ERF
Policy
Research
Report

Drivers of Renewable Energy Adoption in Egypt's SMEs

Abeer Elshennawy
and Mohammed Bouaddi

ECONOMIC
RESEARCH
FORUM

منتدى البحوث الاقتصادية

Table of Contents

List of Tables

Tables

Summary

Increasing the adoption of renewable energy (RE) is essential to reduce greenhouse gases and combat climate change. Using a sample of small and medium enterprises (SMEs) and employing a quantile regression, this paper identifies the main drivers of RE adoption in the case of Egypt. Our findings reveal that firms owned by females are more likely to consider adopting RE. Furthermore, the larger the share of youth in a firm's labor force, the higher the firm's probability to deploy RE. Information and communication technology (ICT) utilization, awareness of RE, and access to information on backup generation technology all strongly influence the likelihood of firms considering RE adoption. These results have important policy implications.

In this context, removing the impediments facing women entrepreneurs should be a priority for policymakers in Egypt since they are more likely to deploy RE. Additionally, since youth are found to be important drivers of RE adoption, providing this group with the necessary skills through education would serve to enhance this role even more. Raising awareness of the benefits of RE is a straightforward means by which firms in Egypt can be encouraged to employ RE, while providing access to information about backup generation technology can reduce the risk stemming from the intermittency of RE and thus promote its adoption.

1. Introduction

Egypt managed to grow by 9.8 percent in the first quarter of FY 2022 (World Bank, 2022), but raising its GDP per capita remains a major challenge in light of rapid population growth. Furthermore, decoupling growth from environmental impact is another pertinent challenge facing the government. Egypt's performance is quite modest in this respect, with the country ranking 94th out of 180 countries on the 2020 Environmental Performance Index after scoring 43.3 out of 100 points (Ministry of Planning and UNDP, 2021). The threats of climate change include (i) declining agricultural yields; (ii) lower productivity of factors of production; (iii) rising sea levels; and (iv) the inundation of a considerable part of the Nile Delta, where agricultural land is concentrated. Mitigating climate change requires concerted efforts to cut greenhouse gases and move away from fossil fuels, which continue to dominate the energy mix in Egypt. To this end, Egypt updated its nationally determined contributions in 2023, setting an ambitious target to generate 42 percent of energy from renewable energy (RE) sources by 2030. Currently, the country has around 5.8 gigawatts of renewable installed capacity, the bulk of which is generated from hydropower and the rest of which (mostly government investments) comes from the sun and the wind (Ministry of Planning and UNDP, 2021). Meanwhile, the share of energy generated from fossil fuels declined from 50 percent to 30 percent (Barsoum and Ehab, 2023).

Sustained demand for RE is essential to generate momentum for continuous expansion in supply. Both residential consumers and firms are key actors in this regard. With the bulk of firms in Egypt's manufacturing sector classified as small and medium enterprises (SMEs), identifying the drivers of RE adoption by these firms constitutes an important step toward evaluating the role of the current regulatory and policy environment. It is also a significant stride toward designing a more enabling regulatory and policy environment that stimulates RE adoption. Understanding what other drivers of RE are at play in the context of Egypt is also important.

The literature on the relative importance of drivers of RE adoption by SMEs is generally scant (Rahbauer et al., 2018), particularly in developing countries (Asenta et al., 2021) like Egypt. Several important drivers of RE are identified in the literature (see Asenta et al., 2021; Seggarra-Blasco and Jove-LLopis, 2019; Rahbauer et al., 2018; Pascaris et al., 2023), including perceived responsibility for the environment, reliability of RE, price, customers' willingness to pay a price premium for goods produced with RE, competitive pressure, age and size of the firm, government regulations, and financial incentives. To the best of our knowledge, several other factors that are important in the context of developing countries have not been rigorously investigated. These include the role of gender, youth, awareness, and access to credit as drivers of RE adoption. Access to credit in particular is one of the most important constraints facing SMEs in developing countries and it is very likely to affect RE adoption.

Operating RE requires specific skillsets like engineering or technical skills. Since this technology is relatively new, it is reasonable to expect these skills to be acquired by the younger generation and that firms adopting RE employ a larger share of youth in their labor force. Awareness of the environment is lacking in developing countries, but it is slowly building up among the youth through education and the media. In the absence of pressure from environmentally aware consumers and environmentally lax governments, pressure for environmental protection is likely to come from employees. A young labor force should then be one of the drivers that facilitate the adoption of RE at the firm level. In another vein and supported by evidence in the literature showing that women are more concerned about environmental issues compared to men, Atif et al. (2021) find that gender diversity on firm boards increases RE consumption. This suggests that women entrepreneurs might be more inclined to employ RE compared to their male counterparts. In short, the role of gender and youth as drivers of RE adoption deserves a thorough investigation.

On the other hand, Pascaris et al. (2023) point to several challenges facing RE adoption, including (i) the liability of newness, which may stem from uncertainties about cost and application, for example; (ii) techno-economic challenges, which relate to the ability to deliver low-cost, competitive products using RE; and (iii) political feasibility, as dictated by the regulatory regime. The intermittency of RE is also a major challenge facing the wide-scale adoption of this type of energy (Kozlova et al., 2023).

