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Article

The impact of fluctuating exchange rates and customs rates on the economic sustainability of solar energy business in Lebanon

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Abstract: Since the beginning of 2020, Lebanon has been facing a severe economic crisis, soaring inflation and currency collapse; yet, there has been a remarkable turnout towards solar energy. This research explores the evolution of the exchange and customs-exchange rate during the crisis, and the impact on the economic sustainability of solar energy business. The primary objective is to examine the economic sustainability of the solar energy business through a thorough analysis of the interplay of factors such as exchange rate, customs exchange rate, market value and profitability of the business and the impact of these rates on such economic metrics. The investigation involves a quantitative analysis of data collected from 10 companies in Beirut/Lebanon on a quarterly basis from 2020 till 2023. To ensure statistical rigor, certain variables were log-transformed, and data was processed in SPSS (Statistical Package for Social Sciences), performing correlation tests, hierarchal regression, mediation, and variation by time analyses. The results of the study indicate that the solar energy business excelled performance, taking into consideration other different factors like lack of electricity, and showed responsiveness to market dynamics. The business exhibits stability and independence in certain aspects, such as profitability, attributed to strategic dollarization and effective cost management. Correlation analysis showed strong relationships between rates and costs, profits, and project market values in Lebanese Lira, yet weak or insignificant correlations for these metrics in US dollars. Thus, dollarization strategies mitigated currency volatility impacts. Mediation analysis revealed that exchange rate plays a dominant role over customs exchange rate, significantly impacting project values in US dollars. Profitability analysis highlighted stable trends, indicating robust adaptability, strategic pricing, and sustainable growth despite fluctuating exchange rates. Analysis of profit margins and return on investment indicates a consistently positive trajectory, reflecting stability that thus fosters confidence among investors and stakeholders. Overall, the insights provided highlight the resilience of the business during the crisis, shedding light on its economic sustainability.

Keywords: economic sustainability; solar energy; exchange rate; customs; profitability

1. Introduction

The solar energy business has gained prominence due to the global trend towards sustainable and renewable energy sources. This is because nations are looking for ecologically favorable alternatives to fossil-fueled energy sources. This stresses the necessity of long-term, reliable, and affordable renewable energy sources to meet future energy. Because of their endless and clean energy potential, photovoltaic (PV) energy systems are acknowledged as the leading renewable energy source (Dinçer, 2011). PV power systems are expected to be quite important in the future electrical landscape.

Set in the center of the Middle East, Lebanon has likewise embraced the global movement toward solar energy solutions in support of sustainable development. Despite this encouraging trend, Lebanon's socioeconomic environment, which has been tainted by financial crises, introduces challenges beckoning for an in-depth study of the dynamics of the solar energy sector in such a context (Ahmad, 2020). Lebanon's economic difficulties have worsened over time, including a financial collapse that has made off-grid solar-plus-battery systems more appealing. With Lebanon's electric grid facing numerous failures, people are turning to solar solutions to cope with power shortages (Tsagas, 2023). These shifts underline the importance of renewable energy, especially solar PV systems, for Lebanon's electricity supply. One key issue Lebanon faces is the impact of fluctuating exchange rates on the solar energy business. Exchange rate changes affect both foreign and domestic businesses, impacting profits, input costs, and sales (Santillán-Salgado et al., 2019). The profitability of domestic industries can be significantly impacted by changes in exchange rates (Bodnar and Gentry, 1993).

In a 2023 interview at the World Utilities Congress in Abu Dhabi, Lebanon's Minister of Energy and Water, Dr. Walid Fayad, emphasized the country's target of achieving 30% renewable energy in its energy mix by 2030. Fayad acknowledged Lebanon's struggles with energy security, noting that the country lacks the necessary financial resources to achieve its goals. While electricity supply has improved slightly, solar energy is being rapidly adopted due to its lower cost compared to diesel generators and grid electricity, especially in the residential and industrial sectors. He also stressed the importance of further investments in solar energy to meet Lebanon's energy needs, despite its challenging financial situation.

An economic system is said to be sustainable if it can be made to continue or even improve in the long run. In the business context, economic sustainability corresponds to preserving financial stability and promoting growth without harming the environment, social well-being, and the capacity to meet economic demands.

Economic sustainability, which refers to promoting financial stability and growth while balancing social and environmental considerations, is crucial for the long-term success of any business. The solar energy sector exemplifies this balance, as it taps into a renewable resource (the sun) to generate power, reducing reliance on limited fossil fuels and lessening environmental impacts. Solar power production emits fewer greenhouse gases than traditional energy sources, contributing to economic sustainability by supporting environmental goals (Safdie, 2024).

Prysmian group magazine (2024) explains that the only goal of economic growth is to increase sales and profits, while the term "economic sustainability" describes the intention to foster a country's or business long-term economic growth while simultaneously monitoring the environmental, social, and cultural ramifications. It involves striking a balance between the effects on people and the environment and the pursuit of profit and economic progress. The Sustainable Development Goals (SDGs), a collection of 17 interconnected objectives that offer nations and governments a blueprint for achieving steady and sustainable progress, include economic sustainability.

This is in the principle and core fundamentals of the solar energy sector since it deals with utilizing the sun's energy, which is a nearly limitless and renewable supply.

Long-term growth is hampered by reliance on limited resources, according to Safdie. By drawing on a plentiful and renewable resource, the solar energy sector lessens this difficulty and provides a sustainable substitute for finite fossil fuels. In the context of the solar energy business, economic sustainability refers to maintaining profitable growth while managing the energy production's environmental impact. Compared to traditional energy sources, the production of solar power generates fewer greenhouse gas emissions, thereby lessening the industry's overall environmental impact. The United Nations Sustainable Development Goals (SDGs) integrate economic sustainability along with social responsibility, environmental protection, and responsible consumer culture. By offering a clean and sustainable energy source, meeting climate action targets, and encouraging responsible energy usage, the solar energy sector helps to achieve these objectives. It also has a good effect on community well-being through enhancing public health and air quality. The solar energy industry plays an important role in achieving sustainable development objectives and promoting a harmonious coexistence of social welfare, environmental preservation, and economic prosperity, and thus in the context of economic sustainability (Safdie, 2024).

The perspectives given by the minister emphasizes the importance of a thorough study into the viability of the solar energy industry in Lebanon. An examination of the economic factors influencing the development and profitability of solar energy solutions, and consequently its economic sustainability, is required in light of the nation's ambitious goal of achieving 30% renewable energy in the energy mix by 2030. This goal is in line with the imperative to secure energy availability and minimize costs, both environmentally and economically. The economic crisis presented economic changes of exchange rate fluctuations, which highlights the necessity of a comprehensive understanding of economic sustainability studying business profitability and durability, and to promote investments from partnering companies. Since no previous literature has taken into consideration such analysis during a critical unique environment as the Lebanese crisis, this study would be essential in assessing the solar energy sector's economic viability in the particular context of Lebanon's socio-economic landscape.

Even if most transactions are made in dollars, analyzing the relations in Lebanese Lira is valuable for evaluating potential impacts on local price dynamics and operating costs. In the meantime, the study in USD continues to be relevant since it shows how well the business is doing financially. This dual approach adds to our understanding of the economic sustainability by offering a thorough understanding of the business financial resilience and flexibility in response to outside economic factors. In the context of the economic crisis, it enables a thorough assessment of the durability, and profitability development.

We aim to elaborate the evolution of the exchange rate and the customs-exchange rate and their impact on solar energy business performance and consequently economic sustainability in Lebanon during the period from 2020 to 2023, through data provided by companies in the industry resembling an approximation of the market dynamics and performance, as well as the mediation effect of exchange rate on the relationship between project market value in USD and profit margin. We will study also the mediation effect of exchange rate on the relationship between customs

exchange rate and project market value in USD, as well as the variations of ROI and profit margin during the crisis. Data was provided as an approximation due to the preservative confidentiality of company information regarding the real numbers. The focus will be on the residential sector, with an average solar energy project assumed to consist of 6 solar panels, 2 batteries and 1 inverter.

At the conclusion of this research, after a comprehensive examination of these dynamics, this study aims to contribute valuable insights into the economic sustainability of the solar energy sector within the unique challenging economic context of Lebanon, delving into the financial health, efficiency, and resilience.

1.1. Literature

Rules pertaining to the administrative, technical and economic conditions associated with self-consumption help establish the economic sustainability of PV system installations (De Gálvez et al., 2024). The literature written about solar energy industry and the impact of exchange rate fluctuations entailed the development of this industry on one hand, and the effect of exchange rate fluctuations in different conditions on the other hand; However, we find that a bulk of the literature in this area is centered on how exchange rate fluctuations and risks affect international trade, with very few exploring the effect on firms' importing performance, and especially in challenging unprecedented circumstances similar to the Lebanese situation. Moreover, among the literature on firms' importing performance, no significant research has studied the interrelation between exchange rate fluctuations and customs-exchange rate fluctuations and the impact on solar energy business, specifically in such challenging environment of a developing country.

A thorough analysis of stand-alone solar household systems (SHS) applied to a developing nation, with an emphasis on Bangladesh, was carried out by (Chowdhury et al., 2019). The data demonstrates that about 13% of the population make use of SHS-provided electricity. The study highlighted the financial benefits and savings while concurrently endorsing environmental sustainability, as SHS is cost-effective and incurs no more fuel expenses over the course of its lifetime after the initial setup charge is settled.

