incentive mechanism design to reduce budgetary costs and benefit from learning economies (Winkler et al., 2018). Theoretically, auction scheme has been considered one of the most effective tools to support renewable energy investments in liberalized electricity markets; it enables cost control and transparency; it does not distort competition in the market; and it leads to better results (in terms of lower prices and costs) if designed properly (Alvarez et al., 2017; Azuela and Barroso, 2012; Kreiss et al., 2017; Polzin et al., 2015; Shrimali et al., 2016). In this scheme, the government conducts an auction to purchase capacity or energy from renewable energy technologies for a specified time at a price determined in the auction. However, this scheme encountered difficulties in the past such as in the UK, and its effectiveness in achieving policy targets were questioned due to underbidding and non-completion problems2 (Azuela et al., 2014; Eberhard et al., 2018; Kylili and Fokaides, 2015; Winkler et al., 2018). If not designed properly, such auctions can lead to aggressive pricing among project developers, and the project becomes infeasible as a result of low prices. Moreover, it may have adverse impacts on the local manufacturing industry because investors may prefer to import cheaper equipment from abroad to meet their obligations. Despite some of the drawbacks of auctions in renewable energy procurement, many governments have started using auctions to determine FiPs and FiTs, and winning bids in recent auctions have declined significantly (DoE, 2018; IRENA, 2018). Table 1.1 shows solar PV auctions conducted in 2016 (some countries had multiple auctions) and their winning bids. As seen from the table, prices ranged from $24.20 (USD)/MWh to 120 USD/MWh, with a weighted average of 57.39 USD/MWh.3 Projections also show that prices are expected to decline, and competitive procurement schemes will contribute to the decline in costs. However, there are mixed results in the literature in terms of efficiency (cost reduction) and effectiveness (renewable target achievement) of auctions; it is on debate that auction scheme is best suited to countries which focus on volume control and competitive price setting (Winkler et al., 2018).

Table 1.1 Solar PV Auctions in 2016

Country	Total Capacity (MW)	Average Price (USD/MWh)
Canada	140.0	120.0
USA	260.0	37.0
Mexico (1st)	1691.0	45.1
Mexico (2nd)	1853.0	31.8
Peru	184.5	48.1
Chile	300.0	37.8
Denmark*	21.6	19.9
Germany (7th)	200.0	70.1
Morocco	170.0	60.0
Zambia	73.0	67.4
UAE (Abu Dhabi)	1170.0	24.2
UAE (Dubai)	800.0	29.9
India	6800.0	71.4

China	1000.0	77.9
*Premium price over spot price		
Source: IRENA (2017)		

1.3 An overview of Turkey's energy policy

Turkey has a growing economy with increasing energy demand. The annual electricity demand increased to 304.4 TWh in 2018 which was covered by coal (36%), natural gas (30.3%), hydropower plants (20%), wind (6.5%) and other energy sources (7%) (TEIAS, 2018). Due to low oil and natural gas reserves, Turkey had to import more than 75% of its primary energy supply, 97% of its natural gas consumption, and 89% of oil consumption in 2018 (IEA, 2018). Therefore, Turkey's energy policy has been based on securing energy supply, providing affordable energy, and decreasing import dependency. Former governments could not implement a long-term and comprehensive energy strategy in the past; hence, Turkey became much more import dependent in the '90s as a consequence of natural gas use in electricity generation (OECD/IEA, 2016b). Recent governments have prioritized increasing energy efficiency, deployment of renewable and indigenous energy resources, and establishment of liberalized and competitive energy markets to eliminate problems related to high dependency on imported fuels. Due to the Turkish economy's economic growth performance over the last two decades, energy demand is expected to increase; however, foreign debt of companies, rising inflation, and high exchange rate volatility raise concerns about the sustainability of energy investments in the coming years (OECD/IEA, 2016b).

Following the international experience in the restructuring of the electricity sector, Turkey enacted the Electricity Market Law (EML) in 2001, and initiated reforms that aim to increase efficiency and improve resource allocation. As a part of these reforms, restrictions on private investment in the electricity market were removed, state-owned generation and distribution utilities were privatized, and day-ahead/intraday electricity markets were established (OECD/IEA, 2016b). Private companies are allowed to invest in power generation capacity by obtaining a license from the Energy Market Regulatory Authority (EMRA) – but there are exceptions for renewable energy technologies if their capacity is less than the threshold set by EMRA. Similar to most European counterparts, transactions in the wholesale electricity market are made through bilateral contracts and electricity exchange, which consists of day-ahead, intra-day, and balancing markets. Nevertheless, almost 60% of investments made in the last fifteen years have power purchase guarantees from the government (SHURA, 2019) which creates concerns about the effective functioning of the electricity market.

Turkey has significant renewable energy potential notably in hydro, geothermal, and solar sources with a total realizable renewable energy potential equal to 13% of EU-27's total potential, ranking fifth after Germany, France, Spain, and the UK (OECD/IEA, 2008). However, Turkey has not utilized this potential adequately; large hydropower energy projects were given priority until the early 2000s and only a total of 18.9 MW wind power investments were made during 1985-2001 (Kaya, 2006). In terms of solar power, annual solar radiation varies between 1400-2000 kWh/m^2 and Turkey's technical solar power potential is around 380 TWh/year, which is higher than Turkey's current total electricity demand (OECD/IEA, 2010, 2008). In solar technologies, there are two types of installments: (1) Unlicensed generation[1] which is connected to the distribution system, and (2) Licensed generation which requires a license from EMRA. The installed capacity in the first group increased to 4920 MW by November 2018, and the total installed capacity of solar technologies increased to 5.6% of total capacity (TEIAS, 2018).

Turkey has followed European countries and international experience in its renewable energy policy design and has recently set technology-specific targets for the renewable energy supply. Electricity Market and Security of Supply Strategy (2009) set a target of 30% electricity generation from renewable energy technologies by 2023 (MENR, 2009). In 2014, the Ministry of Energy and Natural Resources (MENR) announced the “National Renewable Energy Action Plan (NREAP)” for the 2013-2023 period (MENR, 2014) and the share of renewable energy technologies is planned to be 30% of the power supply by 2023. Moreover, the target for installed capacity of renewable energy technologies is set to 61 GW for 2023, 34 GW from hydropower, 20 GW from wind, 5 GW from solar (10 GW by 2030), 1 GW from geothermal, and 1 GW from biomass technologies (MENR, 2014; OECD/IEA, 2016b).

1.3.1 Renewable energy support mechanisms in Turkey

Support mechanisms for renewable energy technologies in Turkey started in 1984 with third-party financing, excise, and sales tax exemptions; nonetheless, specific-support measures were only initiated in recent years (Erdem, 2010). In 2005, “Law on the

[1] In April 2019, the capacity threshold for unlicensed solar power plants increased to 5 MW by EMRA.

Utilization of Renewable Energy Resources for the Purpose of Generating Electrical Energy" (hereafter RES Law) was enacted and this law envisaged three main mechanisms to foster renewable energy usage: (1) single feed-in tariffs for all types of renewable power plants to be commissioned before 2011 and have been in operation less than 10 years; (2) Certification of "Renewable Energy Resource" and purchase obligations for retail sale companies; (3) Grid-accession priorities and conveniences for project preparation and land acquisition.

Renewable energy license applications increased considerably following the enactment of RES Law (Erdogdu, 2011); however, some problems adversely affected investments. It appeared that some license applications only aimed to sell the license to other companies at high prices. The measures taken by the government to prevent such applications increased administrative hurdles and delayed investments. Increase in wholesale prices became another problem for renewable investments, and the maximum-level tariff envisaged in RES Law stayed below the wholesale electricity prices (OECD/IEA, 2010). Local opposition against hydro investments and proceeding judicial processes became another problem and hindered new renewable energy investments.

In 2010, Turkey made major changes in RES Law in order to overcome these problems and increase investments. The first major change is the establishment of "Renewable Energy Support Mechanism" (RESM) which will be applied to power plants commissioned between 2005 and 2015 and enable feed-in tariffs for ten years[2]. The second major change

[2] Contrary to the unique tariff system established in the previous system, new tariffs vary according to the source type: Hydro and wind plants will get 7.3 US cent per kWh, geothermal plants will get 10.5 US cent for kWh and biomass and solar plants will get 13.3 US cent per kWh.

is the introduction of support for the use of domestically manufactured equipment in renewable energy power plants. If an investor uses domestically manufactured equipment, then an additional fee varying from 0.6 US cents per kWh to 2.4 US cents per kWh is added to its tariff. In addition to these changes, the coverage of renewable energy definition is extended with the inclusion of landfill gas, and more measures, such as connection priorities and assistance in project preparation and land acquisition, are taken to reduce administrative barriers and decrease grid accession problems[3]. In 2016, EMRA made changes in RESM and renewable power plant operators submit their bids through day-ahead and intraday market, and they receive the difference between the market price and FiT-payment. In fact, this makes no difference in overall revenues for companies, but forces companies to improve their generation forecasts and reduces the overall system imbalance costs.

In solar investments, MENR announced the regions and substations that were allowed for solar PV installations and connections in 2012 to control renewable energy investments within the transmission system constraints. 27 regions that have annual solar radiation higher than 1650 kWh/m^2 were announced as eligible for investment and auctions were made for each region. However, it took almost two years to finalize the regulations and conduct the first auction. According to the regulations, if applications are higher than the available capacity in a substation or a region, then an auction will be conducted by the

[3] Under the Electricity Market Law No. 6446, licensing procedures have two stages: Preliminary licensing and licensing stages. A preliminary licensing period up to three years is introduced with the recent amendments made in 2013. The main rationale behind pre-licensing is to prevent unnecessary applications and bureaucratic processes. If the companies can fulfill their obligations during pre-licensing period, they can obtain their license afterwards; however, they still have to complete their investment within time stated in their license application.

national grid operator (TEIAS), and the highest bidder for the connection charge (contribution fee) will have the connection right. The bid will be made on payment for capacity installed (MW) and it must be paid within three years after the first unit of power plant is provisionally accepted.

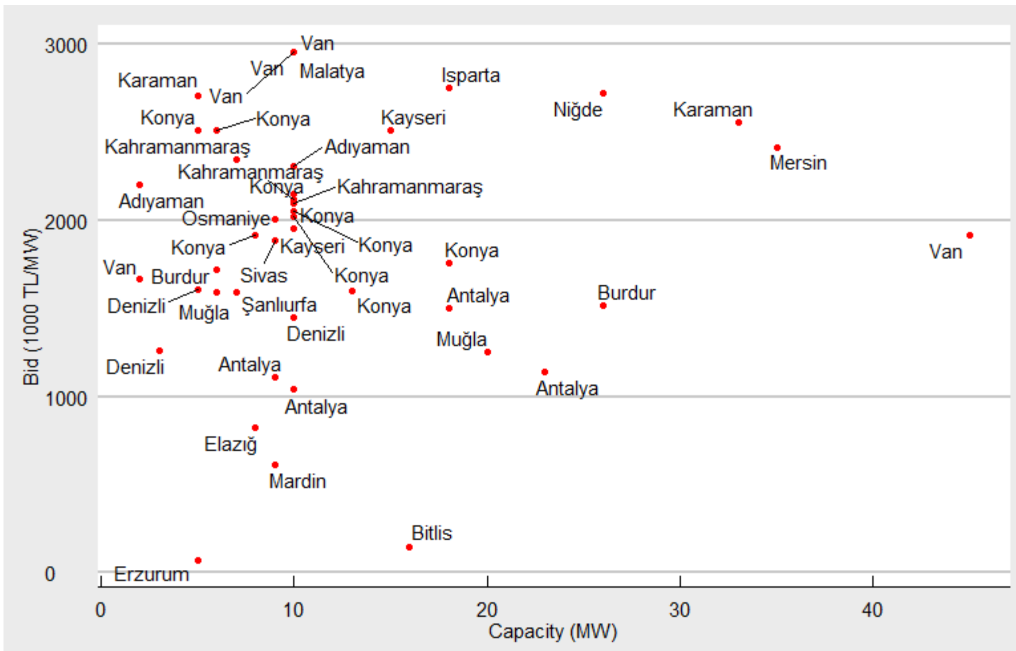

Figure 1.1 Solar PV auctions in 2015 (Source: TEIAS)

Figure 1.1 presents the selected auction results for capacity allocations in various provinces. The average winning bid for those auctions was 1889 MW/TL; however, there was a huge variance among provinces, and more than half of the auctions ended in higher prices than the average. The highest bids were made for three projects in Van province (almost 3000 TL/MW), while the lowest bids were made for Erzurum (68 TL/MW) and Bitlis (150 TL/MW) provinces. The high bids may reflect investors' positive perception regarding the Turkish power market (OECD/IEA, 2016b); however, high bids also challenge the feasibility of the projects given that some winners of hydro and wind power plant auctions went bankrupt or could not finish the project within the allowed time. There might be behavioral or other factors that affect investors' perception regarding the feasibility of the projects, and this may create additional risks for the diffusion of solar technologies in Turkey.

1.3.2 Renewable Energy Resource Zones (RERZ)

In 2016, MENR adopted the "Regulation on the Renewable Energy Resource Zone" (RERZ Regulation), which aims to utilize renewable energy potential and develop domestic innovative capacity in renewable energy technologies using auction mechanism. RERZ auction is a hybrid auction; the five lowest bids are invited to a descending-clock auction after a sealed-bid auction. The project requires installation of 1000 MWe capacity solar PV plant, construction of a solar PV module factory with a production capacity of 500 MWp/year and a research center within 18 months. The winner will get a fixed feed-in tariff for 15 years (no increase or additional payments will be made), and it will sell electricity in the wholesale market afterwards. The winner has to build the research center and factory before the power plant, and the modules produced in the factory will be used in the power plant. All permissions and license requirements for the construction will be completed by the winner, and the power plant is required to be operational within five years. The first auction for solar PV installation in Karapinar region (a district of Konya) was conducted in March 2017 – with a ceiling price of $0.08/kWh. Four consortiums participated in the auction, and Kalyon-Hanwha Consortium won with a bid of $0.0699/kWh in the 19th round (SHURA, 2019).

A significant share of the requirements in the RERZ Solar PV auction are related to the solar PV module factory and RD&D center as shown in Table 1.2. There are strict requirements on the technology choice and their minimum specifications, employment and RD&D plan. Financial requirements and penalties are less strict than the physical requirements. In terms of penalties, RERZ regulation set certain milestones for completing certain tasks of the project, and there are extensions in case of delays. In case of *force majeure*, one-year extension is given without any penalties; however, the license is cancelled, and bid bond is taken as revenue by the Ministry if the delay exceeds 18 months in other cases.

Table 1.2 Requirements for RERZ Solar PV Auction

Financial requirements	- Bid bonds - Previous work experience - Financial competence
Technical requirements	- 75% of modules should be locally produced - Minimum module physical life should be 25 years - Minimum efficiency constraints - Minimum output constraints - Should comply with international technical requirements and standards - Requirements for local production - Requirements for R&D activities
Other Requirements	- Local employment requirements (90% domestic workers for factory, 80% for R&D center)
Penalties	- One-year extension in case of *force majeure*; license is cancelled, and letter of guarantee is taken as revenue by the Ministry if delay exceeds 18 months.
Source: MENR Presentation and auction documents	

In October 2018, MENR announced the second PV RERZ auction. This auction included three projects with a total capacity of 1000 MW in three different regions, and it was similar to the first RERZ auction in terms of financial and technical pre-qualification requirements. The scheme would last for 15 years, and the power plants should be completely operational within five years after the signature of contract. In addition, an energy storage system with a capacity of 30 MW would be built in Bor province. Contrary to the first one, the second PV RERZ did not require any manufacturing capacity, and local content thresholds (more than 50% in each component) were set by the Ministry. However, the project was cancelled in January 2019.

1.4 Economic analysis of Solar RERZ Project

1.4.1 Model assumptions and data

Energy projects are generally large, irreversible, and have very high up-front costs. Moreover, investors have to consider various risks such as market risks, political and regulatory risks, and project-specific risks in investment decisions. Renewable energy technologies have some advantages compared to established technologies such as short-planning and construction time, small-capacity installations, low operation and maintenance costs. On the other hand, they have higher capital costs per unit, and they have different technical features that require flexibility in operation (Kumbaroglu et al., 2008).

In the literature, three major methods are used to analyze renewable energy projects: (1) Real-options (RO) approach; (2) The Net Present Value (NPV) approach; (3) The Levelized Cost of Electricity generation (LCOE) approach[4]. LCOE method is widely used to analyze new investments, because it is easier to conduct, and it allows comparing different technologies with different cost structures (Short et al., 2005). LCOE is the expected

[4] Complex analysis tools such as NREL SAM can also be used for the analysis; however, these models require significant information regarding the projects. In Turkish RERZ case, no detailed information is publicly available about the technology's choice. Hence, LCOE method is preferred in the analysis.

lifetime cost of the power plant divided by the overall electricity generation as shown in Equation 1:

$$LCOE = \frac{I_0 + \sum_{t=1}^{n} \frac{A_t}{(1+i)^t}}{\sum_{t=1}^{n} \frac{M_{t,el}}{(1+i)^t}} \quad (1)$$

, where I_0 is the investment expenditure; A_t is the annual total cost (Operation and Maintenance (OM) Cost + Financing cost + Fuel Cost) at year t ; $M_{t,el}$ is the amount of electricity produced at year t; i is the discount rate (real or nominal), and n is the lifetime of the project (Kost and Schlegl, 2018).

Table 1.3 presents data sources and parameters used in the model. LCOE estimates are based on the construction costs of the overall project, and the analysis does not include the operational costs of the solar PV module factory and the research center. Installation cost is around $1000-1500/kW varying according to the region and technology in the IRENA Renewable Cost Database, but statements of the government officials show that the cost is expected to be around $1.2 billion in total, of which $450 million is the expected cost of the module factory and $750 million for the power plant (Tsagas, 2017).

Table 1.3 LCOE Base Model assumptions

Variable/Parameter	**Description**	**Unit/Initial Value**	**Source**
T_p	Construction time	5 years	EMRA, MENR
T_e	Operational lifetime	25 years	EMRA, MENR
r	Interest rate (April 2018)	6.2%	MTF (2018)
E	Required return for equity	12%	IRENA
I	Investment cost	$1.2 billion	MENR
L	Loan term	10 years	
Q	Installed capacity	1000 MW	
OM	Fixed OM Cost	$13/kW/year	NREL
OME	Annual inflation in USD terms	3%	
Cf	Capacity factor	20%	NREL, PVGIS, GSA
dr	Degradation rate	0.25%	

E:D	Equity: Debt Ratio	30:70	

Solar energy data is collected using National Renewable Energy Laboratory's (NREL) PVWatts calculator[5], World Bank's Global Solar Atlas (GSA) program[6], and European Commission's Photovoltaic Geographical Information System[7] (PVGIS). Annual power generation for 1000 MWp installed capacity ranges between 1500 GWh to 1800 GWh in Karapinar region depending on different technology assumptions. The technology used in the project is not specified yet; therefore, a capacity factor of 20% is assumed, and the annual electricity generation is assumed to be around 1750 GWh in the first year; its generating capacity will gradually decline with a degradation rate of 0.25% per year adopted from (Kost and Schlegl, 2018). The construction time is planned to last 5 years, and the power plant will be operational for 25 years. Equity share is taken as 30% where the debt is 70%, and annual debt payments start when the plant becomes operational. The company has a major partner, so we assume it has better financing options. In this respect, we assume a loan rate of 6.2% (which is Turkish Treasury's 10-year, dollar-denominated Eurobond yield rate in April 2018), and the required return for equity is assumed to be 12%. Solar PV fixed OM cost is taken as $13/kW annually from NREL Annual Technology Baseline[8], and an additional insurance and variable OM cost with half of the fixed OM cost is added. The annual inflation rate is assumed 3%, and we use the weighted average cost

[5] NREL, National Renewable Energy Laboratory, https://pvwatts.nrel.gov/pvwatts.php, accessed at: 07/18/2018

[6] World Bank, Global Solar Atlas, http://globalsolaratlas.info/, accessed at: 07/18/2018

[7] European Commission, Joint Research Center, PVGIS, http://re.jrc.ec.europa.eu/pvgis/, accessed at: 07/18/2018.

[8] NREL, 2017 ATB Cost and Performance Summary, (https://atb.nrel.gov/electricity/2017/summary.html)

of capital (WACC) for discounting. All estimations are done in real terms as suggested by Kost and Schlegl (2018).

1.4.2 Results and sensitivity analysis

Table 1.4 Real LCOE estimates under base scenario and alternative scenarios ($/kWh)

Cost Element	Scenario				
	%20 Increase	**%10 Increase**	**Base**	**%10 Decline**	**%20 Decline**
Total Cost	0.07843	0.07317	0.06791	0.06264	0.05738
Cap.Factor	0.05659	0.06173	0.06791	0.07545	0.08488
Interest Rate	0.07463	0.07121	0.06791	0.06473	0.06168
Fixed OM	0.07019	0.06905	0.06791	0.06677	0.06563
Degradation	0.06823	0.06807	0.06791	0.06774	0.06758

Table 1.4 and Figure 1.2 represent the project’s estimated LCOE under base scenario and its sensitivity under different cost assumptions. Under the base scenario, the estimated LCOE is $0.0679/kWh, whereas it varies between $0.0566 /kWh and $0.0849/kWh depending on change in cost factors. The most influential factor in LCOE is the capacity factor, and 10% change in the capacity factor affects LCOE about the same rate. In other words, if the capacity factor of the plant increases by 20%, then the LCOE declines to $0.0565/kWh. Similarly, if the capacity factor is 20% lower than the base scenario, the LCOE increases to $0.0848/kWh. Total cost and interest rate are other major factors in LCOE, and a 10% change in total cost affects LCOE by 7.75%, while 10% change in interest rate changes LCOE by 5%. Degradation has the lowest effect on LCOE which is less than 1%. 10% change in OM cost, however, only affects LCOE less than 2%. The base scenario LCOE cost is in between the estimates of Karaveli et al. (2015) – $0.0542/kWh (excluding land cost) and $0.1053/kWh (including land cost). Since Karaveli et al. (2015)

did not account for the costs associated with the research center and the module plant factory, the estimated LCOE is also consistent with their findings.