Against this backdrop, this research aims to assess the relative importance of the different drivers of RE adoption in the case of Egypt using a survey of 1,002 SMEs as well as a quantile regression analysis. The importance of this research stems from the RE sector's huge potential as an employment generator and a major key player in the quest to decouple growth from environmental impact.

Our contribution to the literature is three-fold. First, this is the first study on drivers of RE in the case of Egypt and among the very few in the literature that tackle this

issue at the micro level for SMEs, particularly in the case of a developing country. Second, while we control for many factors that may influence RE adoption at the firm level such as size, age, and ownership, we are the first to explore the role of gender and youth as possible drivers of RE adoption. Third, in addition to the role of gender and youth, we are also the first to explore the role of awareness of RE and access to information on backup generation technology as well as how they influence RE adoption in firms. This also holds true for the role of access to credit.

Interestingly, we find that firms owned by females are more likely to consider RE adoption. We also find that the higher the share of youth in a firm's labor force, the more likely the firm is to consider adopting RE. Awareness of RE and access to information on backup generation technology also strongly influence a firm's decision to employ RE. Firms that are constrained by credit probably choose to consider adopting RE since it is a cheaper alternative.

The rest of this paper is structured as follows. Section two presents the literature review, while section three describes the data. Section four lays out the methodology, and section five discusses estimation results. Finally, section six concludes.

2. Literature review

At the outset, it is important to note that there is a large body of literature addressing the constraints and enablers of photovoltaics (PV) in the residential sector, while there is a dearth of research addressing the same question in non-residential sectors (Reindl and Palm, 2021). This makes the contribution of the current research relevant and valuable.

Pascaris et al. (2023) identify three important drivers for and three challenges to the adoption of agrivoltaics that can be generalized to the case of RE adoption. These include (i) the observability of co-benefits, which are namely the environmental and social aspects (though they are hard to quantify); (ii) pressure from the public; and (iii) market signals, as reflected in the financial incentives in place. The latter is considered the strongest driver. On the other hand and as previously mentioned, the challenges facing RE adoption include (i) the liability of newness, which may stem from uncertainties about cost and application; (ii) techno-economic challenges, which can be related to delivering low-cost, competitive products using RE; and (iii) political feasibility, as dictated by the regulatory regime.

In light of the increasing economic competitiveness of solar PV panels, Best and Burke (2023) examine the effect of policy interventions in Australia on the uptake of these panels by the non-residential sector. They use cross-sectional data while controlling for factors such as size (measured by the number of employees), the proportion of businesses in agriculture (since land to install solar panels is relatively abundant), and the climate zone where the business is located. These policy interventions took the form of a renewable portfolio standard which provides (at varying rates) a subsidy per kilowatt of solar PV capacity. The Australian government also provided grants for the installation of solar PVs in addition to the use of financial instruments with different specifications related to collateral, repayment, and purchase options. The estimation results show that a one percent increase in the subsidy rate is associated with a 1.5 percent increase in the number of non-residential solar systems installed. One major constraint that might impede small businesses' adoption of solar PV panels is that these firms might not have access to their own roof space. Financial considerations are also among the main motivators for the adoption of this technology by businesses. The literature review conducted by Best and Burke (2023) points to an important gap in the literature since nearly all studies on the adoption of solar PV panels by businesses are forward-looking and do not analyze historical data. Specifically, the authors suggest that an important venue for future research should consider the role of awareness levels of solar PV as a factor that encourages adoption by businesses (Best and Burke, 2023).

Dingru et al. (2023) reach mixed results when they review both the theoretical and empirical literature and study the impact of trade and FDI on the environment in general and RE consumption in particular. The theoretical literature is based on the pollution haven and pollution halo hypotheses. The former postulates that trade and FDI lead dirty industries to relocate to regions with lax environmental standards, thereby contributing to rising pollution and reducing RE consumption. On the other hand, according to the pollution halo hypothesis, trade and FDI make it possible to shift to better or cleaner technology, which contributes to less pollution. Since the empirical literature is mainly macro in nature and utilizing cross-sectional country data, it is inconclusive.

At the macro level, using a cross-section of Sub-Saharan countries and employing a panel quantile autoregressive distributed lag model for the period 2000-21, Appiah et al. (2023) find that business investment in RE is negatively affected by financial development and fiscal policy, as reflected in government spending. Prioritizing

growth, financial institutions in these countries mainly provide financial resources for sectors reliant on fossil fuels. Meanwhile, RE projects are not able to attract sufficient funds given their high capital to operation and maintenance cost ratio and high development to investment ratio, all of which renders them riskier to finance. Further, fiscal policy results show that the governments of these countries are not interested in promoting RE.

According to Appiah et al. (2023), institutional quality hampers the development of RE in the 10th, 70th, and 90th quantiles, showing that rules and regulations are too tight. Industrialization affects RE development negatively at the 10th, 50th, 70th, and 90th quantiles but positively at the 30th quantile, which suggests that industrialization is not going hand-in-hand with promoting the use of RE. Additional results show that except for the 70th quantile, foreign capital exerts a positive and significant effect on RE. This lends support to the pollution halo hypothesis as opposed to the pollution haven hypothesis. One major constraint impeding expansion in RE in Sub-Saharan countries is limited storage infrastructure.