Because of the initial up-front costs, renewable energy may be seen as high-risk; however, Al-Shetwi (2022) addresses Eder's et al. (2018) findings that when lifespan costs are taken into account, it may turn up being a better investment. In order to address the world's energy needs, renewable energy must be incorporated into the electrical system; solar energy represents an emerging clean and sustainable solution (Al-Shetwi, 2022).

A study in Thailand shows that of different renewable energy options, the option of a renewable energy system consisting of (grid + battery storage system + PV) is the one highly recommended in terms of economic and structural criteria. The results proved it to be the most favored option (Yathip et al., 2024).

With this solar energy industry overview, let's narrow to the scope to have a background about the case in Lebanon.

1.2. Background

Renewable energy is now widely recognized as a sustainable and eco-friendly substitute, playing a vital role in the world's energy supply chain. Promoting the development and use of renewable energies is crucial due to their implications on the environment and the economy (Jouali et al., 2024). Lebanon, with its abundant sunlight, has recognized solar energy's potential to alleviate the nation's chronic electricity shortages, primarily managed through private diesel generators. The Lebanese government has introduced reforms, outlined in the "Policy Paper for the Electricity Sector" in 2010 and 2019, aiming to stabilize the energy market, reduce costs, and promote renewable energy sources, targeting 30% renewable energy by 2030 (Ahmad, 2020).

Lebanon's economic crisis, marked by a 98% currency devaluation and banking sector collapse, poses significant challenges. The nation failed to meet its 2020 solar capacity target, but the crisis underscored the urgent need for renewable energy. Rooftop solar installations grew by 47-fold, yet institutional financing remains scarce, leaving individuals to fund their systems through their own savings, remittances, or the sale of personal assets to pay the $4000–$7000 price tag of solar systems. As Lebanon continues to navigate its financial turmoil, solar energy offers a crucial path toward energy resilience, even if meeting the 2030 renewable energy target seems unlikely (Tsagas, 2023).

Lebanon's solar energy market has experienced rapid growth, with an 88% cost reduction in solar PV installations from 2011 to 2018, further accelerated by the removal of customs charges on solar imports in 2018. By 2019, the number of solar projects surged, with 360 new installations, compared to just 25 in 2011 (USAID/CSP, 2022). However, the financial crisis in 2021 intensified demand for solar energy as blackouts became more frequent and local generator costs soared, making solar energy a more cost-effective alternative.

Since 1924, Lebanon has had the intention of using renewable energy sources, especially hydropower, to generate electricity. Hydroelectric plants provided a sizable portion (41.5%) of Lebanon's electricity by 1974. Unfortunately, because of growing demand, decayed infrastructure, and unstable politics, the electric industry has become a major economic and environmental issue. According to Julian et al. (2020), there will be a 56% difference between output and consumption by 2025, facing difficulties such as insufficient generation capacity, technical losses, and financial strain. With more than 3000 hours of sunshine annually, solar energy becomes a practical option. Laws that allow for the sale of excess energy to the grid, government intervention, and cost-benefit analyses of fuel compared to solar-generated electricity highlight the potential contribution of solar energy. They indicate that Lebanon should take its shift to solar energy production very seriously and quickly (Julian et al., 2020).

Kaakour (2023) repeats the point that there are challenges in the way of Lebanon's attempts to extend its national electricity networks. With decentralized solar systems becoming more and more popular for widespread electrification in the underdeveloped world, it has become an attractive choice. Household income, cost, and technology are factors that affect the adoption of solar systems; price assistance to lower acquisition and maintenance expenses has the potential to improve adoption.

Political and bureaucratic delays have driven decentralized solar projects, streamlining decisions for small-scale systems. Despite challenges, solar power

adoption has expanded as households seek alternatives to unreliable power grids. Custom duties lifted on imported solar equipment and high diesel costs have made solar PV systems increasingly attractive. The market has matured, with solar installations driven by households and small businesses, and interestingly, between 2008 and 2018, the average cost of solar PV dropped by 88%, with PV modules (53%) and inverters (21%), the two main cost components (Ahmad, 2020).

Lebanon's financial crisis has been characterized by depreciation of the national currency, instability in the banking system, and economic recession. Fluctuations in customs and exchange rates have become significant determinants of the financial stability of the industries operating in the country. Due to its reliance on imports for technology and equipment, the solar energy sector confronts unique challenges in determining how these financial factors affect its key performance metrics, such as cost, revenue, and profitability, as well as value. To better understand these challenges, we now focus exchange rate fluctuations and customs impact on business.

1.3. Exchange rate fluctuations and customs rates

A nation's exchange rate is a critical indicator of its economic performance, particularly in developing countries where currency stability is crucial for preventing volatility and maintaining local economic stability. Exchange rate fluctuations significantly affect industries, influencing competition, input costs, and the value of assets in foreign currencies (Azhar, 2022). For Lebanon, the collapse of the Lebanese lira during its financial crisis has worsened purchasing power and posed challenges for sectors like solar energy.

Bodnar and Gentry (1993) highlight how currency fluctuations impact business profitability based on a company's operations. Importers benefit from home currency appreciation, which lowers costs, while exporters suffer. Companies using internationally priced inputs are also affected by exchange rate changes, which alter cash flows and overall profitability. In Lebanon, where the solar industry heavily relies on imported technology and equipment, currency depreciation increases costs, threatening the feasibility and profitability of solar projects.

The relationship between exchange rate uncertainty and company profitability is explored by Baum et al. (2001). Given that there are clear predictions about the signs of relationships, the association between exchange rate uncertainty and company profitability's indeterminate sign is similarly important. Numerous studies have linked the behavior, performance, and valuation of firms to elevated exchange rate volatility; nonetheless, the findings of empirical research are inconclusive. The duration of fluctuations and how they interact with the unique economic characteristics of business determine the impact of exchange rate uncertainty on firms (Baum et al., 2001).

Keeley and Matsumoto (2018) mentioned accessibility to local finance and exchange rate stability as factors in the macroeconomic environment affecting direct foreign investments. In the context of the Lebanese solar energy market, such factors significantly influence the sustainability and profitability of the sector. Solar energy projects, which demand a significant initial investment but low variable costs, are less reliant on local financing access, even though mature financial markets can facilitate

financing for foreign businesses (Keeley and Matsumoto, 2018). This reduces the need for local funding and susceptibility to domestic currency changes, which is particularly relevant for solar projects where a significant portion of revenue is paid in US dollars. However, access to local financing becomes more crucial for project success when tariffs are paid in home currency (Keeley and Matsumoto, 2018). Furthermore, the volatility of the exchange rate is a major concern for investors. Exchange rate instability can deter foreign direct investment (FDI) as it increases the perceived risk, particularly in long-term renewable energy projects with lengthy payback periods. Stability in the exchange rate is therefore crucial to attracting investment, as it mitigates the additional risks that arise from currency fluctuations (Keeley and Matsumoto, 2018).

A crucial component of international trade is customs duties. Certain nations promote trade alliances by providing favorable custom rates, sometimes even reaching 0% (Siddiqui and Siddiqui, 2019). Kirkegaard et al. (2010) highlight that while tariffs on solar cells and modules are generally low or nonexistent in major photovoltaic (PV) markets, averaging around 15% for other solar energy components like batteries, mounting structures, and inverters, non-tariff barriers pose significant challenges to international trade. These non-tariff obstacles include taxes, surcharges, customs, varying industry standards, and political expectations, which can collectively increase costs.

Of vital importance, customs taxes are intrinsically linked to changes in exchange rates as a type of import taxation. The cost of imported supplies and equipment for solar projects is directly affected by high customs duties, which are impacted by fluctuations in exchange rates. Consequently, this has an impact on the general profitability and feasibility of solar energy projects in Lebanon. Research, like the ones done on Chile's solar energy projects, shows how solar project costs are sensitive to changes in customs duties (CE) (Servert et al., 2014). The simultaneous impact of exchange rate dynamics worsens these fluctuations. The complex relationship between customs charges and exchange rates generates a dynamic environment that has a major impact on the cost structure and competitiveness of solar energy companies.

Also, Jouali et al. (2024) mentioned in their study that simplifying permitting processes is an important way to establish an enabling environment for renewable energy development.

Although literature offer valuable perspectives on the distinct effects of currency rates and customs taxes, determining the complex impact that solar energy companies address requires an understanding of how these variables affect business performance, as well as how they interact. As these factors influence the solar energy sector's cost dynamics, it is equally important to assess the broader concept of economic sustainability within this sector to gauge long-term viability.

1.4. Economic sustainability

For businesses to succeed over the long term and in an environmentally responsible manner, economic sustainability is essential. Greenly Earth highlights the role that economic sustainability plays in fostering a company's ability to endure throughout time. Jouali et al. (2024) highlights that the switch to renewable energy

sources can increase energy security and decrease volatility in energy prices by reducing reliance on imported fossil fuels, offering a clear economic advantage to contribute to a more stable energy market, thus promoting sustainable development.

Using a combination of business and economic sustainability indicators, the Solability Sustainable Intelligence assesses economic sustainability. Its foundation consists of thirty-one quantitative measures pertaining to development performance, inclusivity, self-sufficiency, etc. Business wise, what we are interested in is the Stability and volatility exposure classified as financial, and growth and market indicators classified as economic indicators by Solability Sustainable Intelligence.