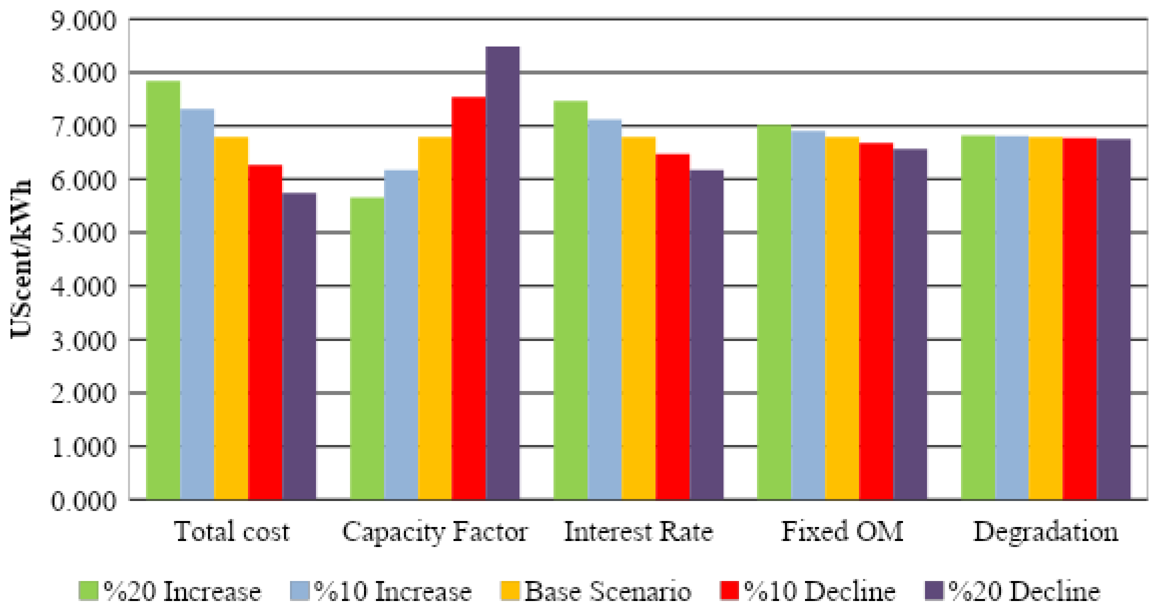

Figure 1.2 Sensitivity graph for RERZ Solar PV

Table 1.5 presents the comparison of Turkish case with international auctions using estimations of Dobrotkova et al. (2018). The authors calculated the nominal LCOEs for the analysis; therefore, we also calculated the nominal LCOE for Turkish case which is \$0.0877/kWh under base scenario; the estimation is very close to the project costs of South Africa and Brazil. On the other hand, the LCOE of the RERZ is almost three-times greater than those of UAE Dubai (\$0.03/kWh) and Chile (\$0.029/kWh), and twice as Mexico (\$0.036/kWh) and Peru (\$0.049/kWh)[9]. However, when the factory and research center

[9] Solar radiation in Dubai is more than three times that of Karapinar region, and estimates show that annual power generation for 1000 MWp installed capacity is around 6900 GWh for Dubai (https://pvwatts.nrel.gov/pvwatts.php). Hence, the capacity factor is very high in Dubai; decreasing LCOE.

investment costs are excluded, the nominal LCOE for the RERZ is $0.054/kWh, which is close to Argentina and less than Jamaica.

Table 1.5 Solar PV Auction Nominal LCOE Estimates

Country (Year)	LCOE ($/kWh)
Turkey (2017)	0.0877
Jamaica (2016)	0.085
Argentina (2016)	0.059
Peru 4th RE Auction (2016)	0.049
Mexico (2016)	0.036
UAE Abu Dhabi (2016)	0.024
Chile (2015/01)	0.029
South Africa (Round 4 - 2015)	0.064
Brazil (6th Auction - 2014)	0.082
South Africa (Round 3- 2013)	0.085
Source: Author calculations for Turkish case, Dobrotkova et al. (2018) for others	

1.5 Discussion on auction experiences in South Africa, Brazil, and Turkey

There is a growing body of literature on renewable auctions, and it has been widely accepted that the effectiveness of an auction highly depends on context-specific factors, and a successful mechanism may not be replicated under a different market context (Alvarez et al., 2017; Kruger and Eberhard, 2018; Winkler et al., 2018). Therefore, several different frameworks are proposed to analyze the design and implementation of auctions (Eberhard et al., 2018). These frameworks generally include pre-qualifications (physical, technical, and financial), liabilities and penalties, winner selection criteria (only price or multiple criteria), and auction features (volume, type, number of participants etc.). In this respect, there is no "best" auction design, and policy goals, compatibility with the electricity market, competition in the bidding and cost information should be carefully evaluated to form an "optimal" auction as discussed thoroughly by Alvarez et al. (2017).

To analyze Turkish case broadly, the design features of Turkish RERZ scheme are compared to those of Brazil and South Africa as shown in Table 1.6. Not only these countries are chosen for their considerable experience in renewable auctions, but also, they have similar institutional quality, economic performance, and macroeconomic conditions as well as significant potential in solar energy as Turkey. According to the Worldwide Governance Indicators, all three countries have similar rankings in regulatory quality, control of corruption, rule of law and government effectiveness (Kaufmann and Kraay, 2019). In terms of economic performance, basic economic indicators such as real GDP growth per capita or inflation rates are similar (Turkey had a surge in inflation in the last two years), while other economic indicators also show similar trends (S&P Global, 2019). When it comes to the business environment, those countries have similar scores in the Global Competitiveness Index; however, Turkey has slightly better scores in the Index of Economic Freedom and Ease of Doing Business Index (Miller et al., 2019; Schwab, 2018; World Bank, 2018). In this respect, Turkey has a similar institutional, regulatory and business environment to Brazil and South Africa, and this similarity helps to reduce the effects of unobserved factors in policy comparison.

Table 1.6 Main features of Solar PV Auctions

Country	South Africa	Brazil	Turkey
Year	2011-2018	2014	2017
Technology	Multiple with capacity limits	Solar PV	Solar PV
Capacity procured	6300 MW Total, 2292 MW Solar PV	890 MW (2014)	1000 MW
Capacity Constraint	75 MW (For each project)	None	None
Type	Hybrid (Pay-as-bid)	Hybrid (Pay-as-bid)	Hybrid (Pay-as-bid)
Site Selection	Developer (Neutral)	Developer (Neutral)	Government (Location specific)
Frequency	Sporadically	Energy Auctions: Twice a year, Reserve Auctions: Sporadically	Sporadically
Local Content Requirement	40%	None in bid, favorable credit conditions if local content is used	75% in modules
Additional requirements	Bid bonds Financial requirement	Bid bonds Financial requirement	Bid bonds Financial requirement
Selection criteria	70:30 Price and economic development criteria	Price	Price
PPA	20 years – indexed to inflation	20 years – indexed to inflation	15 years – fixed
Off-taker	Public Utility	Commercial market*	Commercial market
Winning price	~$0.35/kWh (2011) ~$0.21/kWh (2012) ~$0.10/kWh (2013) ~$0.07/kWh (04/2015-06/2015)	~$0.08/kWh (2014)	$0.0699/kWh
Currency	ZAR	Brazilian Real	USD
Additional Support		Concessional financing through BNDES-FINAME Program Discounts on transmission tariffs	
S&P Credit Rating	BB (2018)	BB- (2018)	B+ (2018)
Market Structure	Vertically integrated national public utility with horizontal unbundling in distribution. Regional power market with day-ahead and intra-day market that allows cross-border trading.	Over the counter (OTC) market for bilateral contracts, auctions are used to procure electricity, mostly restructured power sector with government dominance in generation and transmission.	Bilateral contracts, day-ahead and intra-day electricity market to procure electricity, privatized distribution companies, state-owned transmission company
Notes	*CCEE (Power Commercialization Chamber) was the major off-taker in this auction		

Brazil was one of the pioneering countries that introduced long-term electricity auctions to procure electricity with Law No 10.847 and 10.848 enacted in 2004 (Rego and Parente, 2013; Hochberg and Poudineh, 2018). These laws initiated the second wave of electricity market reforms in Brazil, and the auctions replaced purchasing agreements to attract investments, diversify generation mix and promote competition in the electricity sector[10] (Hochberg and Poudineh, 2018). Eligible consumers can sign bilateral contracts with generators (Free Contract Market – ACL); whereas non-eligible consumers have to purchase electricity from distribution companies which procure power via public regulated auctions (Regulated Contract Market – ACR). Renewable energy technologies were included in auctions in 2007, and 21 auctions were conducted until 2015 (one cancelled and three pending) (IEA/IRENA, 2019a). There are two types of auctions to procure renewable energy: (1) New energy auctions (alternative energy auctions); (2) Reserve energy auctions. The first group is used to procure new generation capacity to meet market demand of distribution companies and guide the expansion of installed capacity (Rego and Parente, 2013). The auction volume is based on demand projections, and the winners have to start delivering electricity within one year to six years from the auction (Eberhard et al., 2018; Förster and Amazo, 2016). New energy auctions are carried out twice a year, and contracts are awarded for 20 to 30 years, depending on the technology. 13 energy auctions were conducted under this group for renewable energy technologies until 2015, and only

[10] Early electricity market reforms in Brazil were implemented in mid-90s to solve insufficient capital investment problems of the vertically integrated and federally owned utility (Eletrobras) and distribution companies owned by the state-level governments. These reforms (Law 8.631, Law 8.987, and Law 9.074) eliminated barriers to private entrepreneurship, abolished guaranteed remuneration to utilities, introduced price-cap regulation, and distribution and generation utilities were privatized (Hochberg and Poudineh, 2018; Pinguelli Rosa et al., 2013)

wind, hydro and biomass technologies were included (IEA/IRENA, 2019a). Reserve energy auctions, on the other hand, are used to contract additional capacity in order to secure supply from new and existing suppliers (Pinguelli Rosa et al., 2013). These auctions are administered by the wholesale market operator - CCEE (Power Commercialization Chamber), and consumers pay a reserve energy charge for these auctions. Contrary to the previous one, this auction is technology specific, and solar PV technologies have been procured via reserve capacity auctions. Both auctions are hybrid auctions in which the bidders first enter an online descending clock auction followed by pay-as-bid sealed bid round. Winning bidders sign power purchase agreements (PPA) in national currency (Brazilian Real) that are guaranteed for 20 years, and the prices are indexed to inflation rate (IEA/IRENA, 2019a). There are no specific local content requirements in these auctions; however, Brazilian National Development Bank (BNDES) provides favorable energy financing packages if local content exceeds a certain threshold (60% in the earlier projects) (Eberhard et al., 2018; Förster and Amazo, 2016). The first solar PV auction was conducted in 2014 as a reserve auction, and 890 MW was allocated to 31 projects. There were two other auctions conducted in 2015; however, they are still pending due to economic stagnation and slow growth in electricity demand (Eberhard et al., 2018; IEA/IRENA, 2019a).

South Africa introduced a renewable energy feed-in tariff scheme in 2009 and National Public Utility (ESKOM) purchased electricity from qualifying renewable energy generators at predetermined prices based on the levelized cost of electricity. This scheme was superseded by the Renewable Energy Independent Power Producer Programme

(REIPPP) in 2011, and ESKOM conducts auctions to purchase power from qualifying technologies. From 2011, five rounds of auctions were conducted, and 2292 MW Solar PV capacity was procured through auctions – but there was a 75 MW cap for each project. South Africa uses a descending clock hybrid auction with a ceiling tariff level established for each technology. Winners sign power purchase agreements (PPA) in national currency (ZAR) that are guaranteed for 20 years, and the prices are indexed to inflation rate (IEA/IRENA, 2019b). In addition, South Africa prioritizes enhancing domestic capacity in renewable energy technologies; therefore, economic development thresholds are set in these auctions (DoE, 2018). The selection is based on scores comprising price (70%) and economic development (30%) criteria. Economic development criteria are based on job creation (25%), local content (25%), ownership (15%), management control (5%), preferential procurement (10%), enterprise development (5%), and socio-economic development (15%) (Kruger and Eberhard, 2018). Besides, bidders have to submit bid-bonds to ensure commitment, and the length of PPA is reduced if there are delays.

Given the discussions in the literature on the design of auction mechanisms, there are seven aspects that should be emphasized in order to understand the strengths and weaknesses of Turkish RERZ scheme in the light of the South African and Brazilian experiences.

1) **Consistency with policy targets:** As emphasized in the literature, political commitment, policy consistency, political stability and predictable regulatory changes are key to successful renewable energy policy (Bointner, 2014; Jager et al., 2011; Keeley and Matsumoto, 2018). Renewable support schemes were changed a couple of times in Turkey, and MENR is continuously revising its renewable energy policy

design. The strong emphasis on technical requirements in the RERZ scheme implies that Turkey prioritizes developing domestic manufacturing capacity over electricity generation (SHURA, 2019). In Brazil, wind and hydro are more preferred to solar PV technologies in energy auctions, and the inclusion of solar PV only in reserve auction caused delays and cancellations in the following solar auctions (Kruger and Eberhard, 2018). Hence, this adversely affected the diffusion of solar PV despite Brazil's significant potential. Contrary to these countries, South Africa has an industrial policy approach to use renewable energy as a source for economic development (DoE, 2018). In addition to increasing generation capacity, renewable energy technologies are used to reduce transmission losses and support local economies in South Africa (del Rio, 2016). Hence, South Africa uses a balanced approach that combines mass diffusion of solar PV with enhancing domestic competence by looking at multiple criteria in evaluation. In this respect, the South African approach is more consistent with developing economies in terms of contributing to overall economic development targets.

2) **Consistency with the internal electricity market:** Electricity markets have become the backbone of many power systems, and electricity market reforms are still continuing in developing economies. Turkey has established a functioning domestic competitive electricity market with day-ahead, intra-day and balancing markets, and it has plans to couple with European power markets. Similarly, Brazil has conducted market reforms; there is an OTC market for bilateral contracts, and auctions are used to procure electricity. However, market operations are different for end users. For

eligible customers, prices are freely negotiated between buyers and sellers through an OTC market, whereas a single buyer model structure is used through energy auctions for non-eligible consumers. Additionally, there is a short-term market used to settle the differences between the contracted energy amounts and the generated/consumed energy (Calabria and Saraiva, 2014). Unlike its European counterparts, Brazilian power market operates in a centrally optimized day-ahead and real-time market (Cramton, 2017). On the other hand, South African power system is dominated by vertically integrated national utility (ESKOM), which carries-out generation, transmission and distribution activities. In addition, there is a regional power pool that operates day-ahead and intraday markets for cross-border trade. However, the trading volume is very low due to capacity constraints and other infrastructural problems (Medinilla et al., 2019).

As renewable energy technologies get higher shares in the power supply, new problems emerge in power markets. The basic problem with long-term fixed payments provided to renewable technologies in competitive electricity markets is its distortive effects on investment signals and investor behavior (Polzin et al., 2015). Moreover, renewable power plant operators try to optimize their bidding-strategies in competitive power markets if market price is incorporated into their revenue system. On the other hand, fixed payments allow operators to supply electricity to the system whenever the plant is available, and this affects system imbalance costs significantly. Therefore, the spot market gap model (varying payment with respect to electricity market price) is recommended to eliminate market risks while reducing the costs on the government budget. In Brazil and South Africa, there is a more centralized approach in investment decisions, and the effect of renewables can be balanced with government intervention. On the other hand, Turkey relies on private investors to a great extent, and this creates more problems for the system operator. Nonetheless, Turkish approach is more consistent with competitive electricity market design, and currently RESM is operated as a spot market gap model.

3) **Allowed capacity and site selection:** Turkish government set a considerable capacity in the RERZ scheme, and this is consistent with policy objectives - to benefit from learning economies and have a reasonable domestic market to support technology transfer. However, this also creates challenges in terms of high capital costs and vulnerability to macroeconomic shocks. Moreover, small and medium-sized companies cannot participate in such costly projects, and this reduces the positive spill-over effects expected from technology transfer. Brazil, similarly, did not set maximum capacity for Solar PV auctions, and there were problems caused by changing macroeconomic conditions. In addition, smaller companies were usually excluded from auctions due to financial requirements (Förster and Amazo, 2016). On the other hand, South Africa set a 75 MW capacity limit for solar PV projects to increase competition in the auction while creating more opportunities for domestic companies (del Rio, 2016; Kruger and Eberhard, 2018). In retrospect, this approach is more appropriate for developing economies, and Turkey is also planning smaller-scale RERZ projects in solar PV in the coming years.

In both Brazil and South Africa, project developers are responsible for site selection and land costs (Dobrotkova et al., 2018). In Turkish case, the government selects location, and the project developer bears no costs regarding permitting and land usage. While this has advantages in terms of reducing risks for the project, there is some criticism that the selected location is not optimal for transmission system. However, there were delays in Brazil due to permitting process, and bidders have to bear significant risks due to obtaining land permits in South Africa (del Rio, 2016; Hochberg and Poudineh, 2018). In this respect, Turkey's approach might be more suitable for developing countries to reduce costs on bidders and increase competition in the auction.

4) **Contract currency and financing:** Keeley and Matsumoto (2018) note that exchange rate stability is recognized as one of the most important factors for foreign direct investments in renewable energy technologies in developing economies. In this respect, many developing countries use hard currency (mostly USD) or local currency pegged to USD for support schemes. As presented in Dobrotkova et al. (2018), only Brazil, South Africa and India used local currency in renewable auctions among 13 developing economies. Local currency has merits in terms of reducing the financial burden on government. However, financing costs are higher in developing economies, and macro-economic shocks lead to serious mismatch between company debt (mostly in foreign currency) and revenue (if local currency used) as project capacity grows. As an example, Brazil encountered difficulties in renewable projects due to depreciation of Brazilian Real against USD recently (Kruger and Eberhard, 2018). South Africa uses local currency as well, but it has smaller projects compared to Turkey and Brazil, and

this makes companies less vulnerable to economic shocks. In Turkish case, payments will be made in USD, so the winner will not encounter exchange rate risk in the project. However, the scale of the project causes high capital costs as shown in the sensitivity analysis, and macroeconomic problems (such as surge in interest rates) emerged after Turkish Lira depreciated more than 30% in a couple of weeks in the summer of 2018. Hence, this creates a significant burden on project finance and government budget. Turkey has similar credit ratings and macroeconomic conditions with Brazil and South Africa; therefore, Turkey may consider using local currency with indexation to inflation rate. While it can be argued that it would be difficult to obtain cheaper finance, Turkish state-owned banks may provide favorable finance for the RERZ project as done in Brazil.

5) **Pre-qualification requirements, penalties, and winner selection:** As important elements in the auction design, pre-qualifications and penalties create trade-offs, and sometimes conflict with policy targets. While stricter requirements and penalties are needed to prevent non-completion problems, these cause higher risk premiums and limit participant diversity in auctions (Hochberg and Poudineh, 2018). Kreiss et al. (2017) suggest that financial pre-qualifications used with physical pre-qualifications lead to successful outcomes, whereas penalties are not as effective in forcing companies to complete the project on time[11]. Shrimali et al. (2016) also emphasize that financial

[11] The authors analyzed several auctions for renewable energy technologies and found out that higher financial pre-qualifications lead to a higher probability of realization, but investors expect higher financial support. They also emphasized that non-realization options affect bidding behavior and bidders tend to offer lower prices; however, this also increases the risk of non-completion of the project. Second, physical pre-qualifications reduce some risks, but they also increase sunk costs and reduce competition by preventing easy entrance (Kreiss et al., 2017).

and physical pre-qualifications are required for better auction design; however, they also suggest strong penalties to prevent non-completion. Brazil has pre-qualification criteria regarding company experience and financial competence (Kruger and Eberhard, 2018). In the event of delays, the contract can be terminated without further justification if delays exceed one year. Moreover, there are penalties for deviations from the contracted electricity production amount (Förster and Amazo, 2016). In South Africa, bidders must satisfy a minimum level of financial, technical, commercial and legal criteria. After fulfilling these criteria and demonstrating their financial viability to complete the project, the project is evaluated on the weighted criteria (del Rio, 2016). Contracts are terminated if the awardee fails to comply with the auction requirements. In Turkish case, there are stricter technical requirements with less strict financial requirements and penalties. This indicates that Turkish government wants to increase the flexibility and attract more bidders to the auction, but this also creates risks on the financial competence of the bidders to complete the project on time.

Price is widely used as the only criterion in selecting the winner in many countries (Eberhard et al., 2018). Similarly, Brazil and Turkey use price criterion in winner selection, contrary to South Africa which uses multiple criteria. While the evaluation process is more complex in multiple criteria approach, it provides a broader process that supports economic development goals.

6) **Administrative processes and regulatory environment:** In general, investors look at macro-economic environment, market dynamics and sector-specific framework in energy investment decisions (European Commission, 2015). In addition, studies have

shown that institutional quality is one of the key factors in attracting investments. Well-functioning conflict resolution mechanisms and transparent administrative procedures support innovative activities and attract foreign investments to new and risky areas (Keeley and Matsumoto, 2018). Inconsistent policies and regulations, unfavorable investment environment and the lack of transparency in bureaucratic processes in developing economies create higher risks and transaction costs for renewable energy investments (OECD/IEA, 2016a). In Brazil, administrative and permitting problems caused delays and cancellations in solar PV auctions (Eberhard et al., 2018). Whereas, South Africa has a specialized procurement unit with significant experience that implements auctions, and this unit helped to reduce bureaucratic hurdles (Kruger and Eberhard, 2018).

In the earlier stages of the renewable support scheme, administrative hurdles and conflicting regulations were encountered during the application process in Turkey (OECD/IEA, 2016b). MENR has established a department for the RERZ scheme, and it will provide assistance to the project developer. Although this may reduce some regulatory burden, there are still other government agencies involved at the different stages of the project- which still creates administrative problems. Therefore, the South African approach that uses a specialized task force composed of various agencies is more reasonable for developing economies to minimize regulatory risks in renewable energy auctions.