Another strand of the literature examines the impact of integration into global value chains (GVCs)—which are defined as firms that both export and import at the same time—on environmental performance. GVCs can lead to environmental degradation if their fragmented nature leads to excess waste and higher pollution levels due to longer shipping routes and excessive use of natural resources. This is particularly the case in places where domestic institutions and environmental regulations are weak. GVCs can lead to improved environmental performance by inducing the diffusion of cleaner technology and forcing firms to stick to more stringent environmental regulations. Although there is a rich body of theoretical and empirical literature addressing this issue, it is mainly macro in nature, while firm-level studies that do not suffer from aggregation bias and allow for a finer identification strategy are generally scant. Existing firm-level studies address single countries and/ or exporting and its impact on environmental abatement (Siewers et al., 2024).

At the micro level, a review of the literature by Siewers et al. (2024) based on the new-new trade theories sets three main hypotheses related to the relationship between firm heterogeneity and environmental performance. The first is the pollution reduction by rationalization hypothesis (PRR), according to which trade liberalization increases the market share of high-productivity firms that are more able to reduce their emissions compared to low-productivity firms, eventually becoming exporters. Low-productivity firms are assumed to be more

polluting and exit the market. The second hypothesis is the distressed and dirty hypothesis (DDI), which posits that trade liberalization—and, consequently, competition from imports—forces firms to abandon plans to abate pollution to reduce expenses. Both hypotheses predict the relocation of polluting firms to countries with lax environmental standards. Finally, the third hypothesis is the pollution offshoring hypothesis (POH), which focuses on the relocation of the most polluting intermediate stages of production to countries with lax environmental standards. Firm-level empirical literature mainly focuses on the relationship between exporting and emission intensity and finds that this relationship is positive. Firm-level studies testing the POH hypothesis produce mixed results (Siewers et al., 2024). At the firm level and using World Bank enterprise data covering a sample of 29 countries in Central Asia, Eastern Europe, North Africa, and the Middle East, Siewers et al. (2024) find that firms that enter GVCs—defined as firms that engage in two-way trade in addition to holding an internationally recognized quality certification—are more likely to switch to clean energy sources and emit less air pollution. However, these firms must be subject to strict environmental standards at home for GVCs to induce these effects.

Lee et al. (2023) estimate the effect of utilizing ICT on RE output and consumption using panel data and the method of moment quantile regression for 126 nations over the period 2000-19. Findings show that utilizing ICT increases both the output and consumption of RE.

The literature examining the relationship between RE adoption and the gender gap is generally scant and establishes that this relationship goes from RE adoption to the gender gap rather than the other way around. For a number of Latin American Countries, Airas et al. (2023) show that a company holding a carbon footprint certificate (i.e., being environmentally responsible) has no effect on gender equity, while foreign ownership is found to have a positive effect on the ratio of female to male employment in the company. Moreover, companies operating in the RE industry are found to hire more females.

The intermittency of RE reduces its reliability and can be an important impediment to firms adopting this kind of energy. To deal with the intermittency of RE, in the case of the European Union, for example, RE support typically co-exists with a capacity mechanism, the role of which is to ensure security in the supply of energy to meet demand at all times. According to this system, compensation is provided for energy generated from fossil fuels like coal or gas. To overcome the detrimental effect on the environment, renewables can be part of the energy mix benefiting from a capacity mechanism. A carbon tax can also serve the purpose of limiting the adverse effect of

this mechanism on the environment or imposing limits on emissions (Kozlova et al., 2023).

In light of the above background, it is clear that there are important gaps in the literature on RE adoption. Firm-level studies in developing countries are lacking. The roles of gender and youth, awareness of RE, and access to information on backup generation technology as drivers of RE adoption have not been investigated.

3. Data

We use a random sample of 1,002 SMEs drawn from all sectors of economic activity in Egypt. A questionnaire was designed and firms in the sample were surveyed through phone interviews in 2023. The data is representative of the Yellow Pages in Egypt (there is no other option to conduct a phone survey), therefore the sectors' distribution in the sample represents the distribution in the Yellow Pages. The average size of the firm was 8.8 employees, with the maximum being 60 employees and the minimum being two employees. Respondents to the phone survey were asked the following question: "Have you personally considered using clean energy (solar/wind) in your business?" which served as the dependent variable in the model. In answering this question, respondents had to choose between "Yes," "No," or "I am using it." Due to the very small number of respondents answering with "I am using it," we excluded this category from the sample.

4. Methodology

To explore the interrelation between RE adoption and its various drivers at the firm level, we use the quantile regression introduced by Koenker and Bassett (1978). Compared to a linear regression where the coefficients capture the average effect of any explanatory variable on the dependent variable, the quantile regression captures the effect in different levels of the distribution of the dependent variable. The coefficient in the linear regression captures the average effect. However, the explanatory variables may have a different effect across different firms with different levels of RE adoption. The quantile regression technique is more flexible in the sense that it can capture heterogeneous effects.
The quantile regression model is given by:

$$y_i = \beta'_q X_i + \varepsilon_{qi} \tag{1}$$

Where y is the dependent variable, X is the vector of explanatory variables, β is the vector of parameters, and

ε is the error term. The dependent variable is a binary variable that takes the value of one if the firm considered using RE in its business and zero if not. The main explanatory variables of interest are female ownership, share of youth in a firm's labor force, awareness of RE, access to information about backup generation technology, integration in GVC (measured by engagement in two-way trade), certification, and affordability of RE. A second set of explanatory variables captures different characteristics of firm managers, including age, education, and experience. A third set of explanatory variables include access to credit, ICT (measured by whether the firm has access to the Internet), and the role of government incentives and policies. We also control for a variety of firm characteristics including location (urban/rural), ownership (foreign/ domestic), formality, share of skilled workers in a firm's labor force, age, and size (measured by number of employees). In Table 1, all these variables and their definitions along with their expected sign (between brackets) are presented.

