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Does Gender Diversity Improve Technical Efficiency in Egyptian SMEs?

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تم النشر لأول مرة في عام 2025 بواسطة معهد التخطيط القومي.

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النتائج والتفسيرات والاستنتاجات والآراء الواردة في هذه السلسلة لا تعبر بالضرورة عن وجهة نظر المعهد وإنما هي مسئولية المؤلف أو المؤلفين.

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سلسلة أوراق عمل - معهد التخطيط القومي

Does Gender Diversity Improve Technical Efficiency in Egyptian SMEs?

هل يحسن التنوع بين الجنسين الكفاءة الفنية في الشركات الصغيرة والمتوسطة المصرية؟

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المستخلص:

تبحث هذه الدراسة في العلاقة بين التنوع بين الجنسين والكفاءة الفنية في الشركات الصغيرة والمتوسطة في مصر. وقد تم دراسة أثر التنوع بين الجنسين على أداء الشركات الصغيرة والمتوسطة الحجم على نطاق واسع في مصر؛ ومع ذلك، ركزت هذه الدراسات في كثير من الأحيان على الربحية بدلا من الكفاءة الفنية، وهو مؤشر أداء حاسم. تبحث هذه الدراسة في دور التنوع بين الجنسين على الكفاءة الفنية. تعتمد هذه الدراسة على تطبيق النماذج الحدودية. نادرا ما استخدمت هذه الأنواع من النماذج في الدراسات حول تأثير التنوع بين الجنسين على الكفاءة الفنية في الشركات الصغيرة والمتوسطة في مصر. وفي هذا الصدد، تم إجراء تحليل لتأثير التنوع بين الجنسين على الكفاءة الفنية للشركات الصغيرة والمتوسطة المصرية في 10 قطاعات اقتصادية مختارة مصنفة وفقا لمعيار ISIC4. تظهر نتائج النموذج الحدودي أن متطلبات رأس المال والعمالة ومستلزمات الانتاج الإجمالية للشركات الصغيرة والمتوسطة لها تأثير إيجابي على انتاج الشركات الصغيرة والمتوسطة ولها دلالة إحصائية عند مستوى 5٪. ومتغيرات المدخلات الأخرى ذات دلالة إحصائية بناء على طبيعة المدخلات المطلوبة لكل قطاع. في حين تختلف مرونة المدخلات بين القطاعات الاقتصادية، فإن مرونة مدخلات العمل في أعلى بكثير من مرونة مدخلات رأس المال، مما يعني أن الشركات الصغيرة والمتوسطة أكثر اعتمادا على العمالة باستثناء (صناعة منتجات المعادن اللافلزية الأخرى)، التي تحتوي على مرونة مدخلات رأس المال أعلى مما يشير إلى أنه أكثر اعتمادا على رأس المال. بينما في معادلة الكفاءة الفنية، وجد أن التنوع بين الجنسين في القوى العاملة يفسر جزءا من الأداء المحسن للشركات الصغيرة والمتوسطة.

الكلمات المفتاحية: الشركات الصغيرة والمتوسطة، الكفاءة الفنية، التنوع بين الجنسين، نموذج العشوائية

Abstract:

This study investigates the relationship between gender diversity and technical efficiency in Egypt's Small and Medium-sized Enterprises (SMEs). The impact of gender diversity on SMEs performance has been widely examined; however, in Egypt, studies have often focused on profitability rather than technical efficiency, which is a crucial performance indicator. This study examines the gender diversity role on the technical efficiency. This study relies on applying frontier models; these types of models are rarely utilized in studies on gender diversity in Egypt. In this regard, an extensive analysis of the effect of gender diversity on technical efficiency of Egyptian SMEs in selected 10 economic sectors classified according to ISIC4. The findings of the frontier model show that SMEs capital, labor and total commodity requirements have positive effects and are statistically significant at the 5% level. Other input variables are statistically significant based on the nature of needed input per sector. While input elasticities differ among the economic sectors, the elasticities of labor input in the stochastic production functions are much higher than capital input elasticities, which means they are more dependent on labor except for industry code (23), that has capital input elasticity higher which indicates it is more dependent on capital; while in the technical efficiency equation gender diversity in the workforce is found to explain part of the improved performance.