7) **Innovative capacity and technology transfer:** One of the major objectives of the RERZ scheme is to develop Turkey's domestic innovation capacity in renewable

energy technologies. Developed economies have dominated renewable energy technology markets for a long time; however, developing economies are investing in research and development of these technologies and research spill-over effects significantly surpass their costs (Gosens and Lu, 2013). Recent studies show that the U.S., Japan, Germany, China and South Korea have the highest shares in patents and scientific publications in solar PV technologies. These countries have dynamic national innovation systems along with strong industrial background, conducive environment in scientific research, strong networks among universities, and competent private sector[12] (Frank et al., 2018; Sampaio et al., 2018). Local manufacturing capacity and innovative activities in Solar PV technologies are relatively low in Turkey, and many manufacturers just produce modules and other equipment under licenses (SHURA, 2019). Turkish government is trying to create a promising environment for new technologies, and the RERZ scheme requires investment in domestic manufacturing capacity. Domestic content requirements are also used by other countries such as China and South Africa, and there has been some degree of success in supporting domestic innovative capacity in these countries (Azuela et al., 2014). Yet, national innovation system has a critical role in this success, and Turkish national innovation system has structural weaknesses that limit research and development activities in the power sector (OECD/IEA, 2016b; Sirin and Erdogan, 2013; World Bank, 2009). Furthermore, there

[12] The research on innovation studies have emphasized that neoclassical approach to remove market imperfection by just subsidizing R&D is not enough to incentivize private companies for innovative activities, and policies should be evaluated under a broader perspective which is generally termed as National Innovation System (Negro et al., 2012).

are some major problems underlined in the literature that affect the success of Turkey's renewable energy policy adversely, such as failure to develop a comprehensive energy-related science and technology policy, weak cooperation between European Union countries in technology development, conflicting policies and administrative barriers related with the authorization, licensing, and the construction of the projects (OECD/IEA, 2016b; Toklu et al., 2010). In this respect, strong emphasis on domestic manufacturing and RD&D expenditures are promising clauses in RERZ scheme; yet, it may not create the desired spill-over effects since an increase in RD&D expenditures does not immediately increase scientific capacity (Bointner, 2014). Hence, innovation in renewable energy technologies should be evaluated under a broad technology policy that aims to develop industrial capacity and support cooperation between universities, government agencies and the private sector. Multiple criteria approach used in the South African case is a reasonable approach to support innovation activities in developing economies, and Turkey can adopt this approach to improve the RERZ auction design.

1.6 Conclusion and policy implications

As global investments continue in renewable energy technologies, the costs have declined significantly, and these technologies have become competitive alternatives to conventional technologies. In this respect, developing economies have opportunities to catch-up with other countries and enhance their innovative capacities in these technologies with a proper and well-designed renewable energy support scheme.

Recently, Turkey has initiated an auction scheme to promote renewable energy investments while enhancing domestic innovative capacity. Even though the auction has been hailed as a success promoting low prices, the economic analysis shows that there are factors that can affect the project adversely. In terms of auction design, the Turkish case carries the characteristics of a successful design; however, it also has weaknesses. First of all, the RERZ scheme aims for large-scale deployment of solar PV, and it is consistent with policy targets of benefitting from learning economies and economies of scale. On the other hand, this project has higher risks given Turkey's recent struggle with macroeconomic shocks and volatility in exchange rates. Therefore, small-scale projects might be more suitable for Turkey's economic conditions rather than large-scale power plants. Second, SMEs have difficulties in winning large-scale projects which prevents spill-over effects in the economy. Hence, Turkey can improve its auction design by using multiple-criteria evaluation like South Africa rather than using price as the only criterion.

In terms of market risks, the company may encounter interest rate and exchange rate risks that have a significant impact on the financial soundness of the project. Turkey has higher exchange rate volatility and higher risk premiums that limit long-term and low-cost financing of renewable energy projects. Turkey has addressed this problem by using hard currency in the auction, which only increases the burden on the support mechanism. Instead of hard currency, Turkey may use inflation-indexed support payment in local currency, which will reduce exchange rate risks.

In terms of innovative capacity, the weaknesses of Turkish national innovation system may hinder enhancing domestic competence in solar PV technologies. Hence, the government should also take measures to overcome the problems in institutional quality and national innovation system while promoting cooperation between the private sector, universities, and government agencies. Furthermore, the evaluation process may utilize multiple criteria to incorporate domestic companies and universities in innovative activities.

Finally, financial and non-financial factors that affect investors' bid decisions in renewable energy auctions (both previous auctions and RERZ scheme) are not thoroughly discussed in Turkey. A detailed analysis of investor behavior is beyond the scope of this paper; however, there are a number of arguments trying to justify such results: (1) The cost of renewable energy technologies has declined significantly; therefore, bidders value grid-connection/market-access priorities more than financial incentives; (2) Turkey has a promising market, and the bidders wants to take first-mover advantage to gain access to both Turkish market and neighboring economies; (3) Investors have biases that cause underbidding in the auctions; (4) The design of the auction causes such results. Further research should focus on investors' bidding strategies and underlying incentives in such auctions to improve the design and increase the effectiveness.

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Chapter 2: How do Macroeconomic Dynamics Affect Small and Medium-Sized Enterprises (SMEs) in the Power Sector in Developing Economies: Evidence from Turkey

Abstract

Developing economies are currently projected to have the major share within global energy demand in the upcoming decades, giving them a key role in addressing climate change. However, new renewable energy investments in these countries have so far been relatively slow. A specific set of challenges dominate the investment environment in developing countries, including higher exposure to macroeconomic and political risks, uncertainties due to climate change, limited domestic manufacturing capabilities, and heavy reliance on foreign debt in capital investments. These factors tend to disproportionately affect the small and medium-sized enterprises (SMEs) which have a sizeable share in renewable and distributed energy technology investments. In addition to the viability of energy transition, this has important energy justice and local economic development implications -- an overlooked subject in the literature. Using a rich, novel data set and panel data methods, this paper estimates the effect of a set of key macroeconomic variables on the capital structure and the investment outcomes of the SMEs within the Turkish power sector. Our results indicate that unfavorable macroeconomic conditions lead to a significant growth in liabilities and bankruptcy risk of power sector SMEs while their investments slow down despite the prevalence of subsidies.

2.1 Introduction

Energy transition is seen as the single most important tool in responding to the emerging global climate crisis (Sovacool, 2016). Thanks to various incentive mechanisms and growing business concerns, global investments in renewable energy technologies have surpassed $300 billion annually since 2015 (IRENA, 2021). However, these investments are still short of achieving the levels necessary to meet the ambitious net-zero carbon targets (Krupa and Harvey, 2017). Official projections of major international agencies indicate that more than $130 trillion investment in clean infrastructure is required between 2016 and 2050 to avoid a major climate crisis (IRENA, 2020). The majority of the global energy demand growth is expected to come from developing economies, giving them a key role in combating climate change. Recent trends in both supply and demand sides within these regions are in line with the rest of the world e.g., decreasing unit costs in new energy technologies, government incentives and subsidies for renewable energy investments, increasing consumer awareness in energy and environment issues, and changing social norms. There have also been institutional reforms in the way markets operate to limit the state control on electricity markets and improve the reliance on market forces for a well-functioning price signal which could incentivize private sector investments. These developments significantly boosted both investment size and firm heterogeneity in recent years (Wustenhagen and Menichetti, 2012). Yet, a number of factors interacting with systematic and idiosyncratic risks lead to a set of concerns regarding the financial sustainability of the renewable energy transition in the developing regions.

First, due to credit constraints, most energy firms rely on external finance for new investments, such as multilateral credits denominated in foreign currency (ADB, 2021). While renewable energy support mechanisms aim to reduce market risks for investors, currency mismatch between subsidies can lead to financial difficulty in the face of devaluation risk. Second, financing costs in these economies are higher compared to developed economies which exacerbates the solvency risk together with the increasing leverage rate in capital intensive projects (IEA, 2021b; Waissbein et al., 2013). Third, growing climate risks lead to higher fiscal risks in developing economies which in turn are reflected in sovereign borrowing costs, inflating the overall financing costs for private companies (Kling et al., 2021; Huang et al., 2018). The global pandemic has amplified the debt burden for many developing economies resulting in even steeper sovereign spread and risk premiums (Hourcade et al., 2021). Fourth, policies targeting climate change may lead to changes in risk-perceptions and create biases (e.g., bandwagon effect, neglect of probability, etc.) that may eventually cause capital misallocation (Bai et al., 2021; He et al., 2019). Fifth, with zero or very low marginal costs, renewable energy technologies such as wind or solar have been displacing conventional generators and leading to decreases in average prices in electricity markets (the merit-order effect). As a result, each new variable (non-dispatchable) renewable investment (VRE) erodes the value of both itself and other generators hurting the returns on investments – an issue known as the cannibalization effect (Lopez Prol and Schill, 2021).

Taken together, all these problems render the energy sector investments vulnerable to domestic or global macroeconomic shocks (Auer et al., 2021). The inadequacy of the current financial systems in mitigating these risks has been highlighted in recent papers (e.g., Egli, 2020; Polzin et al., 2019; Egli et al., 2018; Cormack et al., 2021). However, these studies are mostly limited to developed economies or China where capital markets are relatively more developed and institutional context significantly differs from the rest of the world (Rashid, 2013; Zhang et al., 2016a; Cariola et al., 2020; Hou et al., 2021; IEA, 2022). Another limitation of the existing studies is that the focus has predominantly been on publicly traded firms or large firms, likely facilitated by data availability, while SMEs are mostly overlooked (Jenkins et al., 2016; Zhang et al., 2016a; Bai et al., 2021; Brav, 2009). Due to their central role in the economy, how SMEs fare in the energy transition has important implications for not only achieving global climate goals but also for economic development and energy justice. Relative to larger firms, SMEs encounter more severe financial obstacles such as higher borrowing costs and limited de-risking capabilities (Beck, 2007; Carb´o-Valverde et al., 2009; Serrasqueiro and Caetano, 2015; Alter and Elekdag, 2020). Hence, unfavorable macroeconomic environment together with growing risks tend to disproportionately affect the SMEs (Beck, 2007; ADB, 2021; Kling et al., 2021; Ziaei, 2021). Furthermore, existing studies on renewable energy policies mostly focus on electricity market risks - highlighting the importance of dispatch priorities and purchase guarantees for investors, while inquiries into growing liabilities and financial performance during the energy transition have been rather limited. As argued by Iskandarova et al. (2021), Steffen and Schmidt (2021) and Geddes and Schmidt (2020), this is one of the gaps in the finance and economics literature, and further research is needed to understand how the capital structure of SMEs and their investment outcomes change in developing economies during the energy transition. This paper aims to complement the existing body of literature by exploring the investment dynamics and financial performance of the power sector SMEs in a developing country context, Turkey. Turkey comprises an interesting study case for various reasons. It is one of the earliest developing countries that have taken major steps in restructuring its power sector. Endowed with an abundant renewable energy potential, Turkey also implemented a stable renewable energy support scheme from 2005 to 2020. As a result, private firms have become the major investors in the Turkish electricity sector, and SMEs have more than 22 GW installed capacity (including distributed energy technologies) accounting for about one-fifth of the total installed capacity. On the other hand, Turkish lira (TRY) depreciated more than 60% between 2016 and 2020 as a result of both political and economic problems. In addition, heavy reliance on technology transfer and imports in the renewable energy equipment industry together with depreciating and volatile domestic currency expose the investors to a number of economic and political risks. Therefore, a detailed analysis of the Turkish power sector can provide significant insights for other developing economies in terms of macroeconomic dynamics and their implications on the energy transition. This paper expands the current literature in two important ways. First, we provide empirical estimates of the effect of some key macroeconomic variables on the capital structure and investment dynamics of SMEs within a developing country context using a novel data set on SMEs in the Turkish power sector from 2009 to 2020[13]. Second,

[13] Only few studies have discussed the financial performance of the energy firms in developing economies during the energy transition, such as Bobinaite (2015) covering the Baltic States or Bunea et al. (2019) on Romania; yet these are exploratory analyses not including macroeconomic variables. Existing studies on SMEs such as Cariola et al. (2020) cover firms exceeding a certain asset threshold, whereas this paper includes all firms that submit tax forms to the Ministry of Treasury and Finance (Turkey). Another growing research stream analyzes renewable energy firm performance in stock markets, such as Kocaarslan and Soytas (2019); Shahbaz et al. (2021). Yet, this stream analyzes public firms, which have different capital and management structure, capabilities, and investment motives than private firms, and their analyses do not include SMEs.

existing empirical studies do not take the interaction between firm financial position and electricity market dynamics into account in their analysis, and this causes endogeneity bias in the econometric estimates if not addressed properly. By the very nature of the electricity industry, firms develop their generation strategies as a response to the changes in prices, and even small firms can affect the electricity market clearing price (MCP) by engaging in strategic bidding or capacity withholding. In this paper, we mitigate this issue by instrumenting for the market clearing price. The article continues with the literature in Section 2, followed by an overview of the Turkish electricity market in Section 3. Section 4 presents data and methodology, and Section 5 presents the results. Finally, Section 6 discusses policy implications and concludes the article.

2.2 Theoretical Arguments and Hypothesis Development

Recent trends in the electricity markets such as market restructuring, liberalization, and decentralization pose several challenges for the energy transition. The risk-return profiles within the new competitive market paradigm motivate firms to employ cost-efficient and mature technologies which are more likely to be profitable in the short-term (Bolton et al., 2016). Furthermore, experiences of developed economies have shown that the share of long-term debt has declined significantly in deregulated firms due to increasing focus on short-term profitability, operational efficiency, and growing market risks (Ovtchinnikov, 2016). Therefore, it can be argued that there is a potential conflict between the market dynamics and renewable energy investment goals (Brunnschweiler, 2010). Governments have formulated various instruments that provide partial or complete revenue guaran- tees to support renewable energy investments (for a recent review see Polzin et al., 2019), and these instruments have been the major drivers of renewable energy in- vestments in many countries so far (Bergek et al., 2013; IEA, 2021b). Furthermore, renewable energy investments benefited from the accommodative monetary policies after the 2008 global financial crisis which reduced the financing costs (Egli et al., 2018; Banti and Bose, 2021).

On the other hand, renewable energy investors are still forced to employ higher leverage due to the fact that upfront investment costs of renewable energy technologies per unit are still higher than most of the conventional technologies (Waissbein et al., 2013; Luo et al., 2021). For example, Egli et al. (2018) has shown that the leverage for renewable energy projects in Germany increased gradually from 70% to 80% in the last decade. This situation renders the feasibility of these projects to be more sensitive to the cost of capital (Schmidt et al., 2019; Egli, 2020). Growing debt and liabilities, then, increase the exposure of these investments to economic and non-economic risks and uncertainties (IEA, 2021a).

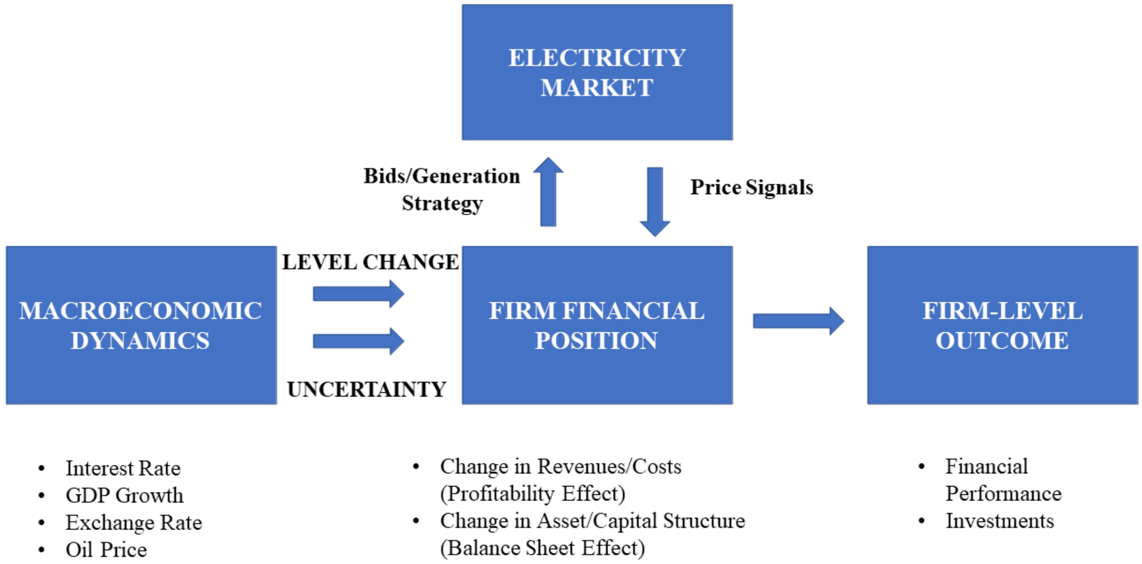

Figure 2.1 Macroeconomic dynamics and firm-level outcomes

The conceptual framework of this study, which is based on the macroeconomics and finance literature[14], is summarized in Figure 2.1. There are two mechanisms through which key macroeconomic variables (exchange rate, interest rate, oil price, and economic growth) affect firms' financial position: Level change and uncertainty. While the former can be considered to have a direct effect on firms' financial position, the latter affects firms through change in risk premiums, risk perceptions, and expectations (Fan et al., 2021). Both mechanisms affect firms' revenues and costs (the profitability effect) as well as asset and capital structure (the balance sheet effect) (Erel et al., 2012; Alter and

[14] An extensive literature review on investment dynamics is beyond the scope of this paper. Interested readers may refer to Frank and Goyal (2009), Angelo and Roll (2015), Kalemli-Ozcan et al. (2019), Banerjee et al. (2020) and In et al. (2022).

Elekdag, 2020).[15] Finally, firms' financial position affects their financial performance (e.g., profitability, leverage, debt maturity, etc.) and new investment decisions. Furthermore, there is an interaction dynamic specific to the power sector indicated with the upward and downward arrows in Figure 2.1. Firms in the power sector operate in national or regional wholesale electricity markets which are based on auctions. Market participants either engage in market operations, use bilateral contracts, or retrieve subsidies which are affected by the wholesale market prices (such as contract-for differences or feed-in premiums). In either case, the whole- sale market prices influence firms' financial position, and firms can also affect market prices by engaging in different bidding strategies.

2.2.1 Capital Structure and Leverage

Finance literature has developed three prominent theories that aim to explain how capital structure changes under market frictions, information asymmetries and cognitive barriers: (1) *the trade-off theory*; (2) *the pecking order theory*; and (3) *the market-timing theory* (Baker and Wurgler, 2002). According to these theories, the capital structure of a firm is affected by firm-specific factors, institutional factors, and macroeconomic environment (Korajczyk and Levy, 2003; Serrasqueiro and Caetano, 2015). The literature has found varying implications of these factors on the financial leverage (leverage, hereafter) and capital structure which are summarized in Table 2.1.[16]

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[15] While the balance sheet effect is used to explain the currency mismatch in firm revenues and debts and subsequent decline in borrowing capacity after depreciation, we use the term in a broader context that covers the change in asset and capital structure (Tovar, 2006).

[16] There are also extensions of these theories such as dynamic trade-off theory or inertia theory. See Heath and Sertsios (2021) for a recent review.

- Interest rate: An increase in the nominal interest rate induced by a higher inflation rate increases the tax advantage of debt financing, making leverage more attractive according to the trade-off theory. On the other hand, an increase in real interest rate increases the cost of debt; hence all three theories assume a negative relation between real interest rate and leverage (Frank and Goyal, 2009).

Table 2.1 The impact of fundamental variables on firms' leverage according to the three prominent theories

Variable	Trade-off	Pecking-order	Market-timing
Profitability	Positive	Negative	Positive
Firm Size	Positive	Negative	Ambiguous
Growth Opportunity	Negative	Positive	Positive
Industry Structure	Positive	Ambiguous	Ambiguous
Asset Tangibility	Positive	Negative	Ambiguous
Macro.Uncertainty	Negative	Negative	Negative
Real Int. Rate	Negative	Negative	Negative
Source: Compiled by the authors through literature review			

- Economic growth: Higher economic growth means growth opportunities for firms. In addition, banks are more willing to provide credit and firms prefer debt during economic expansions (Campiglio, 2016). The trade-off theory fundamentally argues that "capital structure is determined by a trade-off between the benefits of debt and the costs of debt", and the net benefit of debt arises from the tax-shield, agency costs, and bankruptcy costs (Zou and Xiao, 2006). According to this theory, firms may not prefer debt as the first option during expansionary periods; therefore, a negative relation be- tween growth opportunity and leverage is expected (Serrasqueiro and Caetano, 2015).

  The pecking order theory, on the other hand, argues that firms prefer internal financing to external financing as risks and costs increase (Frank and Goyal, 2008). If firms have higher growth opportunities, they are more likely to use debt; therefore, a positive relation between economic growth and leverage is expected (Serrasqueiro and Caetano, 2015). The market-timing theory fundamentally argues that managers evaluate the market conditions, and raise funds accordingly (Frank and Goyal, 2009); hence, a positive relation is also expected.

- Exchange Rate: The impact of the exchange rate depends on how it affects the revenues and costs. If revenues are in foreign currency and costs are in domestic currency, then a depreciation of the domestic currency will increase the profitability of the firms, and a positive relation between the exchange rate and leverage can be expected according to the trade-off theory. On the other hand, the pecking-order theory argues that firms prefer internal financing to external financing; therefore, a growth in profits will reduce the need for leverage according to this theory (Frank and Goyal, 2008). Similar to the trade-off theory, a positive relation between profitability and leverage is expected according to market-timing theory.

  If firms use financing in foreign currency[17], a depreciation of the domestic currency will increase the existing liabilities and the cost of new debt. Furthermore, a depreciation of the domestic currency increases risk premiums in emerging markets; therefore, a negative relation is expected between the real exchange rate and leverage according to these theories.

[17] The finance literature highlights exposure, segmented capital markets, taxes, liquidity, and legal regimes as the determinants of firm foreign-debt preferences (Kedia and Mozumdar, 2003). Nonetheless, recent policy measures include climate or renewable energy funds which provide low-cost foreign debt to investors. So, there is an increasing number of firms preferring foreign- currency dominated debt.