Mesquita et al. (2021) states the Economic indicators, reflected in the literature by Silvius and Schipper (2014) who highlights the "ROI", and Azevedo (2006) who points out "Sales", as well as de Araújo et al. (2006) who sheds light on the "Market" as an indicator, all in addition to other indicators.

Indicators of sustainability, derived from diverse sources including Azevedo (2006), de Araújo et al. (2006), and others, are essential for evaluating and quantifying sustainability. The economic indicators classified by Silvius (2017) are more likely to enhance a thorough assessment. Some of Silvius's (2017) sustainability indicators will be used to categorize the indicators (Mesquita et al., 2021).

Of interest would be for economic sustainability, the return on investment as well as business agility. According to Munns and Bjeirmi (1996), ROI is regarded as an assessment criterion that measures how well a project is performing. Shenhar (2010) also notes that project success, especially in the sustainable domain, can be determined in part by profitability and increasing revenues (Mesquita et al., 2021). Return on investment (ROI) consistently existed as a performance measure and was observable as a sustainability indicator in the economic dimension in every instance, indicating practical outcomes.

In the current competitive business climate, an industry long-term sustainability and growth are largely dependent on its profitability. A key indicator of a company's financial health and viability is its profit margin, which is a fundamental financial metric. It assesses how well a company generates profits in relation to its sales and is commonly considered a crucial component in determining the profitability of an organization (Helm and Stern Branding, 2023).

In the context of Lebanon's unique challenges, these sustainability indicators provide a clear framework for evaluating the feasibility of solar projects as the country continues to navigate its economic instability.

2. Materials and methods

2.1. Approach

The major concern of our study is to understand and analyze the complex dynamics and challenges within the solar energy economic sustainability in Lebanon, particularly in the context of the country's economic crisis. To do this, we will assess the relationships between a set of financial metrics. The variables to be tested are presented in **Table 1** as follows:

Table 1. Variables.

Variable	Variable Type	Description
E.R	Independent variable	Exchange rate relative to the U.S. dollar
C.E.R	Independent variable	Customs official exchange rate
CostLL	Dependent variable	Total cost in L.L.
ProfitLL	Dependent variable	Total profit in L.L.
PMVLL	Dependent variable	Project Market Value in L.L.
CostUSD	Dependent variable	Total cost in USD
PMVUSD	Dependent variable	Project Market Value in USD
ProfUSD	Dependent variable	Profit in USD
RevenueUSD	Dependent variable	Revenue in USD
Prof_marg	Dependent variable	Profit margin (ProfUSD ÷ RevenueUSD)
ROI	Dependent variable	Return on investment (ProfUSD ÷ CostUSD)× 100

Mediating and moderating variable:

ER: Exchange Rate will be predicated with a dual role, both as an independent variable to assess its effect on business economic metrics, and as a mediating variable in the relationship between different metrics.

In our study, we have chosen to log-transform certain variables to address specific statistical considerations and enhance the robustness of our analysis. Log transformation can help also put variables on a similar scale, potentially leading to a clearer analysis.

2.2. Data collection

We collected data over the past three years, on quarterly basis, focusing on key components of solar system projects. **Table 2** provides an overview of the data sources and collection processes:

Table 2. Data collection.

Data Type	Source	Details
Costs of Components (LL & USD)	Solar energy companies	Costs in L.L. for batteries, inverters, and solar panels were provided, and converted to USD.
Profits of Components (LL & USD)	Solar energy companies	Profit data for batteries, inverters, and solar panels were collected and converted to USD.
Market Value of Projects	Solar energy companies	Market value data for batteries, inverters, and solar panels, both in L.L. and USD.
Exchange Rates (E.R.)	Solar energy companies, and open web sources.	Historical exchange rates were gathered over the past 3.5 years.

Due to confidentiality concerns, companies provided approximated figures reflecting the market information, thus significance in studied relations is more of our main focus. Note that exchange rate and customs exchange rate can also be provided from companies in the period of assessing their finances, as well as open web source and Lebanese customs.

Table 3 summarizes the key formulas used in this study and their interpretations:

Table 3. Key formulas.

Metric	Formula	Description
Total Cost (LL/USD)	Cost of Inverters + Cost of Batteries + Cost of Solar Panels (in L.L./USD)	The sum of the costs of key components in Lebanese Lira (L.L./USD)
Total Profit	Profit of Inverters + Profit of Batteries + Profit of Solar Panels	The sum of the profits of key components
RevenueUSD	Cost+Profit (in USD)	Total revenue in USD from the sales
Project Market Value	Price of 2 Batteries + 1 Inverter + 6 Solar Panels	Represents the total market value of a typical household solar system in Lebanon
Profit margin	ProfUSD ÷ RevenueUSD	Provides margin on the financial health
Return on Investment (ROI)	(ProfUSD ÷ CostUSD) × 100, where the CostUSD is considered to be the investment cost.	Efficiency metric that allows determining stability and viability.

Then, the data is imported into SPSS, where we conduct a detailed quantitative analysis. This step allows us to explore the relationships between the variables and uncover valuable insights into how these factors influence the overall financial performance of the business.

3. Results and discussion

In this section, we present the key findings of our analysis offering insights into how various economic factors and project-specific metrics interact. By examining the econometric dynamics, we aim to provide a clearer understanding of the financial performance and viability of solar energy business in the Lebanese market.

3.1. Correlation analysis

Correlation analysis between economic measures and exchange rate helps understand the impact of currency fluctuations and evaluate profitability in the face of such environment. This is important since financial resilience is a key component of economic sustainability. **Table 4** shows the results of the tested correlations.

Table 4. Correlations ER, CER, and economic metrics.

		ER	CER	SSPI	CostLL	ProfLL	PMVLL	CostUSD	PMVUSD	ProfUSD
ER	Pearson Correlation	1	0.771**	0.133	0.763**	0.786**	0.993**	−0.052	−0.917**	0.070
	Sig. (2-tailed)		0.001	0.636	0.001	0.001	0.000	0.855	0.000	0.803
	N	15	15	15	15	15	15	15	15	15
CER	Pearson Correlation	0.771**	1	0.009	0.777**	0.759**	0.717**	−0.027	−0.626*	0.018
	Sig. (2-tailed)	0.001		0.974	0.001	0.001	0.003	0.924	0.013	0.949
	N	15	15	15	15	15	15	15	15	15

Note: ** Correlation is significant at the 0.01 level (2-tailed). * Correlation is significant at the 0.05 level (2-tailed).

After conducting a Pearson correlation analysis, we found:

- The correlation coefficient between customs exchange rate and cost in USD was found to be statistically insignificant (p = 0.924). This suggests that there is no significant relationship between Customs Exchange Rate (CER) and CostUSD in the analyzed data.
- The correlation coefficient between customs exchange rate and profit in USD was found to be 0.018 (p = 0.949). The correlation is weak and statistically insignificant. This suggests that there is no significant relationship between ER and ProfitUSD in the analyzed data.

The correlation study provides insights into potential associations between CER, ER, and certain industry metrics:

Strong positive correlations:

ER and Cost in Lira (CostLL) and Profit in Lira: Lira depreciation versus USD leads to higher costs in LL (due to import prices) and potentially the business compensate by raising values in LL to boost profitability.

ER and Market Value of Project in Lira (PMVLL): This shows that the market value of solar projects in Lebanese Lira (LL) rises in alongside an increase in the exchange rate. This is probably because LL expenses increase with a rising exchange rate since the cost of components, which are imported, is expressed in foreign currency.

The negative correlation between project market value in USD and each of ER and CER solely means that both exchange rate fluctuations and customs exchange rate have a negative impact on the project market value in USD. It reveals that the value of a project has decreased upon the Lira depreciation environment, suggesting that the business tend to decrease prices in order to compensate for the adverse effects of increasing exchange rate climate. In addition, the decreasing trajectory of the market value of projects in USD over the years prompts considerations for adapting pricing strategies or exploring factors influencing project valuation. This decrease of prices may be through various ways, whether through importing lower price components, perhaps explaining the statement of the USAID/CSP (2022) report, lowering the profit, being more competitive , or other opportunities.

Weak and insignificant correlations:

ER and cost/profit in USD: The insignificant correlations show that the exchange rate does not have a direct impact on project costs and profitability USD.

With strong positive correlations with market value, cost, and profit in LL and weak correlations with cost and profit in USD, the results for CER are quite similar to those for ER. This implies that, both ER and CER have comparable effects on the business financial metrics in Lebanese Lira.

The interpretation of the high positive correlations suggests that the valuation of solar energy projects in local currency is influenced by variations in both the exchange rate and the customs exchange rate, which is to be expected given the large margin of instability in exchange rate. Also, despite the increasing impact on costs in L.L., profitability in L.L. is positively influenced by exchange rate. Thus, exchange rates and customs exchange rates continue to impact costs and profits in Lebanese Lira, reflecting the interplay between local and global economic factors.

In a dollarized local landscape, the findings highlight how crucial it is to comprehend the effects of exchange rate changes, in a context where projects are to be assessed in both local and foreign currencies. When taking into account a local currency income customer, the strong positive relationships between ER/CER and numerous economic variables in Lebanese Lira demonstrate how sensitive the solar energy business is to variations in both exchange and customs exchange rate. Thus from a Lebanese resident perception with Lira income, the higher the exchange rate the higher the project price, and still, the higher the business is gaining although business costs became higher. The strong correlation between exchange rates and market value in L.L. implies that citizens may experience fluctuations in project affordability based on exchange rate movements. Depending on exchange rate dynamics and income, citizens may find solar projects to be more or less affordable. This highlights the importance of strategic planning and policies to guaranteeing the widespread and sustainable adoption of renewable energy solutions across a range of consumers and residents with varying economic levels. However, people found ways to access it, as mentioned by Tsagas (2023), relying on their own savings, remittances, or the sale of personal assets, which suggests a further study of customers' perceptions impact.