Keywords: SMEs, Technical efficiency, Gender diversity, Parametric stochastic frontier (SF) model

Introduction:

The goal of achieving technical efficiency has driven the rationale for promoting gender diversity over the last ten years. Sustaining gender diversity would generate many economic benefits for enterprises in specific, as well as the whole economy in general. Therefore, international organizations stressed the multiple benefits of establishing gender diversity through arguments like, "Gender equality is smart economics." The efficiency improvements entail development objectives, business performance, and economic growth (Berik, 2017).

Specifically, technical efficiency refers to the producer's ability to decrease inefficient use of resources by either maximizing output relative to input constraints or minimizing input use in accordance with output production limits (Adusei, 2019). Technical efficiency refers to a firm's capacity to operate at the forefront of technology. A firm operating below the frontier may be considered inefficient, as it fails to achieve optimal results while using the same quantity of inputs (Rajesh Raj, 2007).

In this context, from an alternative viewpoint, SMEs are crucial to a nation's economic performance and serve as vital instruments for economic transformation. They contribute to poverty alleviation, job creation, productivity enhancement, and economic growth (Oduro, 2019). SMEs contribute to generating new products, innovative concepts, and cutting-edge management practices (Hashani, 2014). Consequently, SMEs are more able to penetrate new markets, get deeper insights into customer behavior, and improve product development processes more effectively by fully using information communication technology, hence attaining technical efficiency (Chen et al., 2016).

Global research has extensively studied the impact of gender diversity on the success of SMEs. Nonetheless, existing research does not examine whether a technical performance disparity exists between male and female employees with similar work experience (Shava & Rungani, 2016). This research contributes to the literature on the relationship between gender diversity in technical, sales, and corporate sectors and SMEs performance. This study will focus on the following research questions: Are Egypt’s SMEs labor or capital dependent? Does gender diversity enhance SMEs technical efficiency?

Historically, studies on gender effects in Egypt have rarely utilized frontier models to evaluate the performance of companies. This study explores the importance of gender diversity and performance, particularly regarding technical efficiency. In the case of Egypt, a limited number of empirical research studies have identified the factors that impede technological efficiency within small and medium-sized enterprises (SMEs)[1]. Empirical data and modelling results indicate that women's inclusion enhances productivity and profitability for SMEs (Ramadan and Hassan, 2021; Shaaban, 2022); however, industries in Egypt continue to exclude women from their firms (Othman and Hegazy, 2024; Elsayed et al., 2024).

Nonetheless, the effect on market-orientated performance remains ambiguous, indicating that, while gender diversity may enhance internal success measures, its impact on outward views and values may be affected by other variables (Chapple and Humphrey, 2013: Simionescu et al., 2021). This intricacy underscores the need for more study to comprehend how gender diversity influences diverse market dynamics and stakeholder views, ultimately determining business performance in a varied way. Comprehending these relationships may provide significant insights for organizations seeking to improve their governance frameworks and match them with wider social expectations, thereby promoting a more inclusive corporate climate. These results might assist policymakers in formulating frameworks that foster gender diversity in senior corporate governance, thereby advancing both equality and sustainable economic development and stability.

By prioritizing gender diversity, firms may foster a more innovative and adaptable staff, which is crucial in today's swiftly evolving business environment. This dedication to diversity improves decision-making and bolsters a company's image, recruiting talent and cultivating consumer loyalty in a more socially aware market (Solakoglu and Demir, 2016). By adopting these principles, organizations may generate a ripple effect that shapes industry norms and motivates other firms to implement similar practices, thus fostering a fairer corporate environment. Systemic improvements foster a culture of inclusion, whereby many opinions are esteemed and included in strategic planning, promoting sustained success across several sectors. This innovative strategy not only empowers workers but also establishes

[1] https://mped.gov.eg/adminpanel/sharedfiles/c_The%20impact%20of%20the%20gender%20dimension%20of%20operation%20on%20improving%20establishments%E2%80%99%20performance.pdf

organizations as frontrunners in corporate social responsibility, creating a standard for others to emulate and fostering a more sustainable future. By emphasizing ethical practices and social impact, organizations may improve their brand image while concurrently tackling urgent societal issues, so effecting a significant change in the communities they serve. This dedication to ethical leadership cultivates confidence among customers and stakeholders, generating a ripple effect that promotes more investments in social programs and community involvement.