The q conditional quantile minimizes the following objective function:

$$\frac{1}{n} \sum_{i=0}^{n} f_q(\varepsilon_{qi}) \tag{2}$$

where n is the number of firms in the sample (sample size) and $f_\delta(\varepsilon_{\delta i})$ is given by:

$$f_q(\varepsilon_{qi}) = \begin{cases} (1-q)\varepsilon_{qi} & if \ \varepsilon_{qi} < 0 \\ q\varepsilon_{qi} & otherwise \end{cases} \tag{3}$$

The minimization problem (2) becomes:

$$\frac{1}{n}\left[\sum_{q=0}^{n}(1-q)|y_i - \beta'_q X_i|I_{y_i < \beta'_\delta X_i} + \sum_{q=0}^{n} q\left|y_i - \beta'_q X_i\right|(1 - I_{y_i < \beta'_q X_i})\right] \tag{4}$$

Where $I_{y_i < \beta'_q X_i}$ is an indicator function equal to one if $y_i < \beta'_q X_i$ and zero otherwise.

All firms at different quantiles will be covered by increasing q continuously from zero to one.[1]

Since the dependent variable is a binary variable in our case, we adopt the methodology on the quantile regression for the ordinal variables developed by Zhou (2010). Zhou adapts the work of Machado and Santos (2005) on count data to the estimation of conditional

---

[1] For more details on quantile regression, see Buchinsky (1998), Koenker and Hallock (2001), and the special issue of Empirical Economics Issue 3 of Volume 26 (2001).

quantiles in case of data discreteness. The author uses the latent variable approach to estimate the quantiles. Hong and He (2010) develop a transformation of an ordinal variable known as "jittering" the ordinal variable and prove that this approach could be used to estimate a conditional quantile. We adopt this approach in this paper. Hong and He (2010) apply an artificial smoothness to the dependent variable by means of jittering. In other words, they generate a new variable J given by:

$$J_i = y_i + u_i \tag{5}$$

Where u_i is a random artificial variable having a support (0, 1).

In our empirical application, we assumed that u_i is uniformly distributed in (0,1) and specify the quantile as:

$$QJ_i / x_{1,i}, x_{2,i}, \ldots, x_{19,i} \ (q) = q + \exp(\beta'_q X_i) \tag{6}$$

We use the transformation T of the variable J before we run the quantile regression. That is, we define T by:

$$T(J_i, q) = \begin{cases} \ln(J_i - q) & if \ J_i > q \\ \ln(\eta) & Otherwise \end{cases}$$

where η is a small positive number and the q conditional quantile problem becomes:

$$\min_{\beta_q} \frac{1}{n} \sum_{i=1}^{n} \rho_q \ (\varepsilon_{i,q}) \tag{7}$$

Where $\varepsilon_{i,q} = T(J_i, q) - \beta'_q X_i$ and the check function ρ_q is given by:

$$\rho_q(\varepsilon_{iq}) = \begin{cases} \alpha\varepsilon_{i,q} & if \ \varepsilon_{i,q} > 0 \\ (1 - q)|\varepsilon_{i,q}| & Otherwise \end{cases} \tag{8}$$

Table 1. Definition of variables

Dependent Variable	Have you personally considered using clean energy (solar/wind) in your business?		
Location	Is your firm located in a rural or urban area?	Dummy variable=1 if urban, 0 if rural	(-)
Ownership	Is the ownership of your firm foreign or domestic?	Dummy variable =1 if foreign, 0 if domestic	(?)
Age	What year did your operations begin?		(?)
Female Owner	Are there female owners in the firm?	Dummy variable=1 if yes, 0 otherwise	(+)
Manager Experience	What are the years of experience of the manager of the firm?		(+)
Manager Gender	What is the gender of the manager?	Dummy variable=1 if female, 0 if male	(?)
Manager Age	What is the age of the manager?		(?)
Manager Education	What is the last education level completed successfully by the manager?		(+)
Share of Skilled Workers	What is the share of highly educated workers in the firm's total workforce in 2023?		(+)
Formality	Does the firm have a tax registration?	Dummy variable=1 if has tax registration, 0 if not	(?)
Certification	Does the firm have an internationally recognized quality certification?	Dummy variable=1 if has certification, 0 if not	(+)
Size	What is the number of workers?		(?)
Share of Youth	How many workers are between the ages of 18-29 years old, including the top manager?		(+)
Export_ imports	Does your firm export and import at the same time?	Dummy variable=1 if yes, 0 otherwise	(?)
Access to Finance	Is access to finance/credit a problem?	Dummy variable=1 if yes, 0 if no	(-)
ICT	Do you have Internet access in your firm?	Dummy variable=1 if yes, 0 if no	(+)
Awareness	Are you familiar with RE?	Dummy variable=1 if yes, 0 if no	(+)
Gov Incentives	Do government incentives that support RE influence your decision making?	(SD=1, DA=2, N=3, A=4, SA=5)	(+)
Cost	Is the cost of RE within your financial means?	(SD=1, DA=2, N=3, A=4, SA=5)	(+)
Access to Information About Backup Generation Tech	Do you have access to information regarding backup generation technology?	Dummy variable=1 if yes, 0 otherwise	(+)

Notes: SD=Strongly Disagree, DA=Disagree, N=Neutral, A=Agree, SA=Strongly Agree.