Nevertheless, the analysis suggests that neither the exchange rate nor the customs exchange rate significantly affects cost in USD or profit in USD. Such a level of independence in these aspects from currency dynamics is due to the ability of the business to mitigate the economic circumstances through dollarization. This stability in certain aspects contributes to the overall resilience and sustainability of the solar energy business. Businesses have adopted dollarization approaches to control costs and revenues in US dollars regardless of the short-term exchange rate. This strategic approach ensured a level of stability in financial metrics of the core business, supporting economic sustainability. This stability can be explained due to some factors, as first the customs exchange rate was preserved to be on the same low rate at 1508 for a long time during the crisis, probably as a governmental decision, encouraging the business and preserving a level of local currency exchange. Also the fuel prices and high private-sector electricity bills, as mentioned in the USAID/CSP (2022) report, have impacted the customer perception towards installing solar energy projects, effectively driving the demand and consequently the economic metrics of the market.

Actually, the business thus found the situation as an opportunity, taking into consideration other different factors like lack of governmental electricity and high fuel prices leading to high private-sector electricity bills, and maintained a trending to stable trajectory of performance.

All of the above results prove the main point that the solar energy business have benefited from the situation to prosper its market while ensuring sustained profitability and economic sustainability. Also during the crisis, the business adopted a strategic pricing approach in response to currency dynamics. This strategy aims to maintain competitiveness, manage risks, and ensure affordability in the face of economic challenges. The identified correlations provide insights into the business dynamic nature and profitable performance during economic crisis, highlighting its overall economic sustainability.

3.2. Hierarchal regression analysis

Hierarchical regression analysis plays a crucial role in understanding the factors influencing the profit margin and ROI of the business. It allows to investigate the impact of project market value (PMVUSD) alongside exchange rates (ER and CER) in a step-by-step manner. This method allows for a step-by-step assessment of each variable's contribution to the overall variance explained in profitability, highlighting the incremental significance of exchange rate dynamics. It is particularly useful in this study as it enables the isolation and detailed analysis of external economic factors on business financial metrics, thereby offering deeper insights into the economic sustainability of the solar energy business in a volatile economic environment. This approach can be explained as the following:

Block 1 effect with PMVUSD alone: establishes the initial influence of project market value in USD on profit margin and ROI.

Block 2 adding ER: reveals its independent contribution to profit margin and ROI beyond market value through isolating its effect.

Block 3 including CER: allows to assess its distinct impact on profit margin and ROI.

In our study, we have chosen to log-transform certain variables to address specific statistical considerations and enhance the robustness of our analysis. Log transformation can help also put variables on a similar scale, potentially leading to a clearer analysis. **Tables 5, 6** and **7** show the results of the hierarchal regression performed.

Table 5. Hierarchal regression *R*-square change-outcome profit margin.

Model	*R*	*R* Square	Adjusted *R* Square	Std. Error of the Estimate	*R* Square Change	*F* Change	Sig. *F* Change
1	0.778[a]	0.605	0.575	0.02843	*R* Square Change	*F* Change	Sig. *F* Change
2	0.875[b]	0.765	0.726	0.02282	0.160	80.173	0.014
3	0.929[c]	0.863	0.826	0.01821	0.098	70.854	0.017

Note: [a,] Model 1 includes **PMVUSD** (Project Market Value in USD), establishing its initial influence on profit matgin. [b,] Model 2 adds **ER** (Exchange Rate), revealing its independent contribution to profit margin beyond the effect of Project Market Value by isolating its effect. [c,] Model 3 includes **CER** (Customs Exchange Rate), allowing for the assessment of its distinct impact on profit margin.

Table 6. Hierarchal regression ANOVA-outcome profit margin.

ANOVA[a]						
Model		**Sum of Squares**	**df**	**Mean Square**	***F***	**Sig.**
1	Regression	0.016	1	0.016	19.910	0.001[b]
	Residual	0.011	13	0.001		
	Total	0.027	14			
2	Regression	0.020	2	0.010	19.534	0.000[c]
	Residual	0.006	12	0.001		
	Total	0.027	14			
3	Regression	0.023	3	0.008	23.080	0.000[d]

	Residual	0.004	11	0.000
	Total	0.027	14	

Table 7. Hierarchal regression-outcome profit margin.

Coefficients[a]						
Model		**Unstandardized Coefficients**		**Standardized Coefficients**	***t***	**Sig.**
		B	**Std. Error**	**Beta**		
1	(Constant)	1.557	0.321		4.850	0.000
	logPMVUSD	−0.178	0.040	−0.778	−4.462	0.001
2	(Constant)	−0.902	0.898		−1.005	0.335
	logPMVUSD	0.071	0.093	0.309	0.763	0.460
	logER	0.046	0.016	1.158	2.859	0.014
3	(Constant)	0.180	0.814		0.221	0.829
	logPMVUSD	−0.040	0.084	−0.176	−0.480	0.641
	logER	0.038	0.013	0.954	2.879	0.015
	logCER	−0.014	0.005	−0.435	−2.803	0.017

Block 1:

- *R*-squared (0.605): This indicates that 60.5% of the variance in profit margin is explained by the model after accounting for PMVUSD.
- Significance (*p*-value = 0.001): The model is statistically significant, meaning there's a relationship between PMVUSD and profit margin.

Block 2:

- Increase in *R*-squared (0.160): Adding ER to the model explains an additional 16% of the variance in profit margin compared to Model 1 (using only PMVUSD).
- Significance (*p*-value = 0.014): The model is statistically significant, meaning there's a relationship between ER and profit margin.

Block 3:

- Further increase in *R*-squared (0.098): Including CER alongside ER in the model explains an additional 9.8% of the variance compared to Model 2.
- Significance (*p*-value = 0.017): The model is statistically significant, meaning there's a relationship between CER and profit margin.

PMVUSD (Project market value):

Block 1: The negative coefficient indicates the negative relationship between project market value (PMVUSD) and profit margin.

Blocks 2 & 3: The coefficient for LOGPMVUSD becomes non-significant in the later models. This suggests that the initial negative relationship with PMVUSD might be due to its indirect effect through exchange rates (ER and CER). Once the exchange rates are accounted for, the direct effect of PMVUSD on profit margin becomes statistically insignificant.

LOGER (exchange rate):

Blocks 2 & 3: The positive coefficient for LOGER indicates a beneficial effect of a Lira depreciation on profitability.

LOGCER (customs exchange rate):

Block 3: The negative coefficient for LOGCER indicates a negative relation between customs exchange rate and profit margin, generally due to costs increase.

Thus, perhaps the relationship between market value and profit margin depends on the exchange rate.

Tables 8, 9 and **10** show the results of the hierarchal regression analysis of ROI as outcome model:

Table 8. Hierarchal regression *R*-square change-outcome ROI.

Model	*R*	*R* Square	Adjusted *R* Square	Std. Error of the Estimate	*R* Square Change	*F* Change	Sig. *F* Change
1	0.782[a]	0.612	0.582	3.56081	0.612	20.482	0.001
2	0.868[b]	0.754	0.713	2.94910	0.142	6.952	0.022
3	0.928[c]	0.861	0.823	2.31613	0.107	8.455	0.014

Note: [a,] Model 1 includes **PMVUSD** (Project Market Value in USD), establishing its initial influence on ROI. [b,] Model 2 adds **ER** (Exchange Rate), revealing its independent contribution to ROI beyond the effect of Project Market Value by isolating its effect. [c,] Model 3 includes **CER** (Customs Exchange Rate), allowing for the assessment of its distinct impact on ROI.

Table 9. Hierarchal regression ANOVA-outcome ROI.

ANOVA[a]						
Model		**Sum of Squares**	**df**	**Mean Square**	***F***	**Sig.**
1	Regression	259.704	1	259.704	20.482	0.001[b]
	Residual	164.832	13	12.679		
	Total	424.536	14			
2	Regression	320.169	2	160.085	18.406	0.000[c]
	Residual	104.367	12	8.697		
	Total	424.536	14			
3	Regression	365.527	3	121.842	22.713	0.000[d]
	Residual	59.009	11	5.364		
	Total	424.536	14			

Table 10. Hierarchal regression-outcome ROI.

Coefficients[a]						
Model		**Unstandardized Coefficients**		**Standardized Coefficients**	***t***	**Sig.**
		B	**Std. Error**	**Beta**		
1	(Constant)	196.449	40.205		4.886	0.000
	logPMVUSD	−22.644	5.003	−0.782	−4.526	0.001
2	(Constant)	−96.654	116.043		−0.833	0.421
	logPMVUSD	7.036	11.995	0.243	0.587	0.568
	logER	5.525	2.095	1.092	2.637	0.022
3	(Constant)	46.244	103.541		0.447	0.664
	logPMVUSD	−7.631	10.686	−0.264	−0.714	0.490

logER	4.446	1.687	0.879	2.635	0.023
logCER	−1.838	0.632	−0.454	−2.908	0.014

Block 1:

- *R*-squared (0.612): This indicates that 61.2% of the variance in ROI is explained by the model after accounting for PMVUSD.
- Significance (*p*-value = 0.001): The model is statistically significant, meaning there's a relationship between PMVUSD and ROI.