The contribution of this work is twofold: first, it focuses on the Egyptian SMEs. While rich literature has assessed gender diversity in the SMEs sectors. Lack of data in developing countries underlies the scarcity of studies on price behavior in these countries. Exceptions to this dearth of studies in developing countries (Rajesh Raj, 2007; ElKhouly et al., 2021). Second, we employ frontier modelling in contrast to the type of models applied to the economic census in Egypt.

The remainder of this paper is organized as follows. Section two presents a review of literature assessing gender diversity. Section three describes the SMEs landscape in Egypt. Section 4 presents the methodological approach: the parametric frontier model. Section 5 reports and analyzes the empirical results. Section 6 presents the concluding remarks and a summary of the research results.

Literature Review:

Many empirical studies investigated the effects of gender diversity on firm performance while putting less emphasis on the impact on the profitability of the firm. For example, Nguyen et al. (2015) examined the relationship between a firm's financial performance and gender diversity in a transitional economy characterized by inadequate corporate governance, using a sample of 120 publicly listed Vietnamese companies from 2008 to 2011. The findings indicated that gender diversity on the board influenced the firm's success. The significant proportion of female directors in the boardroom reflects the assumption that an increase in female directors correlates with improved business performance. The positive effect of board gender diversity on performance diminishes when the proportion of female directors attains a threshold of around 20%. The study's outcomes indicated a potential trade-off between the advantages and disadvantages of increased gender disparity. Bennouri et al. (2018) analyzed a sample of 394 French corporations from 2001 to 2010 to examine the correlation between female directorship and accounting

performance Return on Assets and Return on Equity (ROA and ROE) as well as market-based performance of enterprises. The findings indicated that a higher presence of women in directorship significantly enhances ROA and ROE.

Rajesh Raj (2007) employed a trans-log stochastic frontier production function to examine the extent and origins of technological efficiency in the unorganized manufacturing sector in Kerala, India. The analysis utilizes business-level data for five major industry groups and the entire sector. The findings indicated that Kerala's unorganized manufacturing enterprises exhibit significant technical inefficiency. Factors such as size, ownership, location, and operational seasonality significantly affect the lack of technical efficiency across most industrial sectors. Moreover, the accessibility of money and the utilization of hired labor are critical determinants in fostering technical efficiency.

Doss (2017) observed that occasionally female farmers utilize inputs less efficiently than their male counterparts, and in such cases, equal access to resources is unlikely to enhance efficiency or may even diminish it. This suggests that while advocating for gender variety may not always boost efficiency, it doesn't imply abandoning the pursuit of gender diversity. Shava & Rungani's study (2016) study objective was to determine whether there is a significant performance difference between small and medium-sized businesses (SMEs) owned by men and women, as well as the extent to which gender differences in levels of business-related experience could explain any gender gap in SME performance. The results indicate that SMEs owned by men and women function comparably. Consequently, male and female entrepreneurs operate their enterprises in a similar way, regardless of their degree of business expertise. Contrary to existing literature, the study concludes that the influence of gender on entrepreneurship and the comparison of business outcomes between male- and female-owned entities, without accounting for essential factors such as prior business experience, may lead to erroneous conclusions, implying that gender does not affect the performance of SMEs.

Adusei (2019) examined the technical efficiency of several microfinance organizations in Latin America via stochastic frontier analysis. It especially investigated whether disparities in ownership may explain differences in technical efficiency both within and across enterprises. The data collection comprised 1,681 observations from a panel of 315 institutions throughout 18 Latin American

countries, focusing on non-governmental organizations, banks, credit unions, cooperatives, and non-bank financial intermediaries. The results underscore the substantial influence of ownership type on technical efficiency: banks and non-bank financial intermediaries exhibit considerably higher intra-firm and inter-firm technical efficiencies than non-governmental organizations and cooperatives.