Equation (7) becomes:

$$\min_{\beta_q} \frac{1}{n}\left[\sum_{i=1}^{n} q\left|T(J_i,q) - \beta'_q X_i\right| I_{\varepsilon_{i,a}>0} + \sum_{i=1}^{n}(1-q)\left|T(J_i,q) - \beta'_q X_i\right|\right](1 - I_{\varepsilon_{i,q}>0})$$

where $I_{\varepsilon_{i,q}>0}$ is equal to one if $T(J_i,q) > \beta'_q X_i$ and zero otherwise. The minimization problem is solved as a linear programming problem.

The entire conditional distribution of $T(J_i, q)$ will be covered by increasing q continuously from zero to one (Buchinsky, 1998).

In order to average out the effect of the artificial variable ui on the estimated parameters of the model, we generate Q copies of Ji along equation (5). Using these m simulated copies of ui, we estimate Q times the vector of parameters β_q $(\beta_q^{(1)}, \beta_q^{(2)}, \ldots, \beta_q^{(Q)})$. The ultimate estimator of $\beta_{j,q}$ is the average of the Q estimates given by:

$$\beta_{j,q}^{(estimated)} = \frac{\beta_q^{(1)} + \beta_q^{(2)} + \cdots + \beta_q^{(Q)}}{Q} = \frac{1}{Q}\sum_{j=0}^{Q} \beta_q^{(j)}$$

For the model inference, we use the bootstrapped t-statistics and their corresponding p-values.

The main advantage of the quantile regression is that it is more robust than the OLS to outliers. The downside is that if all the Gauss-Markov theorem assumptions are met, the quantile regression will be less efficient than the OLS (the parameter estimates are less precise), which may alter the significance because a quantile regression quantifies the effect of the explanatory variables on the conditional quantile of a dependent variable without assuming any specific conditional distribution. Hence, it models each part of the conditional distribution instead of the mean, as is the case in the standard OLS regression. The quantile regression can explain the relationship between the dependent variable and the explanatory variables more accurately than classical methods in the presence of heteroskedasticity or to study every region of the conditional distribution. In the case of heavy-tailed/asymmetric distribution, the quantile regression is superior to the OLS; however, when the distribution is normal, the OLS is more efficient than the quantile regression.

5. Estimation results

We present the quantile regression results in Table 2. With a statistically significant and positive coefficient for the gender of the owner of the firm, the results support the argument that females tend to be more environmentally conscious compared to males. In contrast, the coefficient of the manager's gender is negative and highly significant for all quantiles, indicating that female managers are not in favor of employing RE. This could be explained by the fact that females are generally under-represented in STEM education and therefore lack the skills necessary for RE adoption. According to UNESCO's Arab Science Podium,[2] although female university STEM graduates in Egypt constituted 47.3 percent in 2019, they only accounted for 38 percent of the STEM workforce. The question is, why do female owners tend to employ RE while female managers do not? It could be the case that when driven by profit maximization and the desire to protect the environment, female firm owners will choose a cheaper and cleaner alternative like RE.

The larger the share of youth in the firm's labor force the more likely that the firm considers employing RE as evidenced by the positive and highly significant coefficient of this variable for the 50th, 75th and 95th quantiles, though it is insignificant for the 5th and 25th quantiles. Youth might be more environmentally conscious in light of the growing emphasis on the environment in school curricula and the media, especially following the hosting of COP 27 in Egypt in November 2022.

Among the variables considered in the model, four consistently appear with a positive and highly significant coefficient across all the quantiles of the distribution. These are ICT, awareness, cost and access to information about backup generation technology. Through in-depth interviews with SMEs in Egypt, Hassan (2023) confirms that the lack of awareness about RE is one of the main reasons why these firms did not make use of this technology. Awareness of successful experiences by other business owners in employing RE is particularly helpful in this regard, as pointed out by the firms interviewed by Hassan (2023). The lower cost of RE compared to other sources of energy is identified by Hassan (2023) (through in-depth interviews with business owners in Egypt) as one of the main reasons encouraging the adoption of RE. The