- Oil Price: Oil price can affect a firm through two channels. The first one is through profitability. Since oil is one of the primary inputs for many industries, an increase in oil price reduces profitability in non-oil sectors. In addition, oil price is an indicator of fossil fuel and global commodity prices, so an increase in oil price indicates growing demand for raw materials and other industrial inputs, which increases costs and reduces profitability.[18]
  The second channel is growth opportunities. An increase in oil price can incentivize firms in non-oil sectors to invest in alternative/renewable energy technologies to reduce their dependence on oil and fossil fuels. Therefore, an increase in oil price provides growth opportunities for the renewable energy sector. So, an increase in oil price will have a negative effect on lever- age according to the trade-off theory, and a positive effect according to the pecking-order and market-timing theories.
- Uncertainty: Macroeconomic uncertainty creates volatility in firms' cash- flows and growth prospects while also shifting creditors and borrowers' risk perceptions (Banti and Bose, 2021). In addition, low leverage can be used as a strategy to deal with increasing uncertainties (Ozgur Arslan- Ayaydin et al., 2014). Therefore, a negative relation between uncertainty and leverage is expected according to all these theories (Rashid, 2013).[19]

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[18] We should note that the arguments regarding the relation between oil price and firm behavior is developed for oil-importing developing countries. For oil exporting countries, an increase in oil prices create additional funds and spillover effects that may have a positive impact on renewable energy investments. But, given that many developing countries are net oil-importers, we keep our focus on these countries.

[19] Yet, there is also ambiguity in the literature regarding the expected relation between lever- age and uncertainty. Colak et al. (2018) posits that firms delay capital structure adjustment as uncertainties increase;

- Firm financial constraints: The extent to which a firm is credit constrained can impact its response to an unfavorable turn in macroeconomic variables (Zhang et al., 2016a; Alter and Elekdag, 2020).[20] Hence, it can be argued that a firm will rely less on debt if it is financially constrained, and this will moderate the effect of macroeconomic variables on leverage rate (Korajczyk and Levy, 2003; Singh and Faircloth, 2005; Alter and Elekdag, 2020; Li et al., 2022).

Based on these arguments, we expect firms to prefer less leverage in the face of unfavorable macroeconomic conditions (e.g., increase in interest rate, decline in economic growth, depreciation of the domestic currency, increase in oil prices). We write the first set of hypotheses to be tested as follows:

- Hypothesis 1A: SMEs prefer less leverage as macroeconomic environment deteriorates.
- Hypothesis 1B: SMEs prefer less leverage as macroeconomic uncertainty increases.
- Hypothesis 1C: Financial constraints moderate the effect of macroeconomic variables on SMEs' leverage.

increasing volatility in macroeconomic factors will increase economic un- certainty, and the adjustment in the leverage will be slower. Hence, firms will compare the costs and benefits in capital structure adjustment, and the relation between the macroeconomic variables and leverage may not be negative in the short-term during volatile periods if adjustment costs exceed adjustment benefits.

[20] Finance literature also highlights that each firm has a target leverage that affects its capital structure choice (Colak et al., 2018). Since, our panel sample is relatively short, we assume this is a firm specific effect that can be considered constant for each firm during the analysis.

2.2.2 Debt Maturity

Table 2.2 The Impact of fundamental variables on firms' debt maturity according to the three-prominent theories in finance literature

Variable	Theoretical Foundation	Short-term Debt		Long-term Debt
Growth Opportunities	Agency Costs	Negative		Positive
Firm Size	Agency Costs	Negative		Positive
Tax Rate	Tax Hypothesis	Positive		Negative
Volatility in interest	Tax Hypothesis	Negative		Positive
Volatility in firm value	Tax Hypothesis	Negative		Positive
Fixed Assets	Maturity-matching	Negative		Positive
Source: Compiled by the authors through literature review				

The effects of various factors on debt maturity based on theoretical arguments and empirical findings are summarized in Table 2.2. In developing economies, the share of short-term debt in total liabilities is expected to grow as macroeconomic environment worsens, which makes long-term financing increasingly challenging to obtain. On the other hand, long-term financing is one of the policy instruments used by governments to support renewable energy technologies, and the diffusion of renewable energy reduces the risk premiums as highlighted earlier. Based on these arguments, the net effect will depend on which factor dominates and needs to be measured empirically.

2.2.3 Capital Expenditure/Asset Structure

The power sector is capital intensive, so the largest effect of macroeconomic variables is expected to be on capital expenditures (or fixed investments in general). Firm capital expenditures are determined by the difference between marginal benefit and marginal cost of capital. If macroeconomic variables affect future cash flows, profitability, and growth opportunities positively, then the marginal benefit of capital expenditure increases so there will be more investments. On the other hand, unfavorable macroeconomic conditions affect the risk-free rate, systematic and idiosyncratic risks, and the market return adversely, and this causes an increase in capital costs (Hou et al., 2021; Bloom, 2014). Besides, uncertainty can affect capital expenditures in varied ways, which are named as the real-option effect and the growth-option effect in the literature (Binding and Dibiasi, 2017). The former posits that if investments are irreversible, then increasing uncertainty makes investors more cautious, and adversely affects capital expenditures (Baum et al., 2001; Kim and Kung, 2017). Empirical studies support the real-option effect (Bloom, 2014; Binding and Dibiasi, 2017). However, there are also studies that argue if an investment is reversible, then firms may increase investments as a response to increasing uncertainty, supporting the growth-option effect of uncertainty (Irawan and Okimoto, 2021; Binding and Dibiasi, 2017).

Based on these arguments, we can conjecture that a downturn in the macroeconomic variables increases the cost of capital and reduces firm capital expenditures. Hence, the second set of hypotheses are written as follows:

- Hypothesis 2A: Capital expenditures of SMEs decrease as macroeconomic environment deteriorates.
- Hypothesis 2B: Capital expenditures of SMEs decrease as macroeconomic uncertainty increases.
- Hypothesis 2C: Firm financial constraints moderate the effect of macroeconomic variables on firm capital expenditures.

2.2.4 Financial Fragility

Finally, a firm's financial performance is determined by operational performance and financing conditions. While foreign currency denominated subsidies are good for profitability, when the domestic currency depreciates, firms have to cover O&M and financing costs which are in the foreign currency as well. Hence, the effect of currency depreciation on profitability depends on the net costs. An increase in oil price reduces profitability in non-oil sectors due to increasing costs and raw material prices. Additionally, worsening macroeconomic environment increases financing costs, reduce growth opportunities, and increase risks for companies. Based on these arguments, our third set of hypotheses are:

- Hypothesis 3A: Financial fragility of SMEs increases as macroeconomic environment deteriorates.
- Hypothesis 3B: Firm financial constraints moderate the effect of macroeconomic variables on firm financial fragility.

2.3 Background on the Turkish Electricity Market

Turkey started electricity market restructuring and liberalization with the enactment of the Electricity Market Law (EML) in 2001. In addition to allowing private investments, a wholesale electricity market consisting of day-ahead, intra- day, and balancing power markets was established. Following the initiation of the Renewable Energy Support Mechanism in 2007, renewable energy investors received feed-in tariff in

US dollars for ten years with bonus payments for domestically manufactured hardware.[21] By October 2021, licensed capacity has reached to 91 GW (34.5% hydro, 27.8% natural gas, 22% coal, 11% wind and 5% other), while this number was 7.5 GW for unlicensed capacity (92% solar, 7% biomass and CHP, and 1% wind and run-of river hydro) (EPDK, 2021). The Turkish power market is relatively unconcentrated, where SMEs (including the unlicensed generation) control approximately the one-fifth of the total operational capacity.

The effect of macroeconomic factors on stock market outcomes in Turkey have been a popular subject of academic studies. For example, Sari and Soytas (2006) investigate the effect of macroeconomic variables on the real stock market return using VAR Model and Impulse Response Analysis for 1987-2004 period. The authors conclude that interest rate affects stock market returns while oil price shocks do not have any statistically significant effect. Analyzing the dynamic correlation between the exchange rate, interest, and the stock market, Sensoy and Sobaci (2014) find that, contrary to the theoretical expectations, there is a positive dynamic correlation between the exchange rate and interest rate. Furthermore, they found a positive correlation between the stock market real return and the depreciation of the Turkish lira. This highlights Turkey's financial vulnerability to external macroeconomic shocks. Catık et al. (2020) studied how sector specific returns respond to oil price and exchange rate risks using state-space model. The authors argue that while there is heterogeneity in sectoral responses, transportation and electricity were the most negatively affected sectors from oil price and exchange rate

[21] Due to 2021 amendments, renewable energy investors will receive payments in Turkish Lira, going forward.

risks. However, these studies were on publicly traded firms, and did not include private companies in their analyses.

Figures 2.2 and 2.3 show the key performance indicators (leverage and profitability) of the median firm within the major sectors in Turkey. For leverage ratio $\left(\frac{Total\ debt}{Total\ assets}\right)$, we see an increasing stable trend over time for all sectors except for the power sector, which declined between 2011 to 2014, then increased significantly to almost 90%. For the median firm in the power sector, the long-term liability ratio $\left(\frac{Long-term\ debt}{Total\ liabilities+Equity}\right)$ doubled from 40% to 80% within a couple of years, while for the other sectors, it consistently ranged between 10% to 20%.

The power sector had negative profitability, $\left(\frac{Net\ profits}{Net\ sales}\right)$, for most of the period.

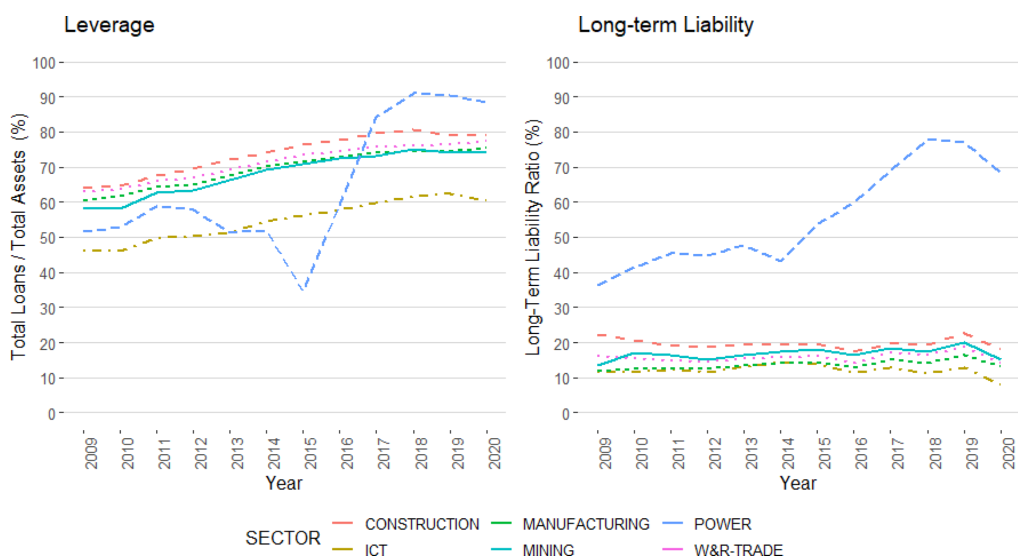

Figure 2.2 Median Firm leverage by sector (Source: CBT)

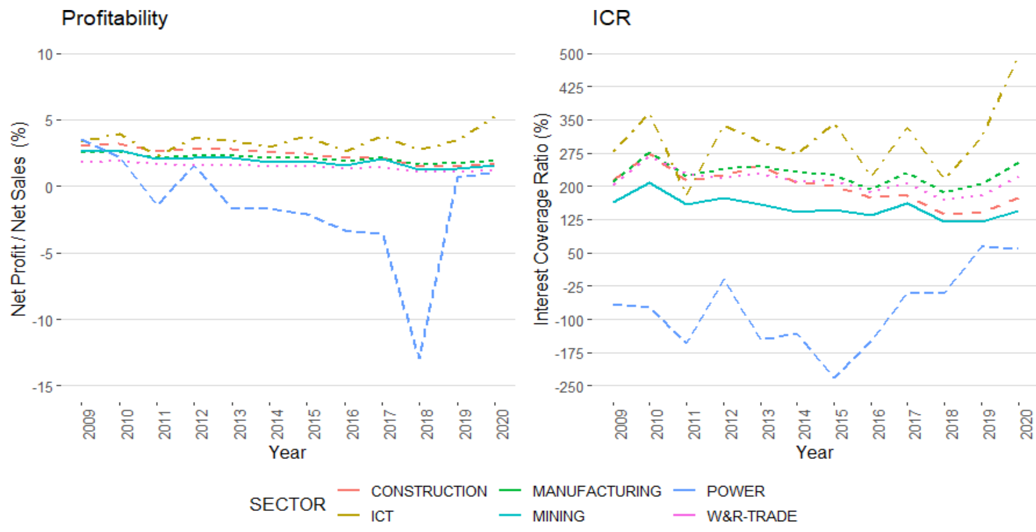

Figure 2.3 Median firm profitability by sector (Source: CBT)

Similarly, we see a negative interest coverage ratio for the power sector, while other sectors had positive ratios for the period. A likely explanation for this discrepancy is the increasing firm heterogeneity due to heightened interest in the sector as a response to the renewable energy policy. Additionally, unlike other sectors, energy investors were able to secure long-term loans and credits with lower interest rates due to less strict eligibility requirements, increasing their risk exposures.

In summary, the figures suggest that the power sector tends to follow a distinct financial pattern compared to the rest of the economy. Specifically, it is evident in these figures that the power sector is relatively more exposed to financial risks, and hence, may face major problems in case of a downturn in the macroeconomic environment.

2.4 Data and Methodology

2.4.1 Data

The data used in this paper are retrieved from the Central Bank of Turkey (CBT)-Real Sector Database, the Energy Exchange Istanbul (EXIST), and the Turkish Statistical Institute (TUIK).

The CBT database contains information on all tax-filing firms. Firms with negative or zero assets, non-operational firms, and firms with a single year of observation are excluded from the analysis. The CBT follows the Statistical Classification of Economic Activities in the European Community (NACE); which we follow in this paper (Eurostat, 2008). We include firms listed as engaging in “Pro- duction of electricity” (Section D, Group 35.11) and are classified as medium or smaller (assets ≤ 125M TL) according to NACE (TCMB, 2021), totaling 3,161 firms and 17506 firm-year observations for analysis. Data includes the fundamental financial indicators retrieved from firms’ balance sheet and income statements.

We utilize macroeconomic variables, electricity market indicators, and meteorological data as explanatory variables. Oil price refers to the Brent oil price obtained from BP (2021), adjusted using the US consumer price index. Interest rate is the one-year bond rate issued by the Turkish Treasury (i.e., risk-free rate). Given that stock market responds to factors that can affect firms’ financial performance, we use the annual volatility of the Istanbul Stock Exchange (XU100) as a proxy for the macroeconomic uncertainty.[22] In

[22] 10In this paper, we do not distinguish risk and uncertainty as separate constructs. Rather, we use volatility as a measure for risk and uncertainty combined as argued by (Bloom, 2014). Volatility can be modelled using geometric Brownian motion (GBM) as in investment analysis (Zhang et al., 2016b), or

addition, following recent studies (e.g., Alter and Elekdag, 2020; Banti and Bose, 2021), we use various indicator variables for the global macroeconomic environment: The first indicator variable marks the period between 2009-2013 when the Fed and other major central banks pursued quantitative easing policies as a response to 2008 financial crisis. The second indicator variable pertains to the period between 2014-2019 when the central banks followed relatively tightening monetary policies, known as the *taper tantrum episode* (Banti and Bose, 2021). Finally, the third indicator variable is for 2020, when the global pandemic hits the world economy. Summary statistics are presented in Table 2.3.

Table 2.3 Descriptive Statistics

	Unit	Mean	SD	Min	Max
Total Assets (log)	TL	14.519	1.966	6.290	20.550
Tangible Assets (log)	TL	13.377	2.622	6.211	19.882
ROA	TL	-.065	.262	-2.387	.828
Total Liability (log)	TL	14.172	2.393	.243	20.197
Real Int. Rate	(%)	.603	3.573	-3.200	6.860
Real Exc. Rate	TL/USD	1.253	.204	.850	1.500
Real MCP	TL/MWh	62.318	6.570	52.810	83.030
Real Oil Price	USD	53.795	18.663	34.200	104.390
Real GDP	(%)	3.516	2.795	-4.800	11.200
BIST Volatility		19.246	9.124	10.540	37.360
Renewable Share		10.442	3.992	.990	14.930
Market Progress		74.737	7.281	45.340	79.100
Temperature	°C	14.361	.531	12.800	15.100
Precipitation	mm	600.166	61.757	507.600	793.800
Leverage		.968	.541	.001	4.147
Long-term Debt Ratio		.479	.478	0.000	1.760
Short-term Debt Ratio		.484	.519	.001	3.815
N			17506		

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using time series methods (Jurado et al., 2015; Rashid, 2013). In this study, we follow Henriques and Sadorsky (2011), and use historical volatility (σ), which is measured as $\sigma = \sqrt{\frac{1}{N}\sum\left(r_t - E(r_t)\right)^2} * \sqrt{N}$ where is$r_t = 100 * \log\left(\frac{P_t}{P_{t-1}}\right)$ and P is the price of variable at time t and $t-1$ respectively.

Source: CBT, TUIK, EXIST, BP (2021)

2.4.2 Methodology

We analyze four different firm level outcomes: Leverage, debt maturity, investment, and solvency (bankruptcy risk). For each outcome, we use key macroeconomic variables as independent variables, and firm-level financial indicators, annual average electricity market price, and period indicators as control variables.

First, we analyze how macroeconomic variables affect firms' leverage rate using the base model shown in Equation 1.

$$\Delta L_{it} = \alpha_1 lnAssets_{it-1} + \alpha_2 lnTangAsset_{it-1} + \alpha_3 ROA_{it-1} + \alpha_4 MCP_t + \sum_{i=5}^{9} \alpha_i X_t + \alpha_{10} FinDistress_{it-1} + \alpha_{11} GME_t + \varepsilon_{it} \qquad (1)$$

The dependent variable is the change in leverage (ΔL) which is measured as the share of total liabilities to total liabilities plus equity. Asset, TangAsset, and ROA refer to total assets, tangible assets, and return on assets, respectively. Firms with larger amounts of total assets can use a variety financing options such as long-term debt or equity, whereas risk premiums and borrowing constraints are higher for small firms (Alter and Elekdag, 2020). Tangible assets, on the other hand, can be used for collateral which allows firms to lower financing costs. ROA is used as a proxy for profitability. We use the first lags of these variables to prevent any simultaneity problems. $lnMCP$ is the logged average day-ahead market clearing price of that year; X represents the vector of macroeconomic variables ($\Delta lnExcRatet$, $\Delta lnOilt, \Delta RealInt, RGDPt, BistVolt$). $lnExcRate$ and $lnOil$ are the log-return of the real exchange rate and oil price, respectively. $RGDP$ is the real

GDP growth rate, $RealInt$ is the real risk-free interest rate, and $BistVol$ is the volatility of the XU100 Index. GME represents the global macroeconomic period indicator and $FinDistress$ is the financial position of the firm at year t − 1 which is proxied by the interest coverage ratio (ICR) - the ratio of earnings before interest and taxes to interest expenses. Finally, ε is the random disturbance term.

The second analysis pertains to how firms' debt maturity response to change in macroeconomic variables as modeled in Equation 2. The dependent variable is the change in the long-term debt ratio $\left(\frac{Long-term\ debt}{Total\ liabilities+Equity}\right)$. The same set of explanatory variables

$$\Delta LTD_{it} = \beta_1 lnAssets_{it-1} + \beta_2 lnTangAssets_{it-1} + \beta_3 ROA_{it-1} + \beta_4 MCP_t + \sum_{i=5}^{9} \beta_i X_t + \beta_{10} GME_t + \alpha_{11} FinDistress_{it-1} + \rho_{it} \qquad (2)$$

In the third stage, we explore how firms' investments respond to the macroeconomic variables. We define net fixed assets as the book value of gross fixed assets minus depreciation, and we define investment as the change in net fixed assets ($\Delta INVit$). We use the base econometrics model shown in Equation 3 for estimation with the same set of explanatory variables used in previous models except for the total assets, which is replaced with total liability ($TotLiability$). This is due to the likely negative effect of increasing total liability on investment decisions.

$$\Delta INV_{it} = \omega_1 lnTotLiability_{it-1} + \omega_2 ROA_{it-1} + \omega_3 MCP_t + \sum_{i=4}^{8} \omega_i X_t + \omega_9 GME_t + \omega_{10} FinDistress_{it-1} + v_{it} \qquad (3)$$

Finally, we use two measures of firm financial position. The first one is the current ratio (CR) which is the ratio of current assets to current liabilities – a measure of short-term liquidity. The second measure is the modified version of the Altman Z-score (ZS) to analyze how the vulnerability (bankruptcy) of firms in response to the changes in macroeconomic variables as shown in Equation 5.[23] Decreasing Z-scores are associated with greater vulnerability, i.e., firms with low Z-scores are more likely to go bankrupt. Equations 4 and 5 present the models used for the analysis.

$$\Delta CR_{it} = \theta_1 lnAssets_{it-1} + \theta_2 lnTangAssets_{it-1} + \theta_3 ROA_{it-1} + \theta_4 \Delta lnMCP_t + \sum_{i=5}^{9} \theta_i X_t + \theta_{10} GME_t + \theta_{11} FinDistress_{it-1} + \eta_{it} \quad (4)$$

$$\Delta ZS_{it} = \varphi_1 lnAssets_{it-1} + \varphi_2 lnTangAssets_{it-1} + \varphi_3 ROA_{it-1} + \varphi_4 \Delta lnMCP_t + \sum_{i=5}^{9} \varphi_i X_t + \varphi_{10} GME_t + \varphi_{11} FinDistress_{it-1} + \psi_{it} \quad (5)$$

An important empirical challenge associated with estimating these econometric models is that firms may adjust their bids/generation strategies with respect to electricity market conditions. Hence, treating the MCP as an exogenous variable can potentially lead to an endogeneity problem caused by this simultaneous relation. We deal with this problem using an instrumental variables approach. We use the annual average temperature, annual precipitation, renewable energy share (the share of renewable capacity in total installed

[23] Following Bobinaite (2015), we calculate Altman Z-Score as $0.717 * WC + 0.847 * RE + 3.107 * EBIT + 0.42 * EQ + 0.995 * SA$ where WC is Working Capital, RE is Retained Earnings, $EBIT$ is Earnings before Interest and Taxes, E is Equity and SA is Sales. While $WC, RE, EBIT$ and SA are normalized using Total Assets , EQ is normalized using Total Liabilities.

capacity) and market progress (the share of total private installed capacity in total installed capacity) as instruments for market clearing price and we use IV-GMM estimator to estimate the coefficients. Table 2.4 summarizes the instruments used for each model. The analysis is conducted in Stata (Version 14) using *xtivreg2* module (Schaffer, 2005).