Gender diversity in entrepreneurship was also a topic of study in Egypt. ElKhouly et al. (2021) explored whether gender diversity influences the success of entrepreneurship in small and medium-sized enterprises by highlighting various factors such as age, education, prior experience, interpersonal skills, goal achievement, and business expansion. Using surveys for SMEs and relying on bivariate analysis tools. The findings indicated that the entrepreneur's gender did not impact goal attainment, employment growth, profit growth, or technological proficiency. This is attributed to the fact that women are less likely to engage in entrepreneurial activities, which adversely affects their integration into the labor market and the initiation of their businesses. Nonetheless, the entrepreneur's gender influenced sales growth, interpersonal skills, and business competencies.

Elhamidi and Baslevent (2010) employed an econometric model to investigate the variations in activity sectors, income, and growth that might be attributed to the entrepreneur's gender in micro and small enterprises. The sample comprises 4,136 permanent businesses in urban regions of Egypt and 4,238 permanent firms in urban areas of Turkey. This study emphasized the industries and activity categories in which women are more likely to succeed, underscoring those areas where government support would be most effective. Other research focused on the correlation between gender diversity, income, and productivity, including Said et al. (2018). This research examined this correlation utilizing the 2013 dataset. The research revealed that in the knowledge-intensive service sector, gender diversity had a favorable correlation with productivity and wages. In less knowledge-intensive service firms and both high- and low-tech manufacturing sectors, productivity and salary were either uncorrelated or negatively linked.

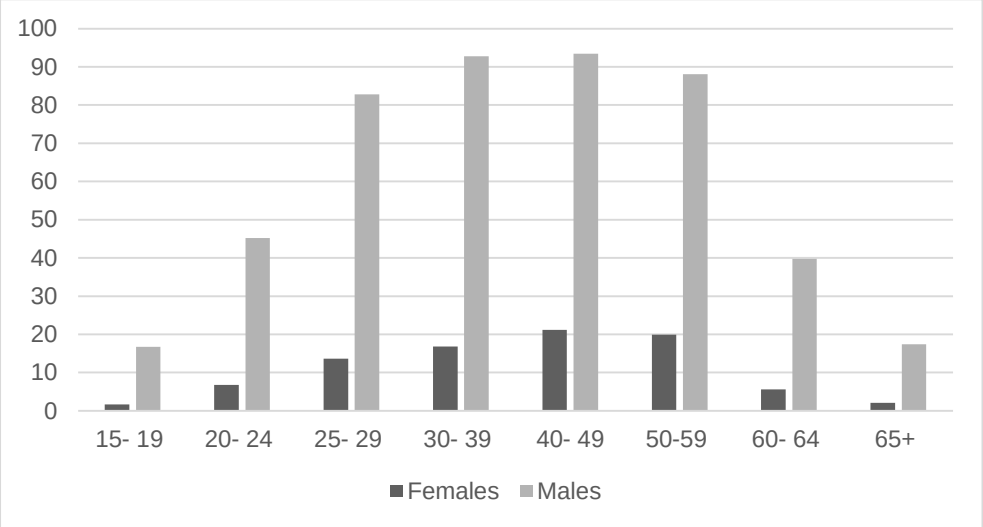
As abovementioned, the impact of gender diversity on firms' performance has received considerable attention in general in the literature, with several contradictory findings, as some studies indicate a favorable correlation, while others discover a

negative correlation (Bennouri, et al., 2018). However, no research has yet investigated this effect on technical efficiency in Egyptian SMEs.

SMEs in Egypt:

The employed population in Egypt represented 28.8 million in 2023, which equals 40 percent of the population, with significant gender diversity, with 24.2 million male workers representing 84.3 percent and 4.5 million female workers representing only 15.7 percent (CAPMAS, 2023). The female worker participation rate in Egypt was stable during the period 2005–2015 and started to exhibit a declining trend from 2015 to 2023, from 22.4 percent to 15.7 percent, respectively.