Table 2. Quantile regression results

Quantile/Variable	5%	25%	50%	75%	95%
Constant	-4.698***	-3.718***	-3.308***	-2.932***	-1.716***
	(0.148)	(0.063)	(0.034)	(0.019)	(0.036)
LOCATION	-0.010	0.047*	0.023	-0.030***	-0.023
	(0.066)	(0.033)	(0.019)	(0.011)	(0.020)
OWNERSHIP	0.780***	0.151***	-0.139***	0.334***	0.020
	(0.139)	(0.086)	(0.055)	(0.029)	(0.042)
FIRM_AGE	0.000	0.002***	0.003***	0.007***	0.001**
	(0.001)	(0.001)	(0.000)	(0.000)	(0.000)
FEMALE_OWNER	0.240***	0.218***	0.204***	0.073***	0.004
	(0.055)	(0.030)	(0.019)	(0.010)	(0.015)
MANAGER_GENDER	-0.248***	-0.350***	-0.357***	-0.350***	-0.135***
	(0.070)	(0.034)	(0.021)	(0.011)	(0.021)
SKILLED	-0.057***	-0.035***	-0.034***	-0.037***	-0.020***
	(0.022)	(0.012)	(0.007)	(0.004)	(0.005)
FORMALITY	-0.167***	-0.170***	-0.215***	-0.249***	-0.384***
	(0.056)	(0.028)	(0.019)	(0.009)	(0.015)
CERTIFICATION	0.118***	0.030	0.078***	0.114***	0.128***
	(0.057)	(0.031)	(0.017)	(0.009)	(0.016)
SIZE	0.003	0.006***	0.000	-0.013***	-0.011***
	(0.003)	(0.001)	(0.001)	(0.001)	(0.001)
YOUTH	0.004	-0.002	0.008***	0.019***	0.008***
	(0.004)	(0.002)	(0.001)	(0.001)	(0.001)
IMPORTS_EXPORTS	-0.090	-0.040	-0.082***	0.017**	-0.277***
	(0.071)	(0.040)	(0.022)	(0.012)	(0.018)
FINANCE	0.171***	0.113***	0.217***	0.400***	0.363***
	(0.072)	(0.041)	(0.024)	(0.013)	(0.018)
ICT	0.133***	0.171***	0.220***	0.198***	0.243***
	(0.049)	(0.027)	(0.017)	(0.008)	(0.012)
AWARANCE	0.407***	0.464***	0.642***	0.940***	0.822***
	(0.049)	(0.024)	(0.019)	(0.009)	(0.019)
GOV_INCENTIVES	-0.006	0.052***	0.037***	0.054***	0.092***
	(0.020)	(0.010)	(0.006)	(0.004)	(0.004)
COST	0.047***	0.016***	0.030***	0.035***	0.031***
	(0.019)	(0.010)	(0.006)	(0.003)	(0.005)
GENERATION_TECHNOLOGY	0.308***	0.426***	0.471***	0.571***	0.271***
	(0.050)	(0.027)	(0.018)	(0.009)	(0.011)
MANAGER_EXPERIENCE	0.000	-0.003***	0.001	0.001***	0.005***
	(0.003)	(0.001)	(0.001)	(0.001)	(0.001)
MANAGER_AGE	0.074***	0.125***	0.115***	0.096***	0.027***
	(0.025)	(0.014)	(0.008)	(0.005)	(0.006)
MANAGER_EDUCATION	0.055***	0.054***	0.077***	0.068***	0.065***
	(0.022)	(0.012)	(0.007)	(0.004)	(0.006)
R-Squared	0.620	0.582	0.578	0.605	0.601
Adjusted R-Squared	0.612	0.574	0.569	0.597	0.593

*Notes: * =significant at 10% level. **= significant at 5% level. ***= significant at 1% level. Standard Errors between parenthesis.*

unavailability of credit/finance pushes firms to consider employing RE as evidenced by the positive and significant coefficient of this variable. One possible explanation could be that firms that are credit constrained find it cheaper to employ RE.

Certification positively influences a firm's tendency to consider employing RE, but this effect is insignificant for the 25th quantile. Except for firms in the 75th quantile, firms that are integrated into GVCs (i.e., firms that are exporters and importers at the same time) do not consider employing RE. In general, one can conclude from this observation that environmental laws are lax in Egypt.

The coefficient of location is insignificant for the 5th, 50th and 95th quantiles. However, this coefficient enters with a positive and slightly significant coefficient in case of the 25th percentile while enters with a negative and highly significant coefficient in the case of the 75th percentile. This provides evidence that firms that are likely to consider employing RE are mainly located in rural areas where there is generally more space to install RE structures. Except for the 50th quantile where the coefficient of ownership is negative and significant and for the 95th percentile where this coefficient is insignificant, foreign firms are more likely to consider using RE given that this coefficient is positive and significant for all other quantiles. These results lend support to the fact that foreign firms tend to use more environmentally friendly technology. Apart from the 5th quantile where the coefficient of age is insignificant, the estimation results for all other quantiles show that older firms are more inclined to consider adopting RE. Formality enters with a negative and significant coefficient for all quantiles. Formal firms must abide by laws and regulations, and it could be the case that in order to employ RE, they have to go through lengthy and cumbersome procedures, all of which can be avoided by informal firms.

Firm size, as measured by the number of employees, has no effect on the tendency of firms to consider employing RE for the 5th and 50th quantiles. For the 25th quantile, the larger the size of the firm, the more likely it is to consider adopting RE. For the remaining 75th and 95th quantiles, the effect of firm size is negative and significant. These results point to the fact that small firms are more likely to employ RE. The share of skilled labor in a firm's labor force exerts a negative and statistically significant effect on the likelihood of the firm adopting RE. This could be explained by the fact that the skills provided by the education system fall short of those required for RE.