Block 2:

- Increase in *R*-squared (0.142): Adding ER to the model explains an additional 14.2% of the variance in ROI compared to Model 1 (using only PMVUSD).
- Significance (*p*-value = 0.022): The model is statistically significant, meaning there's a relationship between ER and ROI.

Block 3:

- Further increase in *R*-squared (0.107): Including CER alongside ER in the model explains an additional 10.7% of the variance compared to Model 2.
- Significance (*p*-value = 0.014): The model is statistically significant, meaning there's a relationship between CER and ROI.

PMVUSD (project market value):

Block 1: The negative coefficient indicates the negative relationship between project market value (PMVUSD) and ROI.

Blocks 2 & 3: The coefficient for PMVUSD becomes in the later models. This suggests that the initial negative relationship with PMVUSD might be due to its indirect effect through exchange rates (ER). Once the exchange rates are accounted for, the direct effect of PMVUSD on ROI becomes statistically insignificant.

LOGER (exchange rate):

Blocks models 2 & 3: The positive coefficient for LOGER indicates that indicates a beneficial effect of a higher exchange rate (Lira depreciation versus USD) on return on investment.

LOGCER (customs exchange rate):

Block 3: The negative coefficient for LOGCER indicates that a negative relation between customs exchange rate and profit margin, generally due to costs.

This also highlights possibility of interaction effects between PMVUSD and exchange rates. Perhaps the relationship between market value and ROI depends on the exchange rate.

The Hierarchal regressions show that, despite the shifting dynamics of the market value (PMVUSD), a significant proportion of the variance in profit margin and ROI can be explained by the models, especially when ER and CER are included and the *R*-square variances are used. This is alongside the rising trend and stability observed in the profit margin and ROI. The statistically significant *p*-values for each model indicate that, despite rising exchange rates and declining project market value, there is still a strong correlation between these variables from one hand and each of profit margin and ROI separately. The positive coefficients for LOGER in blocks 2 and 3 indicate that the business is able to sustain or even improve its revenue and profitability in alongside rising exchange rate fluctuations. Noticing the downward trend in

PMVUSD throughput the analysis, pointing to possible difficulties in keeping project valuation stable, the consistency seen in ROI and profit margin suggests that the solar energy business is resilient enough to adapt and maintain profitability and generating revenue. This emphasizes the idea that the business benefited from the environment of fluctuating exchange rates, likely due to a variety of external factors also, including competition, government policies, lack of electricity provided by the government, and consumer perception, and thus arises the need for additional qualitative research. For the first 12 quarters, CER data indicates consistency in customs exchange rates, which could offer some predictability for the solar energy business. Although there may be cost implications due to customs-related issues, as indicated by block 3's negative coefficient for LOGCER, the business appears to be managing these costs considering the stability of its profit margin and ROI. This may be with the help of maintaining a constant CER for a certain period throughout the crisis probably as mentioned before, as a governmental policy.

3.3. Mediation analysis

In order to test the mediation of ER on the relationship between CER and PMVUSD, Hayes process is also used, and we get the following results.

Evaluating the business economic viability involves taking into account how currency rates affect the market value of solar systems. According to data, the customs exchange rate remained steady until the beginning of 2023, most likely as a result of government policy. Still, interesting results were found. The data doesn't definitively establish a causal relationship between CER and ER; this correlation might not necessarily reflect a cause-and-effect relationship. Subsequently, the discussion can be shifted towards the mediation effect and the significant impact of ER on the project market value in USD (PMVUSD). Regardless of the CER-ER relationship, this part of the analysis remains valid.

Table 11 shows the results of the mediation analysis of ER on the relationship between CER and PMVUSD

Model: 4
Y: logPMVUS
X: logCER
M: logER
Sample Size: 15

Table 11. Mediation analysis of ER on the relationship between CER and PMVUSD.

OUTCOME VARIABLE: LogER

Model Summary

R	R-sq	MSE	F	df1	df2	p
0.5772	0.3331	0.8514	6.4938	1.0000	13.0000	0.0243

Model

Coeff	se	t	p	LLCI	ULCI

Constant	6.2758	1.4401	4.3577	.0008	3.1641	9.3875
LogCER	.4620	.1813	2.5483	.0243	.0703	.8538

****

OUTCOME VARIABLE: LogPMVUSD

Model Summary

R	R-sq	MSE	F	df1	df2	p
.9525	.9072	.0039	58.6839	2.0000	12.0000	.0000

Model

	Coeff	se	t	p	LLCI	ULCI
Constant	9.6752	.1532	63.1559	.0000	9.3414	10.0091
LogCER	-.0279	.0151	-1.8547	.0884	-.0607	.0049
LogER	-.1438	.0188	-7.6459	.0000	-.1848	-.1028

********** TOTAL EFFECT MODEL **********

OUTCOME VARIABLE: LogPMVUSD

Model Summary

R	R-sq	MSE	F	df1	df2	p
.6748	.4553	.0212	10.8685	1.0000	13.0000	.0058

Model

	Coeff	se	t	p	LLCI	ULCI
Constant	8.7728	.2274	38.5853	.0000	8.2815	9.2640
LogCER	-.0944	.0286	-3.2967	.0058	-.1562	-.0325

We found:

A significant relationship between logCER and the mediator ($p = 0.0243 < 0.05$)

A significant influence between logCER and logPMVUSD ($p = 0.0058 < 0.05$)

After accounting for the mediator, the impact logER on logPMVUSD is significant ($p = 0.000 < 0.05$) and that of logCER on logPMVUSD became insignificant ($p = 0.0884 > 0.05$)

The finding that Exchange Rate Fluctuations (ER) render the Customs Exchange Rate (CER) impact on Market Value (PMVUSD) insignificant indicates ER mediates the relationship between CER and PMVUSD. In other words, ER explains the relationship between customs exchange rate and the market value of the solar energy project. This implies that exchange rate fluctuations overshadow the impact of customs on how companies adjust values of solar energy projects in USD during the crisis period.

These findings suggest a strategic response from the business to manage project prices over time in order to remain competitive in the market and make projects more appealing to potential consumers. The business appears to be reasonably adaptive to

the economic situation as seen by its capacity to modify pricing tactics in response to a fluctuating rates economic climate. This approach might also take into account the affordability of solar projects for customers. By aligning prices with local currency dynamics, the business enhances accessibility and appeal to a wider spectrum of consumers. In a dollarized industry, where the majority of financial transactions are made in USD, project pricing adjustments in reaction to ER and CER changes become critical. This adaptation is essential for business ensuring economic sustainability.

In order to test the mediation of ER on the relationship between PMVUSD and profit margin, the data variables are normalized using logarithm ln, and Hayes Process is also used; **Table 12** shows the results of the mediation analysis

Model: 4
Y: prof_mar
X: logPMVUS
M: logER
Sample Size: 15

Table 12. Mediation Analysis of ER on the relationship between PMVUSD and profit margin.

OUTCOME VARIABLE: logER

Model Summary

R	R-sq	MSE	F	df1	df2	p
.9384	.8807	.1524	95.9237	1.0000	13.0000	.0000

Model

	Coeff	se	t	p	LLCI	ULCI
Constant	53.0508	4.4075	12.0366	.0000	43.5276	62.5740
LogPMVUSD	-5.3719	.5485	-9.7941	.0000	-6.5571	-4.1868

****

OUTCOME VARIABLE: prof_mar

Model Summary

R	R-sq	MSE	F	df1	df2	p
.8747	.7650	.0005	19.5344	2.0000	12.0000	.0002

Model

	Coeff	se	t	p	LLCI	ULCI
Constant	-.9023	.8979	-1.0049	.3348	-2.8591	1.0544
LogPMVUSD	.0708	.0928	.7626	.4604	-.1315	.2730
LogER	.0464	.0162	2.8589	.0144	.0110	.0817

********** TOTAL EFFECT MODEL **********

OUTCOME VARIABLE: prof_mar

Model Summary

R	R-sq	MSE	F	df1	df2	p
.7778	.6050	.0008	19.9097	1.0000	13.0000	.0006

Model

	Coeff	se	t	p	LLCI	ULCI
Constant	1.5568	.3210	4.8502	.0003	.8632	2.2503
LogPMVUSD	-.1782	.0399	-4.4620	.0006	-.2645	-.0919

We found:

A significant relationship between logPMVUSD and the mediator (p= 0.000 < 0.05).

A significant relationship between logPMVUSD and profit margin (p = 0.0006 < 0.05).

After accounting for the mediator, we found a significant relationship between logER and profit margin (p = 0.0144 < 0.05) but the impact of logPMVUSD on profit margin became insignificant (p = 0.4604 > 0.05)

The significant impact of PMVUSD on profit margin and the subsequent influence of ER on profit margin, with PMVUSD's impact becoming insignificant after accounting for ER, shows another mediation effect. The solar energy business witnessed significant growth, leading to increase in USD currency in the country. A growing solar sector can attract foreign investment, surging USD currency to the country, through different ways mainly through money transfer from expatriates, and supporting the local currency, explaining perhaps the negative relationship between PMVUSD and ER; and in the case of a decreasing project market value in USD upon the crisis, and as businesses adjusted values to mitigate and took a dollarization approach, a decreased demand for the domestic currency to finance solar projects can depreciate its value relative to other currencies which can further explain the negative coefficient of PMVUSD on the ER. As mentioned before, exchange rates are primarily driven by large-scale economic factors like inflation and overall economic health. The market value of project and costs in LL wouldn't be enough to cause significant fluctuations; it's more likely due to an underlying economic factor impacting both variables. But still, as the results showed significance, it provides a small picture of the complex interaction of the economic dynamics through this modest impact.