Table 2.4 List of variables used as an instrument for MCP in each model. L1: First lag

Model	Instrumental Variable
1	ΔTemp; Renewable Share (L1)
2	ΔPrecip; Renewable Share (L1)
3	ΔTemp; Market Progress (L1)
4	ΔPrecip; Market Progress (L1)
5	ΔTemp; ΔPrecip
6	ΔTemp; Renewable Share (L1)
7	ΔPrecip; Renewable Share (L1)
8	ΔTemp; ΔPrecip

All monetary values are in real terms (2003 = 100). We winsorize data at the 1^{st} and 99^{th} percentiles to eliminate outliers. The first difference of the real interest rate and the log-difference of the exchange rate, electricity market-clearing price, and oil price are used to deal with unit-root problem. Firm-level control variables are also in logarithmic form.

2.5 Results

2.5.1 Leverage

Table 2.5 presents model results for leverage dynamics shown in Equation 1. All macroeconomic variables, except for uncertainty measure (BISTVOL), have statistically significant coefficients in all models. In terms of firm-specific variables, asset size and tangible asset size do not have statistically significant coefficients, whereas previous term profitability has statistically significant positive effect, which is consistent with the trade-off theory. Furthermore, growth opportunities, which are associated with the increase in market-clearing price and real GDP growth rate, have negative and statistically significant coefficients, providing further support for the trade-off theory. Oil price and exchange rate have positive coefficients indicating that firms increase borrowing when there is an increase in exchange rate and oil prices. These results provide mixed support for Hypothesis 1A. Rather than affecting leverage at the same direction, macroeconomic variables have opposite effects on leverage decisions: While firms prefer higher leverage when domestic currency depreciates, oil price increases, or economy slows down, they prefer lower leverage when real interest rate increases.

We see a negative coefficient for uncertainty; however, it is not statistically significant. Hence, the data does not support Hypothesis 1B. We have negative statistically significant coefficients for the exchange rate and interest rate with the firm financial position. Financially constrained (lower ICR) firms prefer less debt when domestic currency depreciates or interest rate increases. While we do not have statistically significant coefficients for all interaction terms, this result shows a partial support for Hypothesis 1C, and firm financial constraints moderate the effect of some macroeconomic variables on firm leverage preferences. In addition, we see statistically significant negative coefficients for the global macroeconomic environment both for 2014-2019 period (MP_2) and the COVID-19 period (MP_3).

Table 2.5 Leverage Model Results

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
Dependent Variable: ΔL (Leverage)								
lnAsset (L1)	0.00295	0.00242	0.00314	0.000814	0.0028	0.00264	0.00216	0.00251
lnTang (L1)	0.00287	0.00308	0.00273	0.00355	0.00297	0.00305	0.00325	0.00314
ROA (L1)	0.285***	0.285***	0.283***	0.284***	0.285***	0.288***	0.288***	0.289***
ΔMCP	-0.0393**	-0.0339**	-0.0399**	-0.0147***	-0.0384**	-0.0375**	-0.0324**	-0.0366**
$\Delta EXRATE$	0.0150**	0.0128**	0.0152**	0.00493*	0.0147**	0.0162**	0.0141**	0.0158**
ΔOIL	0.0135**	0.0116**	0.0137**	0.00495***	0.0132**	0.0128**	0.0111**	0.0125**
$\Delta REALINT$	-0.0348***	-0.0313***	-0.0352***	-0.0191***	-0.0342***	-0.0321***	-0.0289***	-0.0315***
REALGDP	-0.119**	-0.104***	-0.121**	-0.0500***	-0.117**	-0.112**	-0.0979**	-0.110**
BISTVOL	-0.0046	-0.00347	-0.0047	0.000751	-0.0045	-0.00409	-0.003	-0.00392
FinDistress (L1)	0.0186*	0.0186*	0.0188*	0.0188*	0.0185*	0.0573*	0.0562*	0.0567*
MP 2	-0.191*	-0.161*	-0.194*	-0.056	-0.186*	-0.179*	-0.151*	-0.174*
MP 3	-0.555***	-0.514***	-0.560***	-0.370***	-0.548***	-0.540***	-0.502***	-0.533***
ExcRate (Int)						-0.00396*	-0.00383*	-0.0039*
Oil (Int)						0.0000272	0.0000123	0.0000228
RealInt(Int)						-0.00295*	-0.00285	-0.00291*
GDP (Int)						-0.00346	-0.00344	-0.00342
N	11252	11252	11252	11252	11252	11252	11252	11252
RMSE	0.306	0.305	0.306	0.305	0.306	0.305	0.305	0.305
Clustered SE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
IV	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Under-identification	Satisfied	Satisfied	Satisfied	Satisfied	Satisfied	Satisfied	Satisfied	Satisfied
Weak-Identification	Satisfied	Satisfied	Satisfied	Satisfied	Satisfied	Satisfied	Satisfied	Satisfied
Over-Identification	Satisfied	Satisfied	Satisfied	Satisfied	Satisfied	Satisfied	Satisfied	Satisfied

L1: First Lag; Int: Interaction with Financial Distress

* p <0.05, ** p <0.01, *** p <0.001

2.5.2 Debt Maturity

Table 2.6 presents results for debt maturity shown in Equation 2. Similar to previous results, we only have statistically significant and positive coefficient for the previous year's profitability among firm-specific variables, which indicates more profitable firms prefer longer-term debt. For the macroeconomic variables, we see similar signs as previous analysis: Exchange rate and oil price have statistically significant positive coefficients, whereas real interest and real GDP growth rate have negative statistically significant coefficients. In this respect, we can argue that firms' long-term debt preference also follows a similar pattern with the over- all debt preference, suggesting a positive correlation between overall leverage and debt maturity outcomes. So, we can argue that the level effect of macroeconomic variables drives the maturity preferences despite the provision of long-term, low-cost loans for renewable energy investments by the government. On the other hand, the coefficient for macroeconomic uncertainty was not statistically significant, which might be attributable to the availability of long-term subsidies for renewable energy investments. Contrary to the overall leverage rate, firm financial constraints do not moderate the effect of macroeconomic variables on debt maturity. The global macroeconomic environment has the same effect on debt maturity as the leverage rate, and firms prefer long-term debt less as global macroeconomic conditions worsen.

To summarize, we found that the effect of macroeconomic variables is in the same direction on firms' leverage and debt maturity preferences. While we have statistically significant balance sheet effect of macroeconomic variables, their effects differ: exchange rate and oil price have positive effects on leverage and long-term debt preference, whereas growth and interest rate have negative effects.

These results imply the trade-off and market timing theories provide coherent theoretical lenses to analyze the dynamics between macroeconomic variables and debt preferences of SMEs in the Turkish power sector.

Table 2.6 Debt Maturity Model Results

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
Dependent Variable: Δ*LTD* (Long-term Debt ratio)								
lnAsset (L1)	-0.0146	-0.0149*	-0.0146	-0.0162*	-0.0146	-0.0147	-0.0144	-0.0144
lnTang (L1)	-0.0045	-0.0044	-0.0045	-0.004	-0.0045	-0.0044	-0.0045	-0.0045
ROA (L1)	0.0790***	0.0790***	0.0787***	0.0781**	0.0792***	0.0790***	0.0791***	0.0792***
Δ*MCP*	-0.0245**	-0.0200**	-0.0249**	-0.0039	-0.0237**	-0.0196**	-0.0240**	-0.0232**
Δ*EXRATE*	0.0104**	0.00855**	0.0106**	0.00195	0.0101**	0.00830**	0.0102**	0.00985**
Δ*OIL*	0.00851**	0.00694**	0.00865**	0.00137	0.00826**	0.00671**	0.00823**	0.00798**
Δ*REALINT*	-0.0231***	-0.0202***	-0.0234***	-0.0100***	-0.0226***	-0.0196***	-0.0224***	-0.0220***
REALGDP	-0.0750**	-0.0623**	-0.0762**	-0.0173*	-0.0729**	-0.0600**	-0.0724**	-0.0703**
BISTVOL	-0.0036	-0.0026	-0.0037	0.00097	-0.0034	-0.0025	-0.0035	-0.0033
FinDistress (L1)	0.0115	0.0116	0.0114	0.0118	0.0115	0.0202	0.0208	0.0206
MP 2	-0.153**	-0.128**	-0.155**	-0.0395	-0.148**	-0.127**	-0.151**	-0.147**
MP 3	-0.437***	-0.402***	-0.441***	-0.282***	-0.431***	-0.400***	-0.434***	-0.428***
ExcRate (Int)						0.00034	0.00026	0.00028
Oil (Int)						0.00017	0.00018	0.00018
RealInt (Int)						-0.0007	-0.0008	-0.0008
GDP (Int)						-0.0027	-0.0027	-0.0027
N	11252	11252	11252	11252	11252	11252	11252	11252
RMSE	0.252	0.252	0.252	0.252	0.252	0.252	0.252	0.252
Clustered SE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
IV	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Under-identification	Satisfied	Satisfied	Satisfied	Satisfied	Satisfied	Satisfied	Satisfied	Satisfied
Weak-Identification	Satisfied	Satisfied	Satisfied	Satisfied	Satisfied	Satisfied	Satisfied	Satisfied
Over-Identification	Satisfied	Satisfied	Satisfied	Satisfied	Satisfied	Satisfied	Satisfied	Satisfied

L1: First Lag; Int: Interaction with Financial Distress

*p<0.05, ** p<0.01, *** p < 0.001

2.5.3 Investment

Table 2.7 presents the results for investment outcomes shown in Equation 3. While some coefficients have similar signs with the previous models, there are also some major differences. First of all, we see negative statistically significant coefficient for macroeconomic uncertainty in all models, highlighting the adverse effect of uncertainty on investment decisions. Second, the exchange rate and real GDP growth do not have statistically significant coefficients, whereas interest rate, firm financial constraints, firm total liability, previous period profitability, market clearing price and global macroeconomic environment have negative statistically significant effects. While most of these coefficients are consistent with the theory and previous empirical research, the negative effect of previous term profitability and market clearing price on investment seems counter-intuitive. There might be two potential explanation i) SMEs may prioritize short-term profitability over expanding their asset base which pays off in the longer term, ii) expanding beyond a certain threshold of capacity comes with different legal and regulatory responsibilities which the power sector SMEs may not have sufficient resources to meet. Third, oil price has a positive statistically significant coefficient, while the inter- action term is negative. Increasing oil prices also make renewable energy projects feasible alternative for investors, so the positive coefficient indicates the substitution effect between oil and renewable energy technologies. On the other hand, oil price can also be considered as a proxy for the global commodity markets, so the negative interaction term may indicate the negative effect of rising global commodity prices on financially constrained firms' investment decisions.

These results present partial support for Hypothesis 2A. There is no statistically significant effect of the exchange rate and real GDP growth on firms' fixed investments, whereas there is statistically significant effect of interest rate on in- vestment decisions consistent with the hypothesis. Similarly, the negative effect of uncertainty on investment provides support for Hypothesis 2B. We also have partial support for Hypothesis 2C. One notable result is the negative effect of previous term profitability on investment outcome, which supports our previous conjecture that the SMEs have predominantly shorter-term profitability focus rather than long-term expansion goals.

Table 2.7 Investment Model Results

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
Dependent Variable: ΔINV (Investment)								
lnLiability (L1)	-0.244***	-0.244***	-0.244***	-0.244***	-0.243***	-0.244***	-0.244***	-0.244***
ROA (L1)	-0.414***	-0.415***	-0.414***	-0.417***	-0.414***	-0.412***	-0.411***	-0.411***
Δ*MCP*	-0.0586*	-0.0494*	-0.0628*	-0.0228*	-0.0557	-0.0517*	-0.0613*	-0.0585*
Δ*EXRATE*	0.0213	0.0175	0.023	0.0065	0.0201	0.0169	0.021	0.0198
Δ*OIL*	0.0200*	0.0168*	0.0214*	0.00753*	0.019	0.0184*	0.0218*	0.0208*
Δ*REALINT*	-0.0452*	-0.0393*	-0.0479*	-0.0225**	-0.0433*	-0.0409**	-0.0470**	-0.0452**
REALGDP	-0.146	-0.121	-0.158	-0.046	-0.138	-0.126	-0.153	-0.145
BISTVOL	-0.0203**	-0.0183**	-0.0211**	-0.0125***	-0.0196**	-0.0191***	-0.0212**	-0.0206**
FinDistress (L1)	-0.0611***	-0.0607***	-0.0619***	-0.0604***	-0.0608***	-0.0796	-0.0786	-0.0787
MP 2	-0.400*	-0.347*	-0.427*	-0.202**	-0.382*	-0.363*	-0.418*	-0.401*
MP 3	-0.535*	-0.462*	-0.573*	-0.262*	-0.510*	-0.459*	-0.536*	-0.511*
ExcRate (Int)						0.00268	0.00253	0.00256
Oil (Int)						-0.00173**	-0.00170**	-0.00171**
RealInt (Int)						0.00058	0.00046	0.00049
GDP (Int)						-0.0037	-0.0037	-0.0037
N	12071	12071	12071	12071	12071	12071	12071	12071
RMSE	0.639	0.639	0.639	0.638	0.639	0.638	0.639	0.638
Clustered SE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
IV	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Under-identification	Satisfied	Satisfied	Satisfied	Satisfied	Satisfied	Satisfied	Satisfied	Satisfied
Weak-Identification	Satisfied	Satisfied	Satisfied	Satisfied	Satisfied	Satisfied	Satisfied	Satisfied
Over-Identification	Satisfied	Satisfied	Satisfied	Satisfied	Satisfied	Satisfied	Satisfied	Satisfied

L1: First Lag; Int: Interaction with Financial Distress

* p <0.05, ** p <0.01, *** p <0.001

2.5.4 Financial Performance

Table 2.8 presents the results for firms' short-term ability to cover short-term obligations shown in Equation 4. While firm-specific variables are statistically in-significant, the exchange rate and oil price have negative effects on the current ratio, suggesting an increase in these variables increase current liabilities or decrease current assets. On the other hand, market-clearing price and real GDP growth have positive significant effects, indicating a positive contribution to the firms' short-term financial position. A notable result is the positive effect of interest rate, uncertainty, and global macroeconomic environment indicators on firms' current ratios. While an increase in interest rate and uncertainty indicates adverse eco- nomic conditions, the results suggest that firms prefer more liquid assets, or they reduce their current liabilities during financially difficult times. The positive coefficient of the global macroeconomic environment also supports this argument that firms are more likely to hold liquid assets or reduce current liabilities as a response to a macroeconomic downturn.

Table 2.8 Current Ratio model results

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
Dependent Variable: ΔCR (Current Ratio)								
lnAsset (L1)	-0.123	-0.0897	-0.0772	0.1	-0.134	-0.129	-0.0915	-0.134
lnTang (L1)	0.485	0.463	0.483	0.404	0.477	0.484	0.459	0.473
ROA (L1)	-1.049	-0.968	-1.102	-0.83	-1	-1.167	-1.084	-1.116
Δ*MCP*	3.995***	3.470***	3.762***	1.198***	4.004***	3.908***	3.388***	3.895***
Δ*EXRATE*	-1.564**	-1.353**	-1.457**	-0.417**	-1.572**	-1.650**	-1.437**	-1.650**
Δ*OIL*	-1.392***	-1.209***	-1.310***	-0.420***	-1.395***	-1.343***	-1.163***	-1.339***
Δ*REALINT*	2.728***	2.390***	2.590***	0.945***	2.729***	2.555***	2.224***	2.543***
REALGDP	11.37***	9.892***	10.71***	3.512***	11.39***	11.03***	9.570***	10.99***
BISTVOL	0.976***	0.857***	0.927**	0.355**	0.975***	0.945**	0.828**	0.939***
FinDistress (L1)	-0.438	-0.468	-0.384	-0.504	-0.459	-2.708	-2.679	-2.732
MP 2	22.94***	20.10***	21.60***	7.608***	23.03***	22.41***	19.59***	22.37***
MP 3	31.61***	27.71***	29.89***	10.60**	31.73***	31.18***	27.30***	31.13***
ExcRate (Int)						0.232	0.228	0.237
Oil (Int)						-0.0292	-0.0282	-0.0294
RealInt (Int)						0.246*	0.242*	0.248*
GDP (Int)						0.146	0.142	0.14
N	11211	11211	11211	11211	11211	11211	11211	11211
RMSE	22.26	22.22	22.24	22.1	22.27	22.25	22.2	22.24
Clustered SE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
IV	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Under-identification	Satisfied	Satisfied	Satisfied	Satisfied	Satisfied	Satisfied	Satisfied	Satisfied
Weak-Identification	Satisfied	Satisfied	Satisfied	Satisfied	Satisfied	Satisfied	Satisfied	Satisfied
Over-Identification	Satisfied	Satisfied	Satisfied	Satisfied	Satisfied	Satisfied	Satisfied	Satisfied

L1: First Lag; Int: Interaction with Financial Distress

* p <0.05, ** p <0.01, *** p <0.001

Finally, Table 2.9 presents the results for the bankruptcy risk model shown in Equation 5. Compared with Table 2.8, we see the same signs for the macroeconomic variables with statistically significant coefficients. Similar to short-term financial position, exchange rate and oil price have negative coefficients– an increase in these variables increase the bankruptcy risk of firms. On the other hand, an increase in the real interest rate and market uncertainty has a positive contribution to the Z-score. While this is the opposite of the prior expectations, we can argue that an increase in these variables makes firms hold liquid assets, limit borrowing, and refrain from new capital investments. Hence, firms take measures to limit their bankruptcy risks when economic uncertainty increases, and the model result is consistent with the previous model's outcome. The positive coefficients of the global macroeconomic environment indicators also support this argument: we see a positive change in the Z-score on average since 2014. Firm financial constraint has a negative coefficient, but it is statistically insignificant. Similarly, the interaction terms have statistically insignificant coefficients. Hence, we do not have any supporting evidence regarding the moderating effect of firm financial conditions on firm bankruptcy risk.

Based on these results, we have partial evidence for Hypothesis 3A; an increase in exchange rate or oil price harms firm financial position and increase bankruptcy risk. On the other hand, an increase in real GDP growth improves firm financial position. The real interest rate and economic uncertainty have the opposite of the expected signs. A possible explanation for these results is the change in firms' behavior. Under increasing uncertainty, firms may take measures such as refraining from new investments, holding more liquid assets, or borrowing less to improve their financial positions. Similar to the investment dynamics, we have a negative coefficient for the previous term profitability.

Table 2.9 Bankruptcy model results

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
Dependent Variable: ΔZS (Z-score)								
lnAsset (L1)	1.021**	1.039**	1.030**	1.127**	1.018**	1.015**	1.032**	1.013**
lnTang (L1)	-0.22	-0.23	-0.216	-0.257	-0.224	-0.22	-0.23	-0.223
ROA (L1)	-4.228***	-4.214***	-4.213***	-4.152***	-4.228***	-4.236***	-4.219***	-4.234***
Δ*MCP*	1.938**	1.667**	1.906**	0.613**	1.916**	1.884**	1.622**	1.855**
Δ*EXRATE*	-0.758*	-0.647*	-0.743*	-0.213*	-0.749*	-0.789*	-0.679*	-0.777*
Δ*OIL*	-0.666**	-0.572**	-0.655*	-0.206**	-0.658**	-0.635*	-0.544*	-0.625*
Δ*REALINT*	1.337**	1.166**	1.319**	0.496***	1.324**	1.265**	1.101**	1.248**
REALGDP	5.544**	4.787**	5.453**	1.828**	5.486**	5.359**	4.627**	5.281**
BISTVOL	0.496**	0.434**	0.493**	0.202*	0.489**	0.477**	0.417**	0.468**
FinDistress (L1)	-0.135	-0.14	-0.129	-0.155	-0.137	-1.138	-1.115	-1.14
MP 2	11.52**	10.04**	11.34**	4.246**	11.40**	11.18**	9.751**	11.03**
MP 3	16.18**	14.21**	15.86**	6.279**	16.09**	16.05**	14.14**	15.90**
ExcRate (Int)						0.1	0.0962	0.1
Oil (Int)						-0.0219	-0.0214	-0.022
RealInt (Int)						0.0802	0.0774	0.0804
GDP (Int)						0.0469	0.0477	0.0468
N	11225	11225	11225	11225	11225	11225	11225	11225
RMSE	12.23	12.21	12.23	12.16	12.23	12.22	12.2	12.22
Clustered SE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
IV	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Under-identification	Satisfied	Satisfied	Satisfied	Satisfied	Satisfied	Satisfied	Satisfied	Satisfied
Weak-Identification	Satisfied	Satisfied	Satisfied	Satisfied	Satisfied	Satisfied	Satisfied	Satisfied
Over-Identification	Satisfied	Satisfied	Satisfied	Satisfied	Satisfied	Satisfied	Satisfied	Satisfied

L1: First Lag; Int: Interaction with Financial Distress

* p <0.05, ** p <0.01, *** p <0.001

2.5.5 Robustness Checks

We ran the same analyses using alternative macroeconomic variables. We replaced USD with EUR (Euro), Brent Oil Price with West Texas Intermediate Price, Turkish Treasury 1-year bond rate with Turkish Treasury 5-year bond rate, the volatility of XU100 (BIST 100) Index with XU030 (BIST 30) Manufacturing Index and we use the Current Ratio as an indicator of financial distress instead of the Interest Coverage Ratio. The results are shown in Tables A1, A2, A3 and A4 in the Appendix, respectively. The results and coefficients for the new variables are both qualitatively and quantitatively very similar to the original analyses.