Hassan (2023) asserts that the lack of skills necessary to maintain and operate RE is a major challenge.

The top skills required for the green transition include knowledge of mathematics, mechanical engineering, design, building and construction, engineering and technology, and computer and electronics. Several factors constrain the demand for and supply of these skills in Egypt. On the one hand, the enforcement of environmental regulations remains weak. On the other hand, although the government has recently put in efforts to provide training for these skills, the link between policymaking in the areas of environment, education, and training policymaking remains rather weak (Barsoum and Ehab, 2023).

Female managers seem to discourage the use of RE, as mentioned above. Several other managerial characteristics influence the likelihood of firms employing RE. The coefficient of manager's experience is insignificant for the 5th and 50th quantiles, but enters with a positive and highly significant coefficient for the 75th and 95th quantiles while is negative and significant for the 25th percentile. The older the manager the more likely the firm will consider employing RE as evident from the positive and highly significant coefficient of this variable for all quantiles. Managers' education positively influences the tendency of firms to consider RE, again as evident from the positive and highly significant coefficient for this variable for all quantiles.

Government incentives positively influence a firm's attitude for all but the 5th quantile. Feed-in tariffs were initially introduced to promote RE generation and later were replaced by competitive bidding auctions. Also, according to the net consumption measurement policy, the cost of RE consumption can be deducted from an entity's electricity bill whether this entity is a household or a commercial or industrial firm (UNDP, 2021). The policies introduced by the government to encourage investment in RE include a circular from the Central Bank of Egypt requesting banks to put in place sustainable development financing policies. However, this step falls short of providing credit guarantees (Barsoum and Ehab, 2023). Other incentives offered by the government include free-of-charge training for private sector entities interested in operating in the RE energy sector (Hassan, 2023).

The positive influence of government policies to promote RE is also confirmed by a qualitative study conducted by Hassan (2023). In-depth interviews and focus group discussions with participants from privately owned SMEs in Egypt reveal that feed-in tariffs, which were introduced

in 2014, play a pivotal role in encouraging investment in RE. Reducing energy subsidies is also instrumental in pushing firms to shift to RE. Nonetheless, the qualitative study also points to bureaucracy and red tape as one of the most important barriers impeding RE adoption in Egypt in addition to the negative impact of currency devaluation on the cost of importing RE technology, spare parts, and materials used in maintenance. Other barriers to the adoption of RE identified by the study include insufficient infrastructure available for storage or for connecting to the electricity distribution company. This forces firms to revert to fossil fuels at night.

6. Conclusion

Using a sample of SMEs, this paper identifies the main drivers of RE adoption in the case of Egypt. We find that firms owned by females are more likely to consider deploying RE. Additionally, the larger the share of youth in a firm's labor force, the higher the probability that the firm adopts RE. ICT, awareness of RE, cost and access to information on backup generation technology strongly influence the likelihood of firms adopting RE. Additionally, credit-constrained firms opt to consider RE as it is a cheaper alternative. While certification in general positively influences the likelihood of firms employing RE, integration into GVCs leads to a similar conclusion but only for firms in the 75th quantile of the distribution. This latter result reflects lax environmental standards in Egypt. It is worth noting that government policies and incentives encourage firms to consider RE.

These results have important policy implications. Removing the impediments facing women entrepreneurs should be a priority for policymakers in Egypt since they are more likely to consider the adoption of RE. Since youth were found to be important drivers of RE adoption, providing this group with the necessary skills through education would serve to further enhance this role. In general, both these results provide an impetus for NGOs eager to advance the role of women and youth in society. In another respect, they provide firms seeking to adopt RE with guidance in regard to the ideal composition of their labor force, encouraging them to include more females and youth. Raising awareness regarding the benefits of RE presents a straightforward means by which firms in Egypt can be encouraged to deploy RE. In a similar vein, access to information about backup generation technology can reduce the risk stemming from the intermittency of RE and thus promote its adoption. The results of this research also point to the fact that government policies around RE are effective.

This holds policy lessons for other developing countries seeking to encourage the adoption of RE.

References

Appiah, M., Ashraf, S., Tiwari, A., Gyami, B., and Onifade, S. (2023). Does Financialization Enhance Renewable Energy Development in Sub-Saharan African Countries? *Energy Economics*,125:1-14.

Arias, K., Lopez, D., Camino-Mogro, S., Weiss, M., Walsh, D., Gomes, L., and Hallack, M. (2023). Green Transition and Gender Bias: An Analysis of Renewable Energy Generation Companies in Latin America. *Energy Research and Social Science*, 101:1-13.

Asante, D., He, Z., Ampaw, E., Gyamerah, S., Twumasi, M., Opoku-Mensah, E., Kyere, F., Asante, B., and Akyia, E. (2021). Renewable Energy Technology Transition Among Small and Medium Scale Firms in Ghana. Among Small-and- Medium Scale Firms in Ghana. *Renewable Energy*, 178:549-559.

Atif, M., Hossain, M., Alam, S., and Georgen, M. (2021). Does Board Gender Diversity Affect Renewable Energy Consumption? *Journal of Corporate Finance*, 66:1-29.