Figure 1
Employment rates by age groups



Source of Data: CAPMAS economic census 2017/2018. (2023). quarterly bulletin Labor force survey second quarter—September issue. https://www.capmas.gov.eg/Pages/Publications.aspx?page_id=5106&Year=16603

SMEs are important drivers for sustained economic growth and job creation in developing countries. In Egypt, there are around 2.5 million SMEs in the 2012/2013 economic census (3.7 million SMEs in the 2017/2018 economic census), representing 75% of the total employed workforce and 99% of non-agricultural

private sector establishments[2, 3](representing 49% of the total employed workforce in the economic census, 2017/2018[4, 5]). Regarding gender and female workers in Egypt's main economic activities, figures 1, 2, and 3 show that females occupy management positions (Source of data: CAPMAS economic census 2017/2018) and are highly present in basic pharmaceutical activity, followed by food products and retail trade. In addition, wholesale and retail trade, as well as food products and pharmaceutical activities, have the largest number of female specialists and technicians, according to the economic census data that was published by CAPMAS for the year.

Figure 2

No. of Female managers per sector

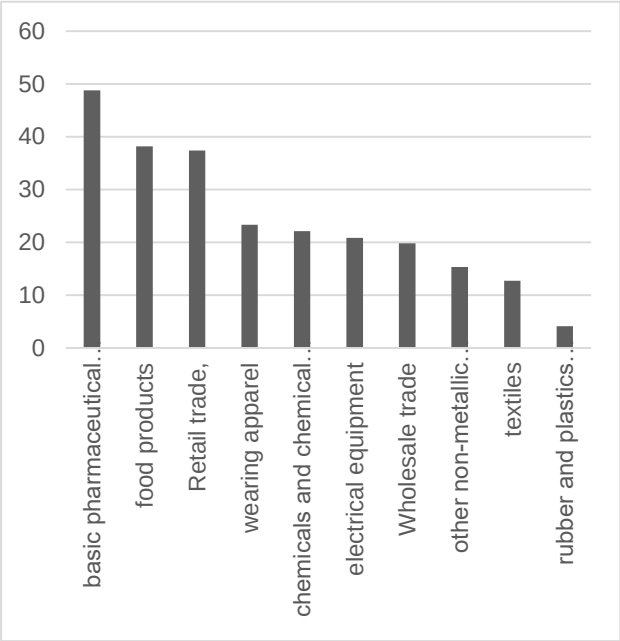
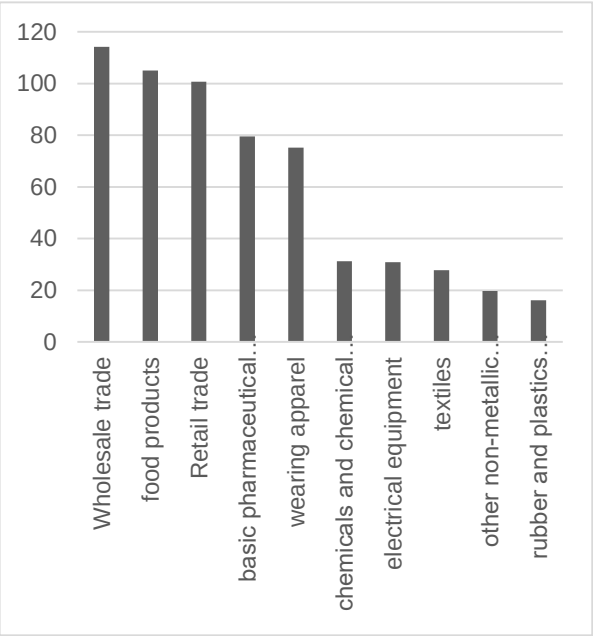