2.6 Policy Implications and Conclusion

The majority of the global energy demand expansion will come from developing economies where the transition to renewable technologies can be hindered by the additional vulnerability due to macroeconomic factors and risks caused by climate change. Government support mechanisms, low-cost financing offered via international organizations, and accommodative monetary policies have arguably stimulated renewable energy investments in these regions. However, many investors in these countries have to import most of their equipment, have higher financing costs, and rely on leverage for their investments. As a result, they become more vulnerable to macroeconomic risks and the energy transition can result in growing liabilities and further exposure to macroeconomic risks.

In this paper, we explored the investment and financial performance of SMEs within a developing country setting. SMEs tend to account for a sizeable share of the overall power supply in developing economies. Furthermore, SMEs play an important role in the adoption of distributed energy technologies and smart-grid applications. Hence, how the macroeconomic factors impact their financial performance has important implications for renewable energy growth, economic development, and the just distribution of the costs and benefits of the energy transition. We examined the financial performance of the SMEs in the Turkish power sector, and our results indicate that unfavorable macroeconomic conditions lead to a significant growth in liabilities and bankruptcy risk within the power sector while their investment slows down despite the prevalence of subsidies. Our findings are consistent with the theory and previous empirical studies, and SMEs respond to macroeconomic dynamics similar to large/public companies to a great extent. Furthermore, our study highlights that the exchange rate is still an important factor for SMEs' financial performance even if subsidies denominated in foreign currency are provided. We also find negative effects of the previous term profitability and market clearing price on power sector SMEs' investment decisions. Higher previous term profitability and higher market price lead to higher investments in large companies as discussed in the literature, but we observe a negative relation in our analysis. We can argue that this may be related to SMEs' priorities or aspirations. SMEs may prioritize profitability over expanding their asset base, and they may refrain from new investments that can adversely affect their profitability in the longer term.

Our findings offer the following insights for the formulation of a well-rounded renewable energy policy in developing economies:

- Renewable energy subsidies are important, but the macroeconomic environment still matters: Renewable energy policies in many developing economies focus on the diffusion of these technologies through creating demand (e.g., grid-access priority) or reducing investment costs (e.g., subsidies or low cost, long-term finance options). However, this alone may not be enough to achieve the energy transition. Our analyses have shown that even if subsidies denominated in foreign currencies and purchase guarantees are provided to reduce market risks, negative macroeconomic dynamics affect investments adversely. Consistent with the earlier studies, our findings indicate that a stable macroeconomic environment is necessary to support the energy transition. Therefore, policies supporting the energy transition should also consider the implications of changing macroeconomic environment on the power sector.
- Regulators and policymakers should pay attention to the growing liabilities: Investors are more likely to underestimate the risks in investment decisions when industries are growing. Furthermore, due to the concerns regarding insufficient funds to support the energy transition (Campiglio, 2016), governments have initiated various credit and loan programs for renewable energy investments. On the other hand, cheaper financing for renewable energy technologies is more likely to distort investors' risk perceptions, leading to risk underestimation or over-investment. As we have shown, the liabilities of the power sector have increased significantly in Turkey, and this can jeopardize the financial sustainability of the SMEs in the face of a down- turn in the macroeconomic variables. In this respect, regulatory authorities should monitor risks and financial

performance in the power sector and develop contingency plans. Further measures to help SMEs for risk management and de-risking (such as credit enhancement, targeted insurance, etc.) can also be used to support renewable energy investments (IEA, 2022).

- New business models are needed for the grid-parity era: Renewable energy technologies have benefited from various support schemes, and this fostered investments dramatically. However, such subsidies are in conflict with the competitive electricity market logic, and many countries have reduced or revoked financial subsidies to these technologies due to increasing financial burden on the consumers. Contrary to large firms, SMEs rely heavily on such subsidies, and they have limited capacity to manage/hedge market risks. Therefore, new business models (such as virtual power plants or aggregators) might emerge as an alternative way to provide a stable revenue stream for small-scale investors while not jeopardizing competitive electricity market dynamics in the grid-parity era. Developing business models for renewable energy technologies is currently an active research area in the literature, and various models are being implemented in different jurisdictions. Policymakers and regulators in developing economies should also develop a regulatory framework that allows new business models within a competitive market context.

Overall, sustainable growth in renewable energy investments in the developing regions is crucial for achieving ambitious climate goals. While this study offers important insights from Turkey, further research exploring the relation between the energy transition and macroeconomic dynamics in other developing countries is needed.

Acknowledgement

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Appendix A. Robustness Checks

A 1 Leverage Robustness Model Results

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
Dependent Variable: Δ*L* (Leverage)								
lnAsset (L1)	-0.0001	0.00015	-0.0006	0.00017	-0.0013	-0.0009	-0.0009	-0.0026
lnTang (L1)	0.00862	0.00851	0.00928	0.00847	0.00914	0.00881	0.00869	0.00942
ROA (L1)	0.264***	0.262***	0.243***	0.263***	0.230***	0.269***	0.266***	0.234***
Δ*MCP*	-0.0403**	-0.0107**	-0.0265***	-0.0103*	-0.0178***	-0.0408**	-0.0103*	-0.0175***
Δ*EXRATE*	0.0195**	0.00427	0.0121***	0.00411	0.00786**	0.0198**	0.00476*	0.00822***
Δ*OIL*	0.00830**	0.00220*	0.00558***	0.00212*	0.00376***	0.00795**	0.00156	0.00314**
Δ*REALINT*	-0.0296***	-0.0151***	-0.0227***	-0.0150***	-0.0183***	-0.0309***	-0.0150***	-0.0181***
REALGDP	-0.0971***	-0.0310**	-0.0657***	-0.0302**	-0.0462***	-0.0996***	-0.0304**	-0.0459***
BIST30VOL	-0.00994*	0.00066	-0.0042	0.00074	-0.0011	-0.01000*	0.00093	-0.0008
FinDistress (L1)	-0.0938***	-0.0931***	-0.0939***	-0.0931***	-0.0939***	-0.0900*	-0.0599	-0.0648
MP 2	-0.299**	-0.0625	-0.178***	-0.0603	-0.109*	-0.302**	-0.058	-0.104*
MP 3	-0.817***	-0.332***	-0.576***	-0.328***	-0.435***	-0.821***	-0.323***	-0.424***
ExcRate (Int)						-0.0002	-0.0014	-0.0012
Oil (Int)						0.00078	0.00105*	0.00107*
RealInt (Int)						0.00186	5.40E-05	-7.00E-05
GDP (Int)						0.00256	0.00028	0.00074
N	11252	11252	11252	11252	11252	11252	11252	11252
RMSE	0.304	0.303	0.304	0.303	0.303	0.304	0.303	0.303

L1: First Lag; Int: Interaction with Financial Distress

* p <0.05, ** p <0.01, *** p <0.001

EXTRATE: TL/Euro; OIL: West Texas Intermediate; REALINT: Turkish Treasury 5-year bond rate; BIST30Vol: XU30 Index

FinDistress: Quick Ratio

A 2 Debt Maturity Robustness Model Results

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
Dependent Variable: Δ*LTD*								
lnAsset (L1)	-0.0131	-0.0128	-0.0128	-0.0128	-0.0129	-0.0116	-0.0118	-0.0119
lnTang (L1)	-0.00931*	-0.00942*	-0.00922*	-0.00943*	-0.00915*	-0.00974*	-0.00964*	-0.00945*
ROA (L1)	0.101***	0.101***	0.100***	0.101***	0.0997***	0.0982***	0.0982***	0.0973***
Δ*MCP*	-0.0159	-0.00723**	-0.0076	-0.00717**	-0.00693*	-0.00767**	-0.0164	-0.00710*
Δ*EXRATE*	0.00835*	0.00404**	0.00425	0.00400**	0.00388*	0.00356**	0.00778	0.00330*
Δ*OIL*	0.00313	0.00131*	0.00139	0.00129*	0.00125	0.00168**	0.00355	0.00155*
Δ*REALINT*	-0.0150***	-0.0107***	-0.0109***	-0.0106***	-0.0106***	-0.0124***	-0.0170***	-0.0122***
REALGDP	-0.0394*	-0.0201***	-0.0211*	-0.0199***	-0.0195**	-0.0172**	-0.0369	-0.0160*
BIST30VOL	-0.0032	-0.0003	-0.0005	-0.0003	-0.0003	-0.0009	-0.0038	-0.0008
FinDistress (L1)	0.122***	0.123***	0.123***	0.123***	0.123***	0.119***	0.112***	0.121***
MP 2	-0.147*	-0.0800***	-0.0830*	-0.0795***	-0.0773**	-0.0870***	-0.154*	-0.0820**
MP 3	-0.456***	-0.317***	-0.322***	-0.316***	-0.311***	-0.330***	-0.471***	-0.320***
ExcRate (Int)						0.0015	0.00177	0.00141
Oil (Int)						-0.000611*	-0.000679*	-0.000594*
RealInt (Int)						0.00208	0.00248	0.002
GDP (Int)						-0.00686*	-0.00638*	-0.00689*
N	11252	11252	11252	11252	11252	11252	11252	11252
RMSE	0.248	0.248	0.248	0.248	0.248	0.248	0.248	0.248

L1: First Lag; Int: Interaction with Financial Distress

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

EXRATE: TL/EUR; OIL:West Texas Intermediate; REALINT: Turkish Treasury 5-year bond rate; BIST30VOL: BIST 30 INDEX FinDistress: Quick Ratio

A 3 Bankruptcy Model Results

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
Dependent Variable: Δ*INV*								
lnLiability (L1)	-0.245***	-0.243***	-0.241***	-0.243***	-0.242***	-0.245***	-0.246***	-0.244***
ROA (L1)	-0.414***	-0.416***	-0.415***	-0.415***	-0.413***	-0.412***	-0.411***	-0.409***
Δ*MCP*	-0.0812**	-0.0057	-0.0155	-0.005	-0.0075	-0.0049	-0.0805**	-0.0068
Δ*EXRATE*	0.0378*	-0.0002	0.00464	-0.0005	0.00053	0.00102	0.0381**	0.00202
Δ*OIL*	0.0176**	0.00177	0.00378	0.00163	0.00202	0.00192	0.0180**	0.00215
Δ*REALINT*	-0.0459**	-0.0093	-0.0153*	-0.0089	-0.0119	-0.0072	-0.0454**	-0.0094
REALGDP	-0.163*	0.00501	-0.0183	0.00658	-0.001	-0.0049	-0.174**	-0.0115
BIST30VOL	-0.0298**	-0.0051	-0.0093	-0.0048	-0.0069	-0.0042	-0.0291**	-0.006
FinDistress (L1)	-0.0099	-0.0073	-0.0064	-0.0073	-0.0056	-0.0373	-0.0837	-0.0289
MP 2	-0.667**	-0.0789	-0.15	-0.0743	-0.0866	-0.068	-0.660**	-0.0764
MP 3	-1.386**	-0.168	-0.328	-0.158	-0.204	-0.15	-1.372**	-0.187
ExcRate (Int)						-0.0032	-0.0012	-0.0036
Oil (Int)						-0.0003	-0.0008	-0.0002
RealInt (Int)						-0.0024	0.00043	-0.0031
GDP (Int)						0.0208*	0.0226*	0.0212*
N	12071	12071	12071	12071	12071	12071	12071	12071
RMSE	0.642	0.639	0.639	0.639	0.639	0.638	0.641	0.638

L1: First Lag; Int: Interaction with Financial Distress

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

EXRATE: TL/EUR; OIL:West Texas Intermediate; REALINT: Turkish Treasury 5-year bond rate; BIST30VOL: BIST 30 INDEX FinDistress: Quick Ratio

A 4 Bankruptcy Robustness Model Results

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
Dependent Variable: $\Delta Z - Score$								
lnAsset (L1)	1.877**	1.912**	2.007**	1.907**	2.080**	1.870**	1.918**	2.093**
lnTang (L1)	-0.537	-0.552	-0.652*	-0.545	-0.677*	-0.543	-0.555	-0.679*
ROA (L1)	-3.607**	-3.731**	-3.620**	-3.735**	-3.563**	-3.619**	-3.762**	-3.600**
ΔMCP	3.142**	0.507	1.077	0.486	0.52	3.196**	0.51	0.515
$\Delta EXRATE$	-1.525**	-0.202	-0.483	-0.192	-0.197	-1.499*	-0.195	-0.199
ΔOIL	-0.676**	-0.118	-0.239	-0.114	-0.124	-0.703**	-0.122	-0.124
$\Delta REALINT$	1.647**	0.382*	0.677	0.369	0.405	1.782**	0.424	0.433
REALGDP	7.072**	1.235	2.514	1.186	1.27	7.347**	1.297	1.301
BIST30VOL	1.064*	0.184	0.378	0.176	0.185	1.086*	0.185	0.182
FinDistress (L1)	2.907***	2.795***	2.641***	2.803***	2.506***	5.913	3.519	2.782
MP 2	23.77**	3.898	8.577	3.708	4.322	24.28**	3.937	4.264
MP 3	50.85**	9.458	18.91	9.08	9.946	51.85**	9.528	9.816
ExcRate (Int)						-0.105	-0.0196	0.00193
Oil (Int)						0.031	0.00679	0.0018
RealInt (Int)						-0.193	-0.0731	-0.0602
GDP (Int)						-0.272	-0.1	-0.0904
N	11252	11252	11252	11252	11252	11252	11252	11252
RMSE	21.42	21.3	21.31	21.3	21.3	21.42	21.3	21.3

L1: First Lag; Int: Interaction with Financial Distress

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

EXRATE: TL/EUR; OIL:West Texas Intermediate; REALINT: Turkish Treasury 5-year bond rate; BIST30VOL: BIST 30 INDEX FinDistress: Quick Ratio

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Chapter 3: Should Children Listen to their Parents' Investment Advice?

Abstract

This study investigates the impact of intergenerational advice on investment behavior in an experimental setting. We explore the effects of positive and negative advice from one generation to the next on asset allocation decisions. Results indicate that the transmission of advice can significantly influence investment behavior, as participants who received positive advice allocated a higher proportion of their portfolio to risky assets. The transmission of advice to allocations appears to be through participants forming more optimistic beliefs about future returns rather than any change in their risk preferences. Even when challenged by a significant downturn, the group that received positive advice continued to hold optimistic beliefs. The study also challenges the assumptions of modern portfolio theory and suggests that inexperienced investors may be more influenced by the advice of previous generations.

3.1 Introduction

The investment decisions we make are shaped not only by our personal experiences and knowledge, but also by the advice we receive from others, especially from previous generations. This paper explores how the advice of one generation (parents) can influence the investment allocations of the next generation (children). Specifically, we examine the effects of positive and negative advice given by from one generation to the next -in an experimental setting. Our results suggest that the transmission of advice from one generation to the next can have a significant impact on investment behavior, as participants who received positive advice from their parents allocated a higher proportion of their portfolio to risky assets across all thirty years of an investment task. We also find that the transmission of advice to allocations appears to be through participants forming more optimistic beliefs about future returns, rather than any change in their risk preferences.

In the experimental task, participants received advice and experienced the actual returns on the S&P 500 including a substantial market crash serving to challenge the impact of the positive advice. Despite the market crash, the group that received positive advice continued to hold optimistic beliefs. Furthermore, the positive advice created an optimistic outlook among participants, leading to higher stock allocations than other cohorts. These results challenge the assumptions of modern portfolio theory and suggest that inexperienced investors may be more influenced by the advice of previous generations than by arguments based on theories proposing rational decision making. This paper contributes to the growing literature on the intergenerational transmission of financial behavior and has important implications for financial education and policy.

This paper starts with a brief overview of the literature in Section 2. Section 3 describes the experimental tasks, design, experiment participants and results. Section 4 presents the econometric models utilized as well as the results and robustness checks. Section 5 overlays the channel of transmission from advice to stock allocations. Finally, Sections 6 concludes the paper with a brief discussion of the results.

3.2 Literature Review

The literature review is examined in four parts. The first part represents the literature on the effect of crashes on financial risk taking, the second and third parts present the transmission of beliefs across generations and how the prior generations affect economic decision making. Finally, the fourth part discusses the role of advice when investing.

3.2.1 The Effect of Extreme Financial Events on Financial Risk-Taking

In their "Depression Babies" paper, Malmendier and Nagel (2011) used survey data to analyze the effects of an extreme financial crash on individuals' attitudes towards future investment behavior. Their work, which opened a new path, revealed that individuals who experienced a market crash tend to participate less in the stock market and are more pessimistic about the future returns.

The -"Depression Babies" paper led to an active research stream using different methodologies attempting to better understand the causes and effects of market crashes. Studies that used survey data have found evidence that experiencing extreme financial events, such as a stock market crash or a boom, affects future financial risk-taking. Guiso et al. (2013); Bassett et al. (2014); Bekaert and Hoerova (2013) validated the results of Malmendier and Nagel (2011)'s paper. Weber et al. (2013) and Ampudia and Ehrmann (2017) found a similar effect with European data. However, European households attach less importance to past experience compared to the U.S.

While the link between extreme financial events and lower future financial risk-taking is well-established, the mechanisms driving such changes are less understood. In order to ascertain causal effects, some researchers shifted their focus to experimental studies. Bucciol and Zarri (2015) found that the effect of traumatic life events on financial risk-taking mainly occurs through a preference channel rather than a belief channel, which is contrary to previous studies (Malmendier and Nagel, 2011; Weber et al., 2013; Cameron and Shah, 2015). Other studies have also supported the preference channel hypothesis (Voors et al., 2012; Callen et al., 2014; Kim and Lee, 2014).

An important question for our research is whether significant market events can be transmitted through intergenerational advice. Can the effects of positive or negative market events be passed down from one generation to the next through advice?

3.2.2 The Transmission of Economic and Financial Beliefs Across Generations

The persistence of market experience on investment behavior has been widely studied in finance literature. However, how market experience is transmitted from one generation to the next is an under-researched area. While previous studies have identified cultural transmission within cohorts, across cohorts, and hybrid (both between and across), little attention has been paid to the intergenerational transmission of economic and financial beliefs (Malmendier and Nagel, 2011; Guiso et al., 2013; Thornberry et al., 2001; Bisin and Verdier, 2011). This gap in the literature calls for further research on how parents' beliefs about investing affect their children's investment behavior.

3.2.3 The Influence of Prior Generations on Economic Decision-Making

Parents play a critical role in shaping their children's views towards risk and investment. Previous research has found that parents' beliefs and attitudes towards risk have a strong influence on their children's risk preferences (Necker and Voskort, 2014; Dohmen et al., 2012; Brown and Van der Pol, 2015; Alan et al., 2017). Additionally, intergenerational transmission of economic beliefs and decision-making can occur through advice from parents or other members of prior generations. Zumbhuehl et al.

(2021) found that greater parental involvement is associated with greater similarity in economic preferences and attitudes, such as willingness to take risks.

3.2.4 The Role of Advice in Investment Decision-Making

The literature on advice in investment decision-making has highlighted the importance of trust in advisors (Foerster et al., 2017). A financial advisor's own portfolio has been found to be strongly predictive of the investments chosen for the client, even after controlling for risk tolerance, time horizon, and expertise. According to Gurun et al. (2017), clients withdraw their funds and deposit more in safer assets if their trust is broken as a result of fraud exposures. Intergenerational advice can also have a significant influence on subsequent individual behavior in strategic interactions (Schotter and Sopher, 2006; Hillis and Lubell, 2015; Sherstyuk et al., 2016). In a study on experimental asset markets, Alevy and Price (2017) found that advice served as a substitute for experience, leading to prices shifting towards the fundamental value.

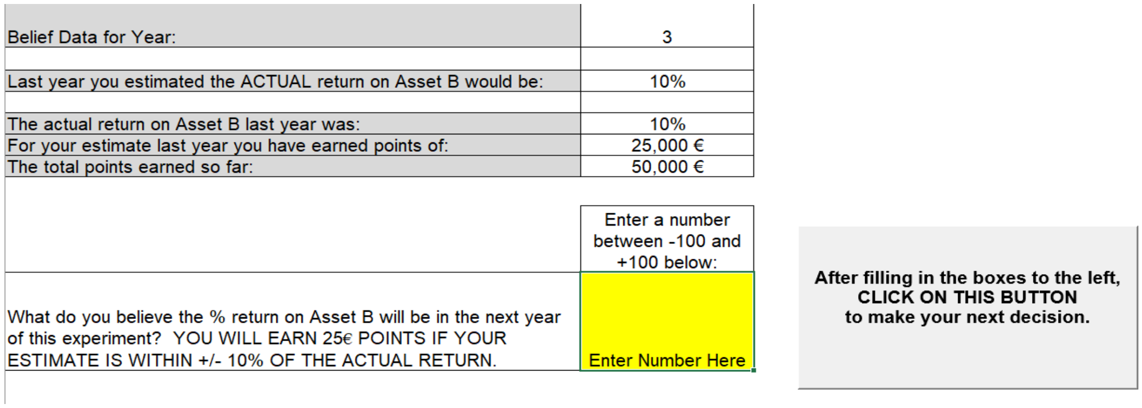
In summary, there is a need for further research on the intergenerational transmission of economic beliefs and decision-making. Parents play a critical role in shaping their children's views towards risk and investment, and advice from prior generations can also have a significant influence on investment decision-making. Our study contributes to this literature by examining the influence of intergenerational advice on non-strategic investment decision-making, providing a more comprehensive understanding of the transmission of economic beliefs and decision-making across generations.

3.3 Experiment

3.3.1 Experimental Task

To start, we provide an explanation of the investment task, followed by a description of the experiment's design. The experiment requires participants to undertake three primary tasks. Firstly, they must provide a forecast of the next period's return on Asset B, the experiment's risky asset. Secondly, they must allocate a sum of money between Asset A, the safe asset with a 3% guaranteed return, and the risky Asset B with a variable return. Finally, participants must periodically provide forward-looking belief estimates on Asset B, including forecasts of the mean, max, min, and tails. We provide a thorough outline of these tasks, demonstrate the software interface, and offer relevant details.