An interpretation for such a result can be related to the fact that, in spite of their higher upfront costs, people are still more interested in solar systems due to factors like rising energy bills or government incentives. In order to sustain profitability and account for fluctuations in currency rates, certain strategic initiatives and effective price modifications in both USD and Lira are also implemented. Therefore, the high and increasing profit margins suggest that other factors resulting from the Lira depreciation environment may influence the impact of exchange rate on the relationship between customs and projects market value in USD, then consequently on profit margins, leading to overall profitability growth. Another interpretation of this

mediation effect is that fluctuations in the exchange rate, influenced by factors such as economic conditions, inflation rates, or monetary policies, may have a more direct and significant impact on the profitability of the company than changes in the market value of solar energy projects alone. Exchange rate fluctuations can affect various aspects of the business, including competitiveness and customers' perceptions, cost structures and other issues which can ultimately influence profit margins.

3.4. Profitability analysis

To have a better reflection of the market-business-wise study regarding market value of projects, we will use the PMVUSD of the projects. **Figure 1** shows project market value in USD variation by time.

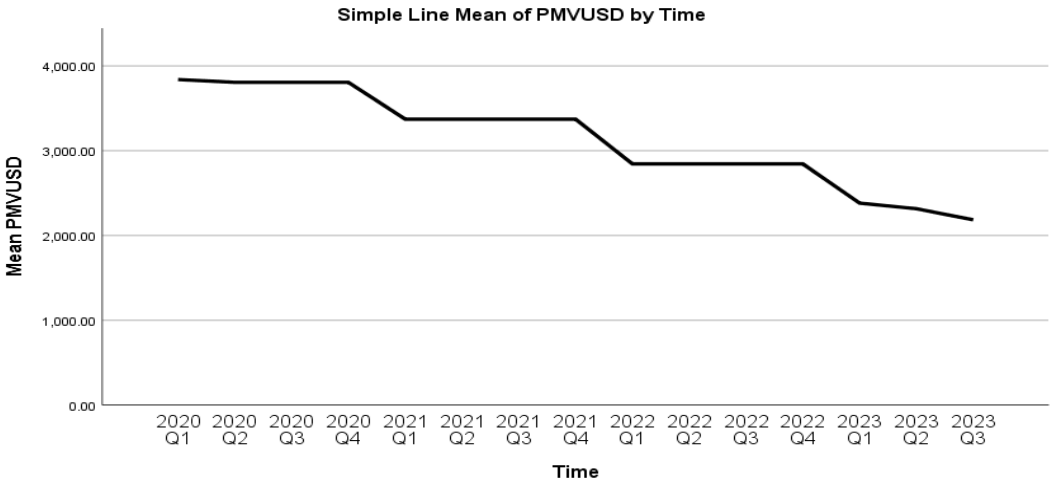

Figure 1. Project market value in USD variation by time.

Project Market Value (PMVUSD) trend analysis during the crisis shows evidence of yearly decrease; still, the stable pattern within each year indicates no significant fluctuations within a year. This emphasizes the pricing adaptation strategy embraced by the business.

To have a better reflection of the market-business-wise study regarding profits, we will use the ProfitUSD. **Figure 2** shows profit in USD variation by time.

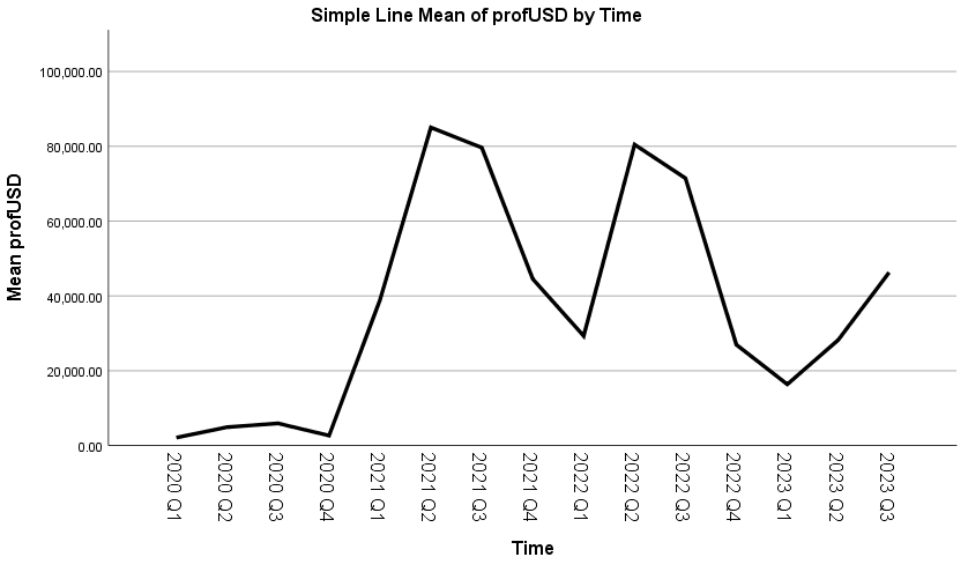

Figure 2. Profit in USD variation by time.

The time series plot illustrates the quarterly company profits over the past three years. The trend component starts with the end of 2020 and takes upward trajectory, then the time series appears relatively stable with gradual ups and downs, then starts to decreases to relatively lower values starting 2023. Seasonal decomposition identifies a noticeable quarterly pattern. Profitability consistently peak during the second quarter of each year (except 2020), reflecting a seasonality effect where the business experiences increased profitability during that specific period.

Furthermore, a consistently profitable business is able to adapt to market fluctuations, contributing to the economic sustainability of the business. The time series analysis of quarterly business profitability in Lebanon's solar energy sector finds several interesting trends and correlations that provide light on the business viability. A dynamic and evolving marketplace during the crisis can be determined by the increasing trajectory of profits starting at the end of 2020, the stable performance with minor variations, and the relative decline in 2023. The seasonality effect, with consistent profitability peaks during the second quarter of each year, underscores the periodic nature in the business, possibly impacted by factors like demand variations, the idea acceptance itself, or external conditions.

The time-series analysis reveals that the business experienced the environment of exchange rate fluctuations (Lira depreciation) as a potential, adjusted its metrics and sustained growth in performance before it relatively declined from its maximum, but still stabilized, driven by additional factors that further needs research. It thus provides important information about the economic sustainability of the business during the crisis in Lebanon. An encouraging sign for economic sustainability is the observed consistency. This enables businesses to plan effectively, control costs, and make strategic decisions.

3.5. ROI and profit margin analysis

Economic sustainability indicators: Now delving into the assessment of profit margins and ROI, they are considered to be main indicators of economic sustainability as mentioned in the studies of Mesquita et al. (2021) and Helm & Stern Branding, LLC

(2023). Profit margins provide insights into the financial health of a business, healthy profit margins are a sign of well-run operations converting revenues into profits. Also, a consistent positive ROI signifies that the business is generating a good return for each dollar invested in its operations (including costs associated with solar systems and installations), highlighting the business viability. Sustainable ROI contribute to economic stability by fostering business growth. **Table 13** shows the correlation analysis between ER, ROI and profit margin, and **figures 3, 4** and **5** shows correlation scatter plots between ER and ROI, ER and profit margin, and ROI and profit margin respectively.

Table 13. ER, ROI and profit margin correlations.

Correlations				
		ER	**ROI**	**prof_marg**
ER	Pearson Correlation	1	0.597*	0.596*
	Sig. (2-tailed)		0.019	0.019
	N	15	15	15

Note: * indicates that the correlation is statistically significant at the 0.05 level