Barsoum, G. and Ehab, A. (2023). Green Jobs and the Future of Work in Egypt: A Focus on the Agriculture and Renewable Energy Sectors, Economic Research Forum.

Best, R. and Burke, P. (2023). Small-Scale Solar Panel Adoption by the Non-Residential Sector: The Effects of National and Targeted Policies in Australia. *Economic Modeling*, 120:1-10.

Buchinsky, M. (1998). Recent Advances in Quantile Regression Models: A Practical Guide for Empirical Research, *Journal of Human Resources*, 33(1): 88-126.

Dingru, L., Onifade, S., Ramzan, M., Al-Faryan, M. (2023). Environmental Perspectives on the Impacts in Sub-Sahara Africa: Accounting for FDI, Income and Urbanization Trends. *Resources Policy*, 80:1-9.

Hassan, R. (2023). Accelerating the Energy Transition in Egypt. An In-Depth Analysis of the Adoption of Renewable Energy Among Micro, Small and Medium Enterprises.

Hong, H. and Zhou, J. (2013). A Multi-Index Model for Quantile Regression with Ordinal Data, *Journal of Applied Statistics*, 40:6, 1231-1245.

Koenker, R. and Bassett, G. (1978). Regression Quantiles, *Econometrica*, 46: 33-50.

Koenker, R. and Hallock, K. F. (2001). Quantile Regression, *Journal of Economic Perspectives* 15(4): 143-56.

Koenker, R. (2005). *Quantile Regression*, Cambridge University Press, New York.

Kozlova, M., Huhta, K., and Lohrmann, A. (2023). The Interface Between Support Schemes for Renewable Energy and Security of Supply: Reviewing Capacity Mechanisms and Support Schemes for Renewable Energy in Europe. *Energy Policy*, 181:1-10.

Lee, C., Chen, M-P., and Yuan, Z. (2023). Is Information and Communication Technology a Driver for Renewable Energy? *Energy Economics*, 124:1-12.

Machado, J. and Silva, J. (2005). Quantiles for Counts. Journal of the American Statistical Association 100 (472): 1226-1237.

Ministry of Planning and UNDP (2021). Egypt Human Development Report.

Pascaris, A., Gerlak, A., and Barron-Gafford, G. (2023). From Niche-Innovation to Mainstream Markets: Drivers and

Challenges of Industry Adoption of Agrivoltaics in the U.S. *Energy Policy*, 181:1-10.

Rahbauer, S., Menapace, L., Menrad, K., and Lang, H. (2018). Determinants of the Adoption of Green Electricity by German SMEs - An Empirical Examination. *Energy Policy*, 123:533-543.

Reindl, K. and Palm, J. (2021). Barriers and Enablers Experienced by Non-Residential Property Owners. *Renewable and Sustainable Energy Reviews*, 141:1-10.

Roger K. and Machado, J. (1999). Goodness of Fit and Related Inference Processes for Quantile Regression, *Journal of the American Statistical Association*, 94 (448), 1296-1310.

Segarra-Blasco, A. and Jove-LLopis, E. (2019). Determinants of Energy Efficiency and Renewable Energy in European SMEs. *Economics of Energy and Environmental Policy*, 8(2):117-139.

Siewers, S., Martinez-Zarzoso, I. and Baghdadi, L. (2024). Global Value Chains and Firms' Environmental Performance. *World Development*, 173:1-18.

World Bank (2022). Egypt, Country Climate and Development Report.

About the Authors

Abeer Elshennawy received a Bachelor of Arts in economics from Cairo University, a Master of Arts in economics from The American University in Cairo (AUC) and a PhD in applied economics from the University of Minnesota in the United States. She is currently a professor at the economics department at AUC. She has taught a variety of courses in the area of environmental economics, growth and development, and macroeconomic and microeconomic theory. Her research interests are in international trade, the environment, and growth and development. She has published several articles addressing the issue of adjustment costs to trade liberalization and climate change.

Mohammed Bouaddi is an Associate Professor in Economics at the American University in Cairo. He was appointed as the director of graduate programs in Economics at the American University in Cairo. Bouaddi's research focuses primarily on Econometrics, Financial Economics and Statistics with specialties in econometrics, time series analysis, and financial economics. He has published a dozen of papers in refereed journals and many others as working papers involving applications of econometric methods to policy-related issues in the fields of portfolio selection, financial econometrics, macro-finance and corporate finance. His interest is in the econometrics of factor models. He got his Bachelor's degree in Economics (1991) from Mohamed V University in Rabat, Morocco, his master's degree (1993) from Hassan II University in Casablanca, Morocco, his M.Sc. in Financial Economics (2002) from UQAM University and finally his Ph.D. in Economics from University of Montreal (2010).

ERF at a Glance: *The Economic Research Forum (ERF) is a regional network dedicated to promoting high-quality economic research for sustainable development in the Arab countries, Iran and Turkey. Established in 1993, ERF's core objectives are to build a strong research capacity in the region; to encourage the production of independent, high-quality research; and to disseminate research output to a wide and diverse audience. To achieve these objectives, ERF's portfolio of activities includes managing carefully selected regional research initiatives; providing training and mentoring to junior researchers; and disseminating the research findings through seminars, conferences and a variety of publications. The network is headquartered in Egypt but its affiliates come primarily from different countries in the region.*