The experiment began by having participants sign an informed consent form to confirm their agreement to participate. They were then given a show-up fee of $5.00, which was separate compensation from their earnings in the investment task. The first task in the experiment required participants to estimate the return on the risky Asset B for the next period, as shown in Figure 3.1 of the software interface.



Belief Data for Year:	3
Last year you estimated the ACTUAL return on Asset B would be:	10%
The actual return on Asset B last year was:	10%
For your estimate last year you have earned points of:	25,000 €
The total points earned so far:	50,000 €
	Enter a number between -100 and +100 below:
What do you believe the % return on Asset B will be in the next year of this experiment? YOU WILL EARN 25€ POINTS IF YOUR ESTIMATE IS WITHIN +/- 10% OF THE ACTUAL RETURN.	Enter Number Here

After filling in the boxes to the left, **CLICK ON THIS BUTTON** to make your next decision.

Figure 3.1 Belief Estimate

Participants were informed that the returns on Asset B would be actual real-world returns from a well-known stock index presented in a random order during a specific sequential time period. The experiment's instructions provided historical return information on the risky Asset B (S&P 500) before the participants' sequential time period shown in Figure 3.2.

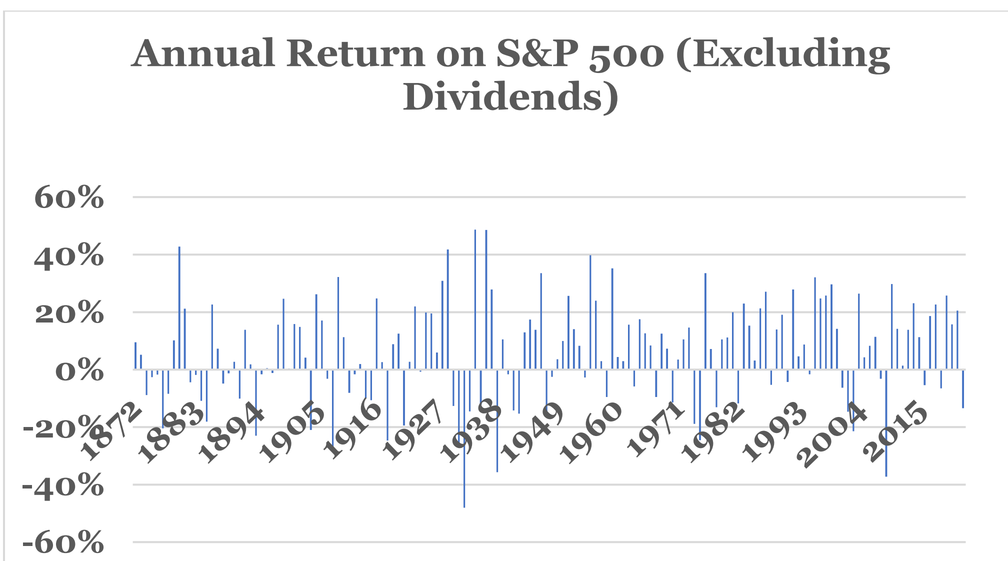


Figure 3.2 S&P 500 Annual Returns

Table 3.1 displays the historical return data given to each of the two cohorts in the experiment. The participants entered their estimate on the software interface for the return on Asset B in the next period. If the participant's estimate was within +/- 10% of the actual return on Asset B, they received a payment of 25,000 points ($0.25) and then proceeded to the asset allocation task.

Table 3.1 Experimental Design

	Generation 1	Generation 2
Base Rate S&P 500 Data Provided in Condition Instructions[24]	1872-1920	1872-1950
(Mean/STD/Max/Min)	(2%/16%/43%/-33%)	(4%/19%/46%/-46%)
Returns Experienced During Investment Task[25]	1921-1950	1951-1980
(Mean/STD/Max/Min)	(6%/22%/46%/-46%)	(8%/17%/41%/-29%)
Experimental Conditions Generational Advice Provided in Condition Instructions[26]	None	Gen 1 Positive Advice Gen 1 Negative Advice

The second task for the participants is to make an asset allocation decision. In this task, the participants are required to allocate their account balance between Asset A, which is safe, and Asset B, which is risky. The software interface for this task is displayed in

[24] The base rate data includes the annual price appreciation returns on the S&P 500 (excluding dividends) calculated from December to December for all years prior to the starting year of the cohort experience.
[25] The experienced returns are the actual returns on Asset B for the 30-year investment period.
[26] The generational advice is the information passed from one generation to the next in the condition instructions.

Figure 3.3. Participants enter the percentage portfolio allocation for Asset B, and the allocation for Asset A is automatically set to 100 minus the allocation for Asset B. The screen displays the total account points balance that needs to be allocated.

When you are finished making your asset allocation decisions for this year click on this button.

Enter your asset allocation decisions in these columns:

Year	Beginning Account Balance (€)	% Asset Allocation to Asset A	% Asset Allocation to Asset B (0-100)	Total Allocation (Must Sum to 100%)
1	100,000 €	50	50	100%
2	107,582 €	40	60	100%
3	129,690 €	60	40	100%
4	137,426 €	25	75	100%
5				
6				

Figure 3.3 Asset Allocation

After making the final allocation decision, participants receive the return information on each asset, as displayed in Figure 3.4. The results page shows the actual portfolio percentage return, the number of points gained or lost, and the new ending account balance.

Click here when you have finished reviewing the results and are ready to continue.

RESULTS

Results for Year:	% Asset A Allocation	% Asset B Allocation	Asset A % Return	Asset B % Return	Actual Porfolio % Return	Yearly Account € Return:	Ending Account Balance €:
1	50%	50%	3%	12%	8%	7,582 €	107,582 €
2	40%	60%	3%	32%	21%	22,108 €	129,690 €
3	60%	40%	3%	10%	6%	7,736 €	137,426 €

Figure 3.4 Return Information

The third task for participants involves providing a more extensive estimate of the distributional properties of Asset B in the future. At the beginning of the first period and every ten periods thereafter, participants are required to estimate what they believe the average, high, low, and tails of the Asset B distribution will be. The software interface for this task is shown in Figure 3.5.

We would now like your assesment of Asset B. Please answer the following questions:

	Enter Answers in this Column:	Whole Number Entered should be between:
1. On a scale from 1-5 (1= Not at all risky, 5= Extremely Risk) how risky is Asset B to you?	3	1-5
2. Going forward, I think the ***AVERAGE % return*** on Asset B will be:	10	-100 to +100
3. Going forward, I think the ***HIGHEST % return*** on Asset B will be:	42	-100 to +100
4. Going forward, I think the ***LOWEST % return*** on Asset B will be:	-30	-100 to +100
5. Going forward, I think the ***percent chance*** that Asset B will have a return **HIGHER THAN 30%** is:	15	0 to +100
6. Going forward, I think the **percent chance** that Asset B will have a return **LOWER THAN 30%** is:	10	0 to +100

Click on this button when you are ready to continue.

Figure 3.5 Distribution Questions

Participants had to repeat these tasks for 30 years or periods. To prevent time horizon effects, they were not informed that there would be 30 investment periods. Instead, they were told that they could complete the task easily within the given time of one hour.

3.3.2 Experimental Design

The experimental design's outline is presented in Table 3.1. To simulate the idea of intergenerational advice being passed down, we followed the following procedure. The first cohort (Generation One) took part in the allocation task and received historical base rate information on the returns of Asset B. Generation One was given the actual return stream of the S&P 500 from 1921-1950, although they were not told the specific time-period from which the returns came. Before the experiment's start, Generation One was provided with base rate information on the returns of the S&P 500 from 1872-1920 (refer to Table 3.1). Each generation in the experiment received base rate information on the returns of the S&P 500 from 1872 up to the year preceding their respective return stream's starting year.

A crucial aspect of the experiment pertains to how the returns on Asset B would be generated, which was explained to the participants through the condition instructions as follows:

“How the Return on Asset B Will Be Generated.

- Each year of the experiment a random draw from a distribution of the actual returns from the Stock Index will be made to determine the annual return on Asset B. The distribution of returns and random draw will be made using the following procedure.

1. The distribution of returns on the Stock Index will be the actual real world returns on the index from a specific sequential time period. For example, you might receive the returns on the index in the time period from 1890-1925 or from 1970-2004.
2. You have been assigned a starting year sometime between 1892 and 2000. The returns on Asset B will be the returns for a consecutive time period from this starting year. For example, if your assigned starting year is 1890, you would then receive the returns from 1890-1925.
3. To understand the random drawing process, imagine the following. Assume that each of the annual returns on the Stock Index from the actual time period of returns used is written on a different chip and then all of these chips are placed in a bucket. Then imagine you stuck your hand in this bucket and randomly pulled out one chip. The return written on this chip would be the return on Asset B for that year. That chip would then be set aside and another random draw from the remaining chips will take place for the next year.

- To speed up this process and so that each of you can proceed at your own pace, the computer and a random number generator have been used to simulate the drawing of a chip from a bucket and the order of the returns on Asset B.
- To reiterate, the returns on Asset B will be actual real world returns from a well-known Stock Index from a specific sequential time period presented in a random order."

Table 3.2 displays the real return streams that each cohort experienced. The return streams for the S&P 500 were taken from a dataset maintained by Robert Shiller. It is essential to note that the annual returns reflect the S&P 500 index price change from December to December, excluding dividends. To prevent any participant from knowing the actual S&P 500 return stream, the sequential year block of returns given to subjects were presented in a random order.

Table 3.2 Return Streams for Generations One and Two

Generation 1 (1921-1950)		**Generation 2 (1951-1980)**	
Year	Return	Year	Return
1921.12	0.073	1979.12	0.122
1932.12	-0.192	1975.12	0.322
1949.12	0.089	1959.12	0.104
1938.12	0.152	1965.12	0.093
1933.12	0.462	1966.12	-0.113
1928.12	0.326	1971.12	0.101
1943.12	0.206	**1973.12**	**-0.193**
1929.12	-0.076	**1974.12**	**-0.292**
1939.12	-0.025	**1962.12**	**-0.127**
1936.12	0.308	1954.12	0.408
1925.12	0.226	1961.12	0.263
1950.12	0.194	1955.12	0.297
1922.12	0.201	1977.12	-0.104
1924.12	0.188	1970.12	-0.012
1923.12	-0.026	1958.12	0.326
1942.12	0.087	1976.12	0.18
1926.12	0.083	1978.12	0.024
1934.12	-0.071	1957.12	-0.132
1941.12	-0.168	1953.12	-0.046
1930.12	-0.275	1967.12	0.172
1944.12	0.141	1964.12	0.132
1948.12	0.011	1963.12	0.184
1937.12	-0.354	1980.12	0.238
1927.12	0.294	1952.12	0.112
1935.12	0.408	1960.12	-0.038
1945.12	0.323	1969.12	-0.145

1947.12	**-0.007**	1972.12	0.185
1940.12	**-0.149**	1968.12	0.118
1931.12	**-0.456**	1951.12	0.185
1946.12	**-0.127**	1956.12	0.024
Mean	0.062	**Mean**	0.08
Std Dev	0.224	**Std Dev**	0.172
MAX	0.462	**MAX**	0.408
MIN	-0.456	**MIN**	-0.292
Skewness	-0.372	**Skewness**	-0.206
Kurtosis	-0.263	**Kurtosis**	-0.562

Upon concluding the asset allocation task, Generation One participants were directed to fill out an online survey. The survey aimed to capture the intergenerational advice that Generation 1 would pass down to Generation two. Participants were presented with the following motivation, and two questions were posed:

- "For the next cohort that participates in this experiment, we would like to know what information you would like to pass along regarding investing in Assets A and B. The returns for Asset B for the next set of participants will be the Stock Index returns in the 30-year period after the 30-year period you just experienced. Imagine that you are a parent and are passing advice to your children about investing in Asset B for the next 30 years.
- Question 1: Below, please rank the following statements based on which statement you would most prefer is told to the next set of participants.
- o Investing in Asset B is dangerous as you can lose almost everything. For example, there was a three-year period where if you invested €100,000 in Asset B, then you would only have €40,442 left. (1)

  - Investing in Asset B is how you make a lot of money. For example, there was a three-year period where if you invested €100,000 in Asset B, then you would have over €241,116. (2)
  - Asset B is going to keep going up. Put all your money in Asset B. (3)
  - Asset B is going to crash. Do not put any money in Asset B. (4)
- Question 2: What message would you like to send along to the next cohort participating in this experiment?

Table 3.3 presents a sample of the advice provided by the Generation One cohort. The Generation Two cohort was subjected to two experimental conditions. The first condition entailed only positive advice from Generation One, while the second condition received only negative advice. The advice provided was based on either the positive (2) or negative (1) statement in Question 1, along with two written messages from participants in Generation One.

Table 3.3 A Sample of Advice Provided by Generation One

Invest in B early on just like you would invest your IRA in common stock then slowly move over to Asset A.
Asset B rides a high percentage return then crashes so be careful with how you allocate your money
high risk but also potentially high reward
after halfway, be really careful on how much to put on asset b
every 5 year period Asset B has a signifigant fall. Be mindful and do not invest more than 10% on asset B. Sometimes it will have a great return, but it is better to be cautious than sorry. Do not compromise your money on Asset B. Play it safe.
You should allocate at least a small percent to asset B every time

No risk, no reward. Remember it is random but look at that possible trends and if your asset B is negative or below 3% not worth allocating much to it.
Investing is a risky decision; however., in the long-run you are getting more money and increasing your earnings, even if there is some sort of crash.
Be wise with your decision, and focus on consistency. Asset A is the safe option and I advise allocating most of your money on A for a steady increase in your investment.
Asset B can be extremely volatile, so pay much closer attention to the percentage allocated to it.
Nice experiment I liked it a lot!
Be weary, once you gained a big profit do not gamble all your profit on the next hands only lose percentage of previous profits captured.
Asset B is extremely risky.
Its all about risk a gut judgement, if you feel that its going to increase invest more.
It can be a large gamble to put a majority of you portfolio into asset B, but it sure is fun when you get a great percentage return. However it also really hurts to lose nearly half of your portfolio in one year.
Focus more on making money then trying to get within +/- 10%
The return can drop out of nowhere so be careful how you spend your money

The intergenerational advice from Generation One was framed in the following way in the condition instructions for the Generation Two cohort:

“At the end of the experiment, you will be asked to respond to the following:

- For the next cohort that participates in this experiment, we would like to know what information you would like to pass along regarding investing in Assets A and B.

- The returns for Asset B for the next set of participants will be the Stock Index returns in the period after the period you just experienced. Imagine that you're a parent and are passing advice to your children about investing in Asset B.
- A sample of the information the prior cohort assessed important to pass along to you includes the following":

Negative Advice Cohort from Generation 1 to Generation 2

- "Investing in Asset B is dangerous as you can lose almost everything. For example, there was three-year period where if you invested €100,000 in Asset B, then you would only have €40,442 left."
- "It can be a large gamble to put a majority of your portfolio into asset B, but it sure is fun when you get a great percentage return. However, it also really hurts to lose nearly half of your portfolio in one year."
- "Asset B is extremely risky."

Positive Advice Cohort from Generation 1 to Generation 2

- "Investing in Asset B is how you make a lot of money. For example, there was a three-year period where if you invested €100,000 in Asset B, then you would have over €241,116."
- "Invest in B early on just like you would invest your IRA in common stock."
- "High risk but also potentially high reward."

The experiment is a between-subjects experiment that investigates the impact of positive and negative intergenerational advice passed from Generation One to Generation Two.

There are several essential aspects of the return streams experienced by both the Generation One and Generation Two cohorts. Firstly, the risky asset B return stream experienced by the participants in both cohorts provided a higher average return compared to the base rate historical return. For Generation One, the base rate average historical return from 1872-1920 was 2%, and the experienced return stream from 1921-1950 was 6%. For Generation Two, the base rate average historical return from 1872-1950 was 4%, and the experienced return stream from 1951-1980 was 8%. The return streams for both cohorts included a reasonably significant market crash. For Generation One, the crash occurred in years 27-30 of the task, and the value of $1 in year 26 fell to $0.41 in year 30. For Generation Two, the crash occurred in the early years 7-9 of the task, and the value of $1 in year 6 fell to $0.50 in year 9. The crash occurring in the last years of the task for Generation One, a deliberate design choice, resulted in a painful ending to the investment task that is likely to be particularly salient and influential in the type of intergenerational advice (e.g., depression babies) that is passed (Redelmeier et al., 2003).

3.3.3 Participants

The experiment recruited participants through announcements in university classes and a university subject pool. The total number of participants was 118, with 41 in Generation One and 37 and 40 in Generation Two Negative/Positive, respectively. The average age for Generation One was 20.8 while 47% of the participants were male. In Generation Two, the average age for the cohort who received a negative advice was 22.5 and 44% of the participants were male. Finally, for the cohort (Generation Two) who received a positive advice had an average age of 22.3 of which 39% were male.

3.3.4 Experiment Hypothesis

Based on the literature review and experimental design, we test the following base hypotheses in the experiment:

- **Hypothesis 1:** Positive advice passed from Generation One to Generation Two will lead to higher allocations to the risky Asset B in the positive condition compared to the negative condition.
- **Hypothesis 2:** Positive advice passed from Generation One to Generation Two will lead to more optimistic beliefs regarding the future returns on risky Asset B in the positive condition compared to the negative condition.
- **Hypothesis 3:** Negative advice passed from Generation One to Generation Two will lead to a higher risk aversion attitude compared to the positive advice condition.

3.4 Experiment Results

3.4.1 Mean Allocation to Risky Asset by Cohorts

Figure 3.6 displays the average allocation to the risky asset (Asset B) by year for participants in the Negative and Positive cohorts in Generation Two. The results demonstrate that the average allocation to the risky asset is consistently higher in the Positive cohort compared to the Negative cohort in every year of the allocation task.

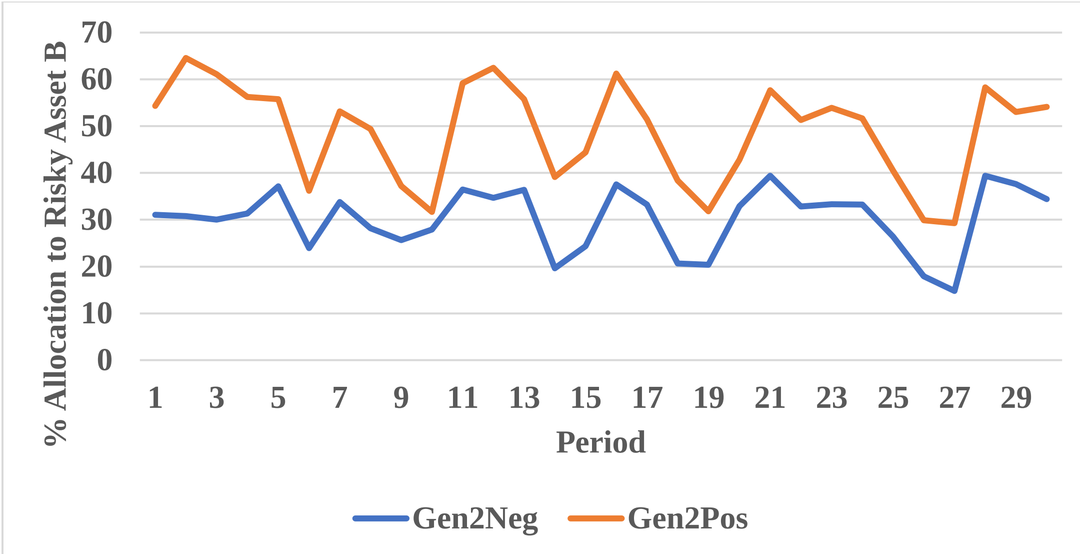


Figure 3.6 Allocation to the Risky Asset by Generation Two

Descriptive statistics for the mean allocations by cohort are presented in Table 3.4, where the overall mean in allocations is 49% in the Positive condition versus 30% in the Negative condition.

Table 3.4 Descriptive Statistics for Allocations and Beliefs

Treatment	Average of Risky Asset Allocation	STD of Risky Asset Allocation	Average of Belief	STD of Belief	# of Subjects
Generation 1	44.3	27.9	0.10	0.15	41
Generation 2 Negative	30.2	24.1	0.06	0.14	37
Generation 2 Positive	48.9	33.3	0.09	0.17	40

Figure 3.7 illustrates the mean beliefs of Generation Two across the Negative and Positive cohorts. The findings reveal that participants in the Positive cohort had higher

beliefs regarding the future returns on the risky asset in almost all of the thirty experimental periods.