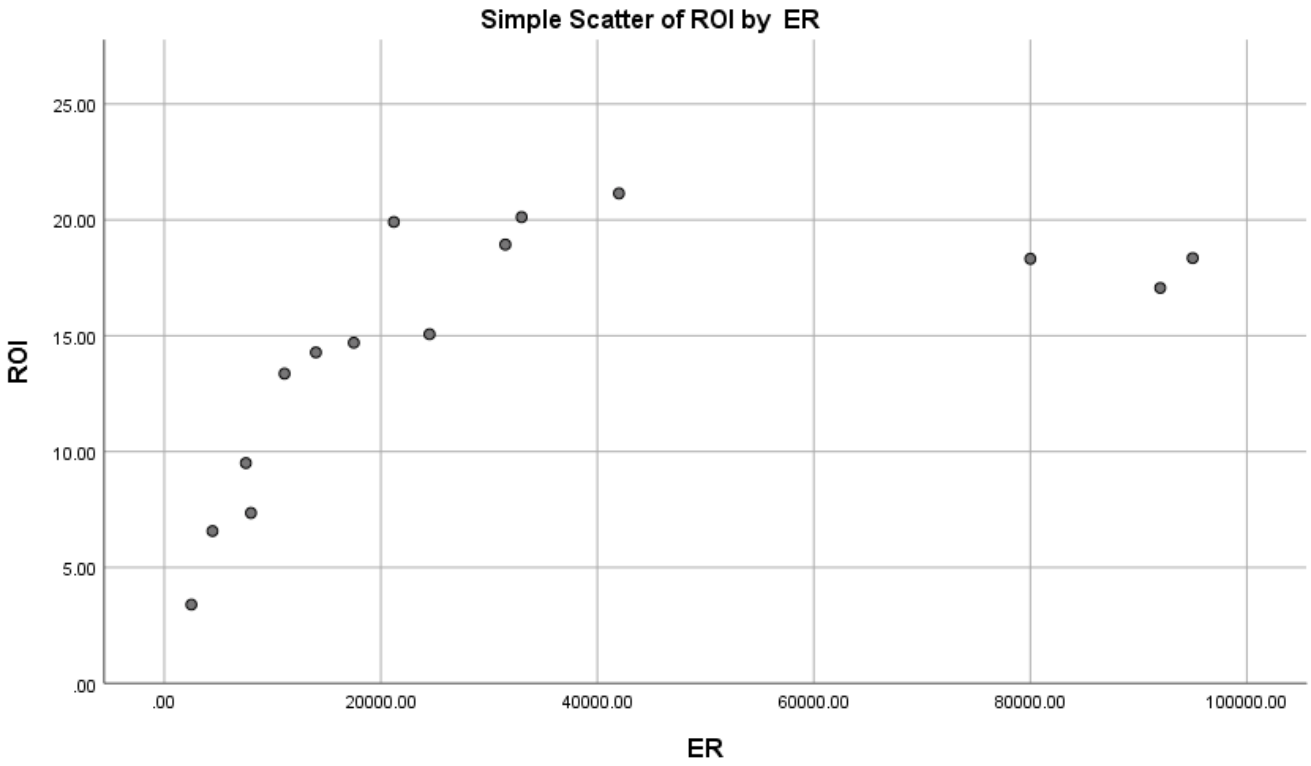

Figure 3. ROI and ER correlation scatter plot.

These results indicates:

A significant positive correlation between Exchange Rate ER and the ROI ($r = 0.597$, $p < 0.05$). This indicates that as Lira depreciates versus USD, ROI tends to increase as well.

A significant positive correlation between Exchange Rate ER and the profit margin ($r=0.596$, $p < 0.05$). This indicates that as Lira depreciates versus USD, profitability tends to increase as well. The relationship is statistically significant.

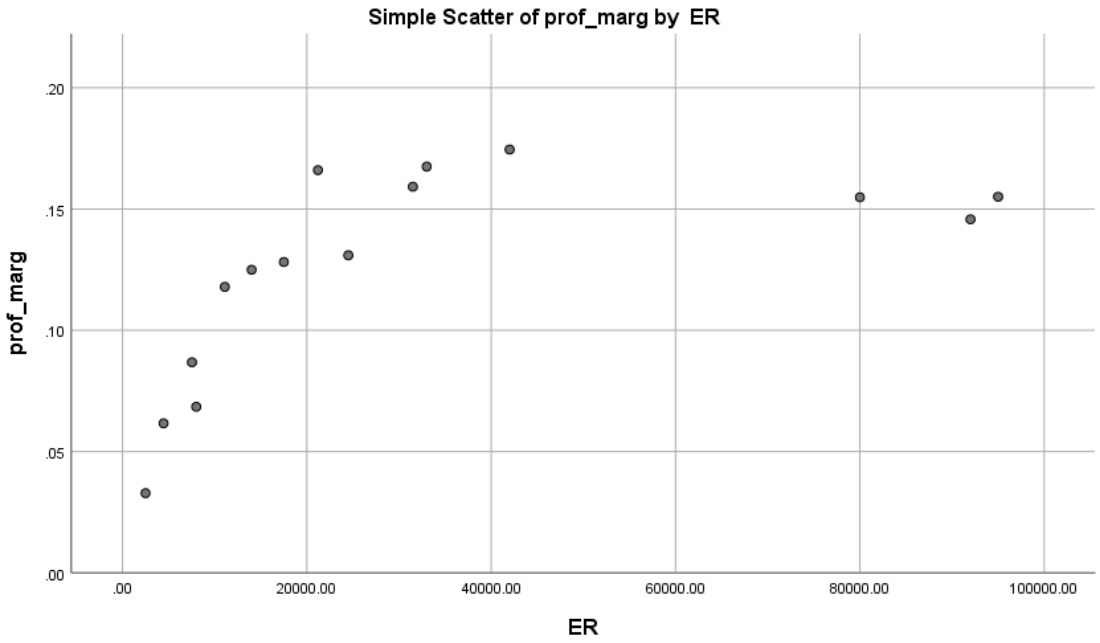

Figure 4. ER and profit margin correlation.

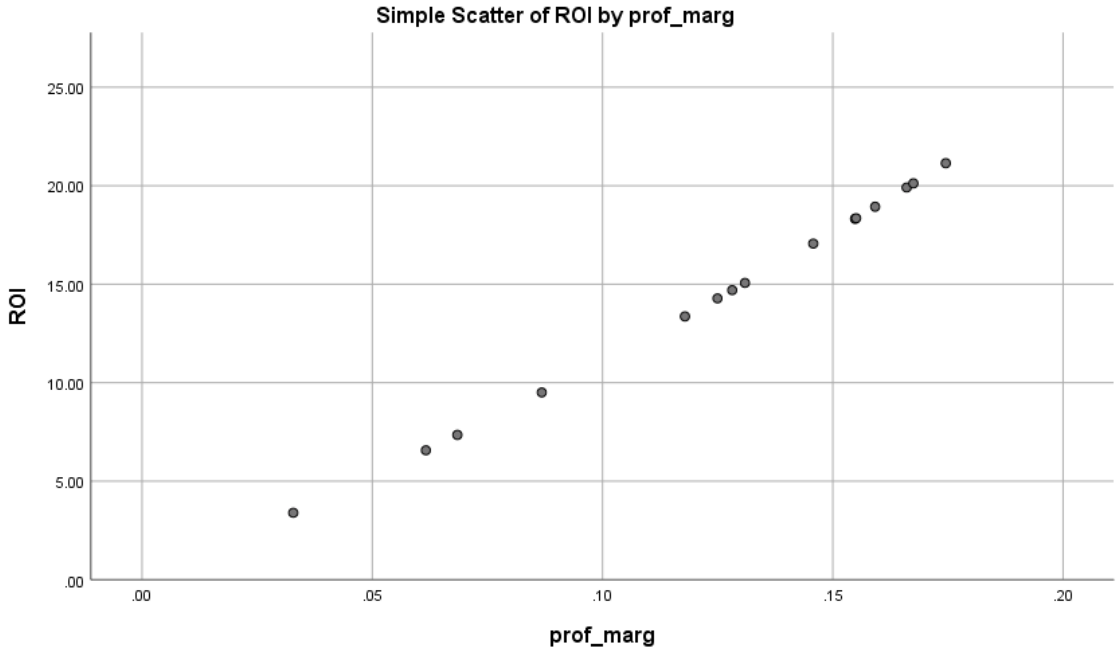

Figure 5. ROI and profit margin correlation.

A strong positive correlation between Exchange Rate ER and the ROI is clear from the above figure. This indicates that as Lira depreciates versus USD, ROI increases as well.

The moderate positive correlation between exchange rate (ER) and ROI and the strong positive correlation with profit margin indicate that the business is benefiting

from the current exchange rate environment, but probably as mentioned before, affected by various factors that require a more qualitative research assessing the customers' perception impacts driving the demand. As Lira depreciates versus USD, ROI and profitability tend to rise as well, suggesting a positive impact on the economic health of the business, as the business took advantage of the situation and excelled its performance and still maintaining it.

The strong positive correlation also between Return on Investment (ROI) and Profit Margin during the crisis period provides that as the business profitability increases (as indicated by the profit margin), so does its return on investment. Despite the crisis period, the business demonstrates robust healthy financial performance.
To have a look on the profit margin variation by time, as well as the ROI variation by time, **figures 6** and **7** respectively provide a clear view of these variations.

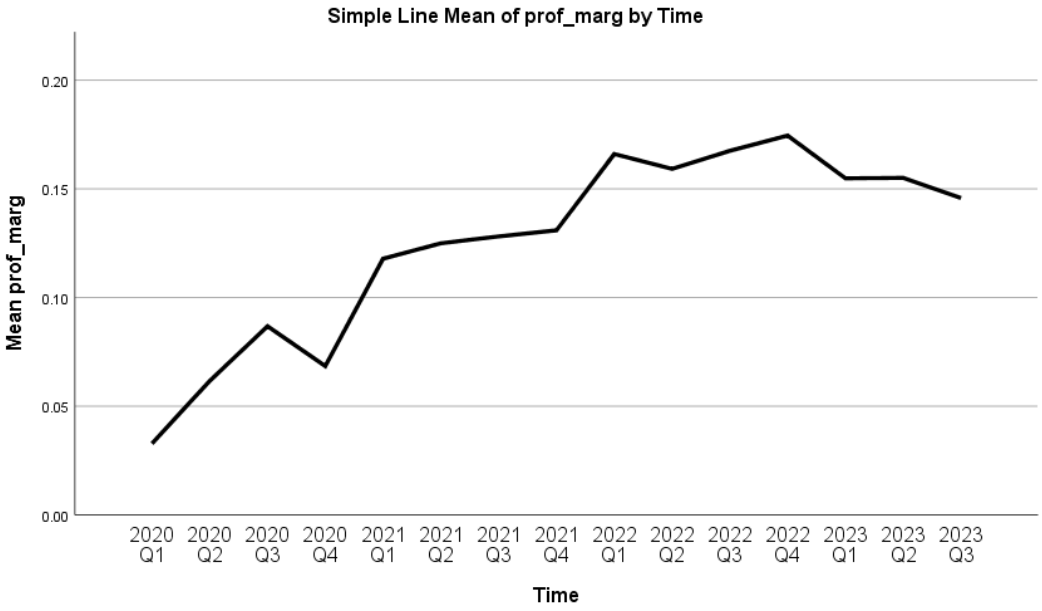

Figure 6. Profit margin variation by time.