Figure 3

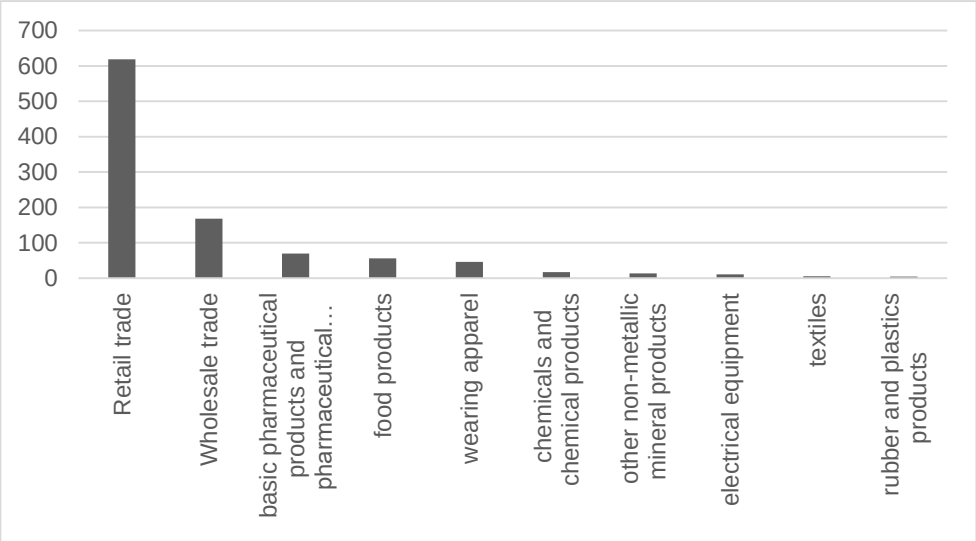
No. female specialists and technicians



[2] https://documents1.worldbank.org/curated/es/997581487153582013/pdf/112821-WP-MNA-Islamic-Banking-Executive-Summary-PUBLIC.pdf
[3] https://www.eeas.europa.eu/node/43122_en
[4] https://www.capmas.gov.eg/Admin/News/PressRelease/20185613155_work_e.pdf
[5] https://censusinfo.capmas.gov.eg/metadata-ar-v4.2/index.php/catalog/1592

Figure 4

No. of female sales workers.



Methodology

There is a large body of work that focuses on measuring technological (in)efficiency using stochastic frontier models. This research has been ongoing since the groundbreaking investigations conducted by Aigner et al. (1977) and Meeusen van den Broeck (1977). Typically, a half-normal or truncated normal distribution is used to represent inefficiency in most models. To calculate the technical inefficiency scores, a transformation known as the JLMS estimator, developed by Jondrow et al. (1982), is used. Several following stochastic frontier studies have focused on elucidating inefficiency. In order to achieve this objective, several research studies, particularly those conducted by Kalirajan (1981) and Pitt and Lee (1981), have used a two-step approach. Initially, the production frontier is calculated, and then, the technical inefficiency scores are generated for each individual business. During the second stage, the technical inefficiency scores are subjected to regression analysis using a collection of factors that are believed to have an impact on a firm's inefficiency. Considering the limitations of the two-step method, several subsequent research studies have opted to estimate both the inefficiency scores and external impacts in a single step. Among these research studies, the most well recognized

ones are the works of Kumbhakar et al. (1991), Huang and Liu (1994), and Battese and Coelli (1995). To analyze the external impact on inefficiency, the authors assign a parameter to the average value of the pre-truncated distribution. The models mentioned, Caudill and Ford (1993), Caudill et al. (1995), and Hadri (1999), enhance the existing models by including the possibility of heteroscedasticity via the parameterization of the variance of the pre-truncated distribution. In his 2002 study, Wang suggests a comprehensive model that integrates both approaches to one-step models.

The analytical model

This research uses a two-stage technique. The initial phase involves estimating technical efficiency scores for the sample of small and medium-sized enterprises (SMEs) using a stochastic frontier analysis (SFA), which is a parametric approach. In SFA, the production function that represents the relationship between inputs and output is assumed to be known (Alvarez and Crespi, 2003; Battese and Coelli, 1992; Kumbhakar and Lovell, 2000). In this work, the Cobb-Douglas production function is used as the preferred functional form for stochastic frontier analysis (SFA). In the second stage, the estimated technical efficiency scores are subjected to regression analysis with hypothesized explanatory variables (Coelli et al., 2005; Battese and Coelli, 1992; Battese and Coelli, 1995; Kumbhakar and Lovell, 2000).