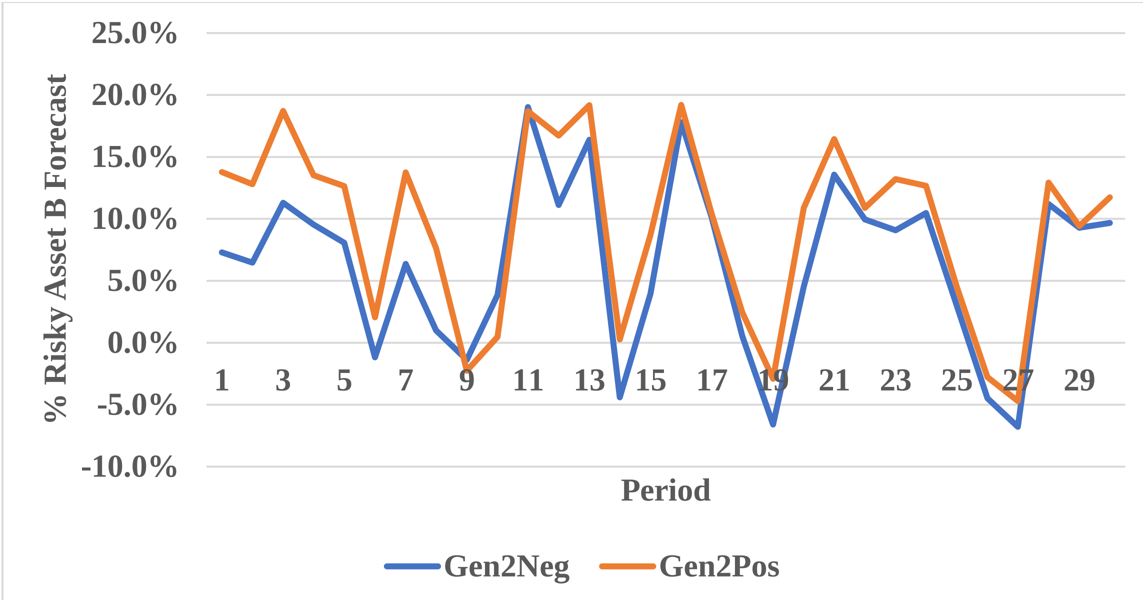


Figure 3.7 Beliefs by Generation Two

3.4.2 Econometric Estimation Methods

Various estimation methods were employed to analyze the data, but each method presents unique challenges that must be addressed. To begin, we will discuss the limitations of each method and the techniques used to overcome these limitations. The first regression specification method utilized is OLS, which is effective in summarizing the basic correlations present in the data. Additionally, OLS estimates can be used for comparison with other estimation methods that may be deemed more appropriate. However, OLS has limitations when dealing with this type of data, including the presence of correlated panels, a dependent variable that is bounded from above and below (the share of stocks ranges from 0 to 100 or from 0 to 1 in the Fractional Response Model

(FRM) specification), and a potentially truncated distribution of the share of stocks variable.

Due to the presence of positive autocorrelation from one period to the next in the experiment data, we employed GLS as a second estimation method. We specifically used Prais-Winsten regressions under the assumption of AR (1) errors, as tests of serial correlation within panels indicated the presence of AR (1)-type autocorrelation.

The third specification method employed in our analysis controls for the potential truncation of the dependent variables (i.e., share of stocks, belief), as both are bounded. Specifically, the share of stocks ranges from 0 to 100, while beliefs range from -100 to 100. To address this potential truncation, we used Tobit regressions, which allow for censoring of the dependent variable at the bounds of the distribution. By using Tobit regressions, we can better account for the limitations imposed by the bounded nature of the dependent variables.

The following specification method is the Random Effect Model estimates, which involves a weighted average of the purely cross-sectional and purely over-time (within) estimates. Random Effects estimates are useful as they utilize all the information in the data set, unlike fixed effects that rely only on the within variation in the data.

The next estimation method we present is the Mixed Linear Model (MLM). The MLM is a commonly used estimation method in literature because it combines both fixed and random effects. This model allows for individual-specific effects, such as differences in investment behavior or beliefs, to be captured by random effects, while fixed effects capture the average effect of variables that are the same for all individuals. The MLM can be useful in analyzing panel data, such as our experiment, as it allows for the incorporation of time-varying variables and the estimation of the effects of variables on both the individual and group level.

As our data is experimental, it is not naturally hierarchical, so it is not clear which level should be used for clustering standard errors other than by subject. Thus, in most regression specifications, standard errors are clustered by subject. For most right-hand side regressors, clustering by condition is not appropriate except in the case of experimental treatment variables. Most right-hand side regressors lose their statistical significance if standard errors are clustered by condition, while experimental treatment variables do not.

The final approach to specification that we introduce is the Fractional Response Model. As our dependent variable, "share of stocks," can be thought of as a fractional variable taking values between 0 and 1, we follow the recommendation of Papke and Wooldridge (1996) and present the estimates from Fractional Response Models, in line with some of the most recent literature in behavioral financial economics (Bucciol and Zarri, 2015, for instance).

In summary, our methodological discussion identified two potential issues with the OLS estimates of the allocation to stocks, namely correlated panels and bounded dependent variables. To accurately quantify the magnitude of these problems, we utilized GLS and FRM estimation methods, respectively. Our regression tables below demonstrate that neither issue appears to be too severe, as the quantitative estimates remain relatively stable across different specifications within each experimental dataset. However, the

FRM specification indicates that the other estimation methods may significantly underestimate the treatment manipulation on the share of stocks variable, by approximately half the true effect. This highlights the importance of employing appropriate estimation methods in analyzing experimental data to obtain more precise and accurate estimates of the effects of different factors.

3.4.3 Dependent and Independent Variables

Our analysis commences with a regression of the stock allocations made by subjects in Generation Two for both the Positive and Negative cohorts. The dependent variable used in our regression analysis is the allocation made to the risky asset in the portfolio.

Our econometric models include several explanatory variables:

1. The first lag of each subject's account balance at the start of each period, which is measured right before subjects report their beliefs and make their asset allocations. This variable acts as a proxy for wealth effects, which can bias other regression coefficients if left unaccounted for. Specifically, the treatment effect may be biased upward if this variable is omitted.

2. Age, measured in years,

3. Sex, where male is assigned a value of 1 and female is assigned a value of 0,

4. Education, measured on a 1-7 scale, where 1 denotes less than a high school degree and 7 denotes a doctoral degree,

5. Experience, which is the self-reported level of financial experience, measured on a 1-4 scale where 1 indicates no experience and 4 indicates a lot of experience, and

6. Dummy variables to identify treatment effects for each cohort. For instance, "gen2negdummy" is used to identify the cohort in Generation Two that received negative advice from Generation One.

To account for endogeneity concerns and potential simultaneity bias, we have excluded the "belief" variable, which records subjects' self-reported beliefs about future risky asset returns, from regressions where stock allocations are the dependent variable. Doing so prevents any potential bias in the estimates for other explanatory variables in the regressions. However, we have found that the coefficient for the "belief" variable is strongly positive and statistically significant at conventional levels in the experiment if it is included in the stock allocation regressions. This result indicates that subjects were not hedging their bets by declaring optimistic beliefs while allocating most of their funds to the safe asset. Although the "belief" variable has not significantly altered any qualitative results when used as an explanatory variable in regressions where stock allocations are the dependent variable, it does not "steal" explanatory power from other regressors.

To address concerns about simultaneity bias, we have similarly excluded the self-reported measure of risk aversion, which subjects reported every ten periods during the experimental task, from regressions where "stocks" are the dependent variable. Including risk aversion as a control variable on the right-hand side leads to a statistically significant coefficient, ranging from 5% to 10% depending on the econometric specification used.

For every point increase in risk aversion, subjects reduced their stock holdings by approximately two percentage points.

3.4.4 Results

We will begin by discussing the regression results for Generation Two. Firstly, we will present the results for the dependent variable "share of stocks." Specifically, we will compare the share of stocks held by subjects who received negative advice from Generation One with those who received positive advice and summarize the main findings in Table 3.5. The primary control variables used are the account balance lagged once (to control for wealth effects), age, sex, education, and investment experience. The variable of main interest is "gen2negdummy," which takes a value of one if the subject received negative advice from Generation One and zero if the subject received positive advice.

Table 3.5 Regression Results for Stock Allocations

Dependent Variable is Stocks						
	(1)	(2)	(3)	(4)	(5)	(6)
Variables	OLS	Tobit	Auto	RE	MLM	FRM
Beginning account balance (Lag 1)	2.29e-05**	2.18e-05*	2.29E-05	-1.53e-05**	-1.37e-05***	6.07e-07***
	(0.0000103)	(0.0000118)	(0.0000204)	(0.00000698)	(0.0000048)	(0.000000193)
age	-0.315	-0.347	-0.315**	-0.322	-0.329	-0.00905
	(1.079)	(1.168)	(0.149)	(1.104)	(1.0020)	(0.00664)
sex	0.1	0.457	0.1	-0.34	-0.346	-0.000638
	(4.418)	(4.765)	(1.193)	(4.537)	(5.191)	(0.0351)
education	1.042	1.318	1.042***	1.011	1.019	0.0298*
	(2.691)	(2.94)	(0.326)	(2.763)	(2.675)	(0.0176)
experience	7.161**	7.487**	7.161***	7.607**	7.558**	0.195***
	(3.014)	(3.273)	(0.463)	(3.093)	(3.043)	(0.0211)
gen2negdum	-13.73***	-14.14**	-13.73***	-14.57***	-14.53***	-0.367***
	(5.158)	(5.552)	(1.31)	(5.341)	(5.225)	(0.0346)

Constant	26.99* (15.83)	25.31 (16.94)	26.99*** (5.562)	34.73** (16.07)	34.61** (17.45)	-0.609*** (0.113)
Observations	1,972	1,972	1,972	1,972	1,972	1,972
R-squared	0.119		0.119			
Number of groups					68	
Number of subjects			68	68		

Robust standard errors in parentheses (std. errors clustered by subject except for (5), which is clustered by condition)

*** p<0.01, ** p<0.05, * p<0.1

According to Table 3.5, after controlling for wealth effects, age, sex, education, and investment experience in all regression specifications except the last one, subjects who received negative advice from Generation One held between 13.75 to 14.57 percentage points less in stocks than subjects in Generation Two who received positive advice from Generation One. In the last column, which employs the fractional response model, the difference is even more pronounced: subjects who received negative advice from Generation One reduced their share of stocks by 36.7 percentage points compared to subjects who received positive advice. This is a substantial difference, highlighting the significant impact of advice from the previous generation on stock allocations in Generation One.

3.4.5 Robustness

To test the robustness of the regression results for stocks, we expanded the set of controls by adding a set of additional variables to the right-hand side. These variables include: (i) losses, which measure the monetary losses experienced by subjects each period as a proxy for loss aversion; (ii) the square of losses, which checks for the concavity/convexity of loss aversion and the potential for "double-down" effects in the face of large losses; (iii) gains, which measure the monetary gains of subjects in each period of the investment game, if any; (iv) the square of gains, which tests for the existence of diminishing returns in the domain of gains; and (v) a measure of IQ, proxied by the sum of scores corresponding to the answers subjects provided to the three questions comprising the Cognitive Reflection Test (CRT), which they took as part of the post-experiment survey. These additional controls help to strengthen the validity of the regression results and provide a more comprehensive understanding of the factors influencing stock allocations in Generation Two. The results of the robustness are given in Table 3.6.

Table 3.6 Robustness

Dependent Variable is Stocks						
	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	OLS	Tobit	Auto	RE	MLM	FRM
beginning account balance (Lag 1)	-5.65e-05***	-6.66e-05***	-5.65e-05***	-5.65e-05***	-4.61e-05***	-1.60e-06***
	(0.00000748)	(0.00000952)	(0.000021)	(0.00000748)	(0.00000515)	(0.000000222)
age	-0.371	-0.423	-0.371**	-0.371	-0.452	-0.0112*
	(0.715)	(0.774)	(0.149)	(0.715)	(0.863)	(0.00629)
sex	-1.793	-1.773	-1.793	-1.793	-2.457	-0.0553
	(3.157)	(3.354)	(1.223)	(3.157)	(4.709)	(0.0362)
educ	0.628	0.808	0.628*	0.628	0.637	0.0188
	(1.641)	(1.772)	(0.325)	(1.641)	(2.298)	(0.0157)
exper	4.647**	4.731**	4.647***	4.647**	6.736***	0.136***
	(2.09)	(2.255)	(0.665)	(2.09)	(2.608)	(0.0203)
gen2negdum	-9.200***	-9.211***	-9.200***	-9.200***	-13.40***	-0.267***
	(3.176)	(3.38)	(1.534)	(3.176)	(4.534)	(0.0318)
losses	-0.00279***	-0.00296***	-0.00279***	-0.00279***	-0.000666***	-7.63e-05***
	(0.000345)	(0.000374)	(0.000668)	(0.000345)	(0.000173)	(0.00000779)
losses2	-3.11e-08***	-3.19e-08***	-3.11e-08**	-3.11e-08***	-6.16E-09	-8.53e-10***
	(0.00000000823)	(0.00000000939)	(0.0000000156)	(0.00000000823)	(0.00000000443)	(0.000000000232)
gains	0.00156***	0.00169***	0.00156***	0.00156***	0.000810***	4.26e-05***

	(0.000105)	(0.000126)	(0.00026)	(0.000105)	(0.0000699)	(0.00000278)
gains2	-6.83e-09*** (0.00000000142)	-7.03e-09*** (0.00000000191)	-6.83e-09* (0.00000000355)	-6.83e-09*** (0.00000000142)	-4.36e-09*** (0.000000000992)	-1.73e-10*** (0)
crtsum	2.109 (1.826)	2.577 (1.969)	2.109*** (0.57)	2.109 (1.826)	2.824 (2.155)	0.0634*** (0.0169)
Constant	26.68** (10.46)	25.90** (11.14)	26.68*** (5.347)	26.68** (10.46)	35.26** (15.09)	-0.627*** (0.111)
Observations	1,972	1,972	1,972	1,972	1,972	1,972
R-squared	0.382		0.382			
Number of groups					68	
Number of subjects			68	68		

Robust standard errors in parentheses (std. errors clustered by subject except for (5), which is clustered by condition)

*** p<0.01, ** p<0.05, * p<0.1

The results indicate that the treatment effect variable (gen2negdummy) maintained its statistical validity in all cases, and the quantitative effect was unaffected by the inclusion of the additional set of controls. This suggests that the treatment effect is robust and reliable, and not compromised by the introduction of the additional variables.

The added regressors were found to be generally statistically significant at conventional levels, except for CRT (except in FRM and AR (1)). The coefficients on the Prospect Theory-inspired variables, including losses, square of losses, gains, and square of gains, were found to be quantitatively small and did not warrant inclusion in the main set of regressions.

3.5 The Channel of Transmission from Advice to Stock Allocations: Subjects' Beliefs About Future Stock Returns

Providing advice to subjects can have both a direct and indirect effect on asset allocations. The advice itself can directly affect allocations, or indirectly affect allocations through either the channel of beliefs about future stock results or the through channel of altering the subject's level of risk aversion. The nature of the advice received can make subjects more or less risk-averse, and/or more optimistic or pessimistic about future stock returns.

The behavioral finance literature investigating individual behavior in laboratory investment games similar to those studied in this paper (e.g., Guerrero, et al. (2012), Lejarraga et al., 2016, Safford et al., 2016, Papadovasilaki et al., 2018, etc.) has produced inconsistent findings regarding the most significant transmission channel from treatment manipulations involving shocks to stock returns and subjects' stock allocations. Some studies have identified beliefs as the primary driver, while others have pointed to risk aversion as the most relevant transmission channel for shocks to stock market returns. In our experiment, beliefs serve as the most influential indirect transmission channel.

Table 3.7 represents the statistical summary of the relationships between stock allocations, subjects' incentivized self-reported beliefs and subjects' self-reported risk aversion for the experiment.

Table 3.7 Statistical Summary of the Relationship between Stock Allocations, Beliefs and Risk Aversion

Generation Two (Positive)						
	AVG	AVG	AVG	median	median	median
	Stocks	Belief	RA	Stocks	Belief	RA
Yr 1	53.77	0.14	3.26	60	0.07	3
Yrs 1-3	59.55	**0.15**	3.26	60	**0.08**	3
YRs 4-30	47.72	0.09	3.46	50	0.08	3
YRs 10-30	47.45	0.09	3.46	50	0.08	3
AVG Yrs 1-30	48.9	0.12	3.36	55	0.08	3
Generation Two (Negative)						
	AVG	AVG	AVG	median	median	median

	Stocks	Belief	RA	Stocks	Belief	RA
Yr 1	31.03	0.07	3.49	30	0.05	3
Yrs 1-3	30.62	0.08	3.49	30	0.07	3
YRs 4-30	30.13	0.06	3.45	25	0.06	3
YRs 10-30	30.17	0.07	3.45	25	0.08	3
AVG Yrs 1-30	30.18	0.06	3.46	27.5	0.07	3

Generation Two (Positive) t-tests of differences in means			
	Stocks	Belief	RA
Yrs 1-30	48.9	0.12	3.36
N	1170	1170	156
n^(1/2)	34.20526275	34.20526275	12.489996
std Dev	33.26	0.1685	0.9
StdError	0.97	0	0.07

Generation Two (Negative) t-tests of differences in means			
Gen2Neg	Stocks	Belief	RA
Yrs 1-30	30.18	0.06	3.46
N	1110	1110	148
n^(1/2)	33.3166625	33.3166625	12.16552506
std Dev	24.08	0.14	0.88
StdError	0.722761471	0.004202102	0.072335554

Differences in means			
	Stocks	Belief	RA
Yrs 1-30	-18.72	-0.06	0.1
StdError	0.847563231	0.004564122	0.072196612
t-stat of diff.	22.0868477***	13.14086147***	1.399312772

The results in Table 3.7 show that the distribution of beliefs is skewed to the positively to the right for the cohort in Generation Two that received positive advice from Generation One, especially early in the experiment. However, the distribution for risk aversion is symmetric and stays the same throughout the experiment. For the cohort receiving negative advice, the distributions of beliefs and risk aversion are symmetric. The differences in means on risk aversion between those receiving positive and negative advice, is statistically insignificant at conventional levels of significance; the difference in means on beliefs between the positive and negative cohorts is statistically significant. Based on the findings in Table 3.7, we conducted further regression analyses with beliefs as the dependent variable, using the same set of controls employed in the previous regressions with the share of stocks as the dependent variable. The results of these regressions are presented in Table 3.8 below.

Table 3.8 Regression Results for Belief

Dependent Variable is Belief

	(1)	(2)	(3)	(4)	(5)
VARIABLES	OLS	Tobit	Auto	RE	MLM
beginning account balance (Lag 1)	-9.28e-08**	-1.27e-07***	-9.28E-08	-1.18e-07***	-1.18e-07***
	(0.0000000388)	(0.0000000446)	(0.000000116)	(0.0000000402)	(0.0000000337)
Age	-0.00151	-0.000849	-0.00151	-0.00152	-0.00156
	(0.00188)	(0.00235)	(0.00101)	(0.00189)	(0.00216)
Sex	-0.0191	-0.0279*	-0.0191**	-0.0194	-0.0194*
	(0.0131)	(0.0158)	(0.008)	(0.0131)	(0.0112)
Education	0.000559	-0.0025	0.000559	0.000539	0.000621
	(0.00497)	(0.00683)	(0.00326)	(0.00499)	(0.00576)
Experience	-0.00242	0.00119	-0.00242	-0.00213	-0.00192
	(0.00753)	(0.00793)	(0.00287)	(0.00756)	(0.00655)
gen2negdum	-0.0242**	-0.0236*	-0.0242***	-0.0247**	-0.0247**
	(0.0112)	(0.0125)	(0.00526)	(0.0114)	(0.0113)
Constant	0.152***	0.155***	0.152***	0.157***	0.157***
	(0.0354)	(0.0388)	(0.0371)	(0.0361)	(0.0382)
Observations	1,972	1,972	1,972	1,972	1,972
R-squared	0.017		0.017		
Number of groups					68
Number of subjects			68	68	

Robust standard errors in parentheses (std. errors clustered by subject except for (5), which is clustered by condition)

*** p<0.01, ** p<0.05, * p<0.1

The subjects who received negative advice from Generation One held beliefs that were roughly two percentage points more pessimistic compared to those in Generation Two who received positive advice from Generation One (gen2negdum=-0.0242, $p<0.05$). This finding held true even after controlling for wealth effects, age, sex, education, and investment experience in all regression specifications. It is important to note that the dependent variable "belief" is not bounded between 0 and 1, unlike the share of stocks in the last column of Table 3.5, and therefore cannot be estimated using the FRM method.

At first glance, a two-percentage point decrease in beliefs may not seem like a significant amount. However, it is important to note that some of the most optimistic subjects in Generation Two initially held beliefs indicating that they expected 20% positive returns from stocks. For these individuals, a 2-percentage point reduction corresponds to a notable 10% decline in their expectations following negative advice. This effect is certainly non-negligible. For subjects whose expectations were more aligned with the historical return distribution provided, the effect of negative advice was even more pronounced.

Furthermore, it is worth noting that, aside from wealth effects (and in two specifications, "sex"), none of the other independent variables included in Table 3.8 demonstrate a statistically significant effect at conventional levels. This means that the decrease in optimism following negative advice is not being influenced by factors such as education, investment experience, IQ, or age.

3.6 Discussion and Concluding Remarks

The results of the experiment reveal two main findings. First, participants who receive positive advice framed as coming from their parents allocate a higher proportion of their portfolio to risky assets across all thirty years of the investment task. Secondly, the indirect transmission of advice to allocation appears to be through participants forming more optimistic beliefs about future returns, rather than any change in their risk preferences.

The differences observed in the experiment are significant given its design. Participants in both the Positive and Negative conditions received identical historical base rate return information, underwent the same return stream during the thirty-period investment task, and encountered a market crash in the middle of the task. The only distinguishing factor between the two conditions was the positive or negative advice conveyed by Generation One. Participants were explicitly informed that the return stream they were experiencing was the actual real-world return stream that followed the years of Generation One.

How would a "rational" participant behave in this investment task? Participants in Generation Two were informed that the historical average return on the risky asset was 4% (with a standard deviation of 19%), while the safe asset would provide a guaranteed return of 2%. According to modern portfolio theory (Markowitz, 1962), participants might have selected a portfolio allocation (e.g., 60/40) and maintained it throughout the thirty periods, but very few did so. Out of 118 participants, only one did not alter their allocation at all over the thirty periods, and the average standard deviation in allocations across all subjects was approximately 30. Previous research (Guerrero et al., 2021) on a similar investment task has demonstrated that participants change their allocations quite frequently in response to recent returns on the risky asset.

As with most inexperienced investors starting their retirement savings, participants in this experiment probably had limited experience in making portfolio allocation decisions and forming beliefs about future returns. Therefore, subjects followed the advice of a previous cohort with whom they had no prior interaction except for participating in a similar experiment. Despite this, Generation Two participants appeared to anchor their beliefs and allocations based on the positive or negative advice passed on from Generation One and adjusted accordingly.

Given these results, future studies should replicate and extend these results in another set of experiment that uses the same design in which the advice is passed from both Generation One and Generation Two to Generation Three with a larger variety in cohorts. In doing so, the results can be expanded, and the intergenerational effect can be observed more in detail.

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