This time series plot shows the increasing then stable trend of profit-margins over the last 3.5 years.

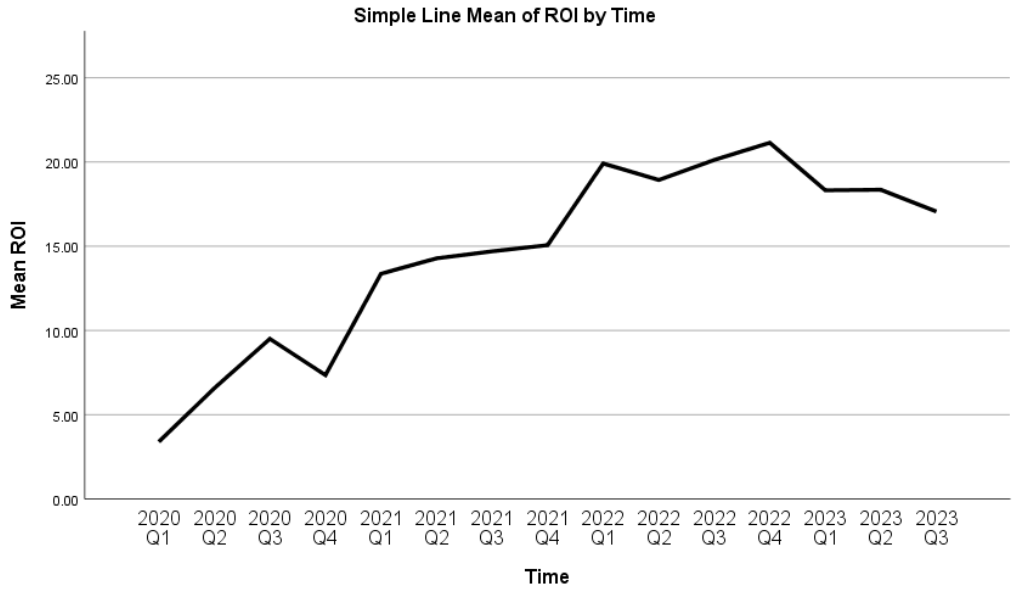

Figure 7. ROI variation by time.

This time series plot shows the increasing then stable trend of company ROI over the last 3.5 years.

This provides an optimistic view of the business financial performance. The sustainable growth is linked to the proved business ability to effectively manage the balance between profitability and consumer affordability, as well as preserve its successful and healthy performance taking the potential of such situation.

In summary, the observation that Return on Investment (ROI) and Profit Margin exhibit a trending stable pattern during the crisis period is a remarkable finding that further enhances the following points regarding the solar energy business:

Growth and stability amid crisis: the consistent pattern of ROI and profit margin during the crisis era proves that the business was able to enhance its financial performance and health, providing evidence of its economic sustainability.

Adaptability: The business has successfully adjusted its operations and plans to the crisis environment, taking advantage of various circumstances and adapting through the crisis period, reflected by the trending steady pattern in ROI and Profit Margin.

Confidence in market: These results signal to investors and stakeholders that the business is strong and able to generate consistent returns, boosting thus the trust and attracting support and investments, and fostering confidence in the business economic sustainability.

Lastly, economic sustainability: A business resilience in the face of a crisis is demonstrated by its capacity to maintain a consistent return on investment and profit margin. By keeping profitability levels high, the business is able to grow, support its operations, and manage economic conditions in order to continue to succeed and expand.

Combining ROI, profit margins, economic metrics, and overall performance provides a holistic view of a business financial performance. This thorough research aids in comprehending the business's economic sustainability. All things considered, these insights help to create a thorough grasp of the dynamics of the solar energy

industry and give stakeholders useful insight into various aspects of business operations and metrics. The findings demonstrate the several impacts on the business metrics and its ability ensure economic sustainability.

4. Conclusion

In conclusion, the solar energy business thrived throughout the crisis. Exchange rates fluctuations did not hinder growth; in fact, the business excelled during the situation with a dollarized approach. The Customs exchange rate was maintained stable till the start of 2023, providing some certainty for cost management. The business showed a remarkable capacity to adapt pricing tactics to the fluctuating exchange rate environment, maintaining affordability and competitiveness for a larger clientele including the LL income consumers. This strategic approach helped the business develop significantly and maintain healthy profit margins, suggesting the enhancement of the business economic sustainability.

Additionally, customers still found ways to invest in solar despite fluctuations. In fact, the exchange rate influenced project market value in USD, it proved to act as a mediator and overshadow the impact of customs on how companies adjust values of solar energy projects in USD during the crisis period. Although project market value PMVUSD witnesses a decline, the business shows signs of remarkable resilience and endurance in maintaining profitability. Statistical analysis including exchange rates and customs exchange rates explain a significant portion of profit margin and ROI variance.

This points out to the efficiency and adaptability of the business through managing costs and prices to counter the effects of currency fluctuations and helps to make sure that cost structures align with the fluctuating exchange rate landscape for sustainable project valuation.

Within a declining project valuations environment, the business was capable to maintain its profitability. The result of the high correlation between exchange rate and profit margins and ROI highlights the business ability to benefit from these fluctuations circumstances. This success is likely also influenced by a combination of other factors, including external drivers like high electricity bills and government policies. Further qualitative research is needed to fully understand these influences and consumer perception in this context. Furthermore, the study identified another mediation effect involving ER. ER influenced the relationship between USD project market value and profit margin. Despite potentially decreasing PMVUSD, the business likely adjusted pricing strategies to maintain profit margins within a fluctuating exchange rate situation. This demonstrates the intricate relationship that exists between price, costs, currency rates, and profitability in the end. People are still more interested in solar systems despite their higher upfront costs due to factors like rising bills or government incentives. This mediation effect signifies those fluctuations in the exchange rate, influenced by factors such as economic conditions, inflation rates, or monetary policies, may have a more direct and significant impact on the profitability of the business than changes in the market value of solar energy projects alone. Such fluctuations play a role also in shaping competitiveness, consumer

perceptions, cost structures, and other variables that can eventually affect profit margins.

The observed increasing and stable trend in profit margin and return on investment (ROI) over the past three years indicates a well-managed business that has successfully struck balance between profitability and economic dynamics impacts. The business adaptability and ability to seize opportunities are evidence of its resilience. Sustaining this level of stability attracts critical support and investments for further expansion by fostering confidence among stakeholders and investors. Maintaining strong profitability also enables the business to grow and navigate challenging economic conditions.

The key result supported by all of the aforementioned data is that the solar energy business signified economic sustainability within a fluctuating exchange rate environment, and has prospered from the situation to develop and excel. It experienced the environment of exchange rate fluctuations (Lira depreciation) as a potential and adjusted its metrics to sustain growth in the market. The findings shed light on its dynamic nature through responsiveness, well-management, and consistency amid the financial crisis. This study offers a comprehensive picture of the solar energy business performance by fusing financial measures with operational data. These factors, as demonstrated by this success, are crucial for ensuring long-term economic sustainability in the Lebanese solar energy sector, encouraging further exploration research.

To support the sector's continued growth, key recommendations include providing government subsidies for solar energy companies, which would lower project costs and make solar solutions more affordable to a broader consumer base. Partnerships between the government and private sector can also facilitate innovative financing models, such as low-interest loans and pay-as-you-go systems, reducing the reliance on high upfront investments for solar installations. Raising public awareness about solar energy's environmental and economic advantages, as well as promoting adaptation programs, can also increase adoption rates and enhance the sector's stability amid Lebanon's economic conditions. Together, these policy measures could maintain a favorable environment for renewable energy and drive Lebanon closer to its renewable energy targets, even in the face of economic challenges.

While the study underscores the business resilience, limitations are acknowledged. Company data confidentiality limited accessibility to data from different companies, and hindered the possibility of providing exact numbers instead of approximations representing the variation, but still expert insights were consulted to validate such variations. Also, the analysis focused on residential projects, taking an average system of 2 batteries, 6 panels, and 1 inverter. The methodological approach relied on quantitative analysis without the inclusion of qualitative insights like customer perspectives. Add to that, the study resembles mostly a case study with the aid of an expert. Finally, the timeframe of data was limited until the middle of 2023, since data availability whether through company or customs website is managed not further than that time.

Future research is recommended to gain a deeper understanding. A customer perception study could explore how exchange rate fluctuations and project costs impact affordability and decision-making, and how further do they find such projects

beneficial financially and in life. By addressing these limitations and future considerations, stakeholders can develop effective strategies to ensure the long-term viability of the solar energy sector and contribute to a more sustainable national energy landscape in Lebanon.

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