First stage

A multi-input factor (6 inputs) and one output Cobb–Douglas production function in logarithmic form utilizing cross-sectional data can be expressed as follows:

$$\ln Y_i = \beta_0 + \beta_1 \ln X_{1i} + \cdots + \beta_6 \ln X_{6i} + (V_i - U_i)$$

where:

Y_i = Total production
X_{1i} = Capital
X_{2i} = Labor
X_{3i} = Total commodity requirements
X_{4i} = Operating costs (subcontractors)
X_{5i} = Operating costs (maintenance)
X_{6i} = Operating costs (research and experiments)

V_i = A random error term for firm i, and is assumed to be an independently and identically distributed normal random variable with zero mean and variance V_i : iid$N(0, \sigma_v^2)$ independently distributed of U_i; and

U_i = A non-negative random variable for firm i, accounting for technical inefficiency in the production function and is assumed to be independently distributed such that U_i is defined by the truncation of the normal distribution with mean μ1 and variance σ_u^2

V_i and U_i are also assumed to be independently distributed for all firms (i =1,2,…, N) (Battese and Coelli, 1995; Coelli, 1996; Coelli et al., 2005). If U_i is equal to zero the firm is defined as being totally technically efficient and is at its maximum output level given the inputs used. If U_i is greater than zero, the firm is defined as being technically inefficient (Coelli, 1996; Kumbhakar and Lovell, 2000). The subscript i refers to firms, β_0 represents the intercept term, $\beta_{1\ to\ 6}$ represents the coefficient estimates of inputs.

Second stage

There is no single theory that guides selection of variables to be used in regression analysis of possible causes of inefficiency of the production units (SMEs) under investigation. The standard practice is to draw from literature, emphasizing potentially important local characteristics of factors while being mindful of constraints imposed by data availability. In this context the following explanatory variables are emphasized in this study for the sample of Egyptian SMEs: Gender specific skilled labor (knowledge and skill intensity), No. of female managers, No. of female specialists and technicians and No. of female sales workers. Hence, potential firm specific factors that could influence technical efficiency can be modelled in an inefficiency functional form as follows:

$$U_i = \delta_0 + \delta_1 Z_{i1} + \delta_2 Z_{i2} + \delta_3 Z_{i3} + \xi_i$$

Z_{i1} = Female managers

Z_{i2} = Female specialists and technicians

Z_{i3} = Female sales workers

Z_{i4} = Male managers

Z_{i5} = Male specialists and technicians

Z_{i6} = Male sales workers

The coefficients of the stochastic frontier production function and technical inefficiency effects model can be estimated utilizing the maximum likelihood method. The maximum likelihood function is defined in terms of the variance parameters as follows (Battese and Corra, 1977; Coelli et al., 2005):

$$\sigma^2 \equiv \sigma_v^2 + \sigma_u^2$$

$$and$$

$$\gamma = \sigma_u^2/\sigma^2$$

where:

σ_v^2 = random error variance

σ_u^2 = Technical inefficiency effects variance

γ denotes the proportion of technical inefficiency within the total residual variance. If the value of γ is near zero, deviations from the frontier are mostly caused by noise, whereas a value close to one suggests that departures from the frontier are mostly due to technical inefficiency (Coelli et al., 2005; Tran et al., 2008).

Data and variables

We use firm-level data from economic censuses for 2017 compiled by the Central Agency for Public Mobilization and Statistics (CAPMAS) of Egypt. The total number of surveyed SMEs included in the 2017 economic censuses is 170,330. The sample was filtered based on the firm ownership (private investment, private organized, private), economic activity (manufacturing, wholesale, and retail), and geography (national). Based on this filtering criteria, the sample was reduced from 170,330 SMEs to 2,924 SMEs. The key variables utilized for the first stage are in 1000 EGP values. The gender variables (male and female administrative and technical positions in the SMEs) are utilized in the second stage of the frontier model and obtained from the economic census data. Table 1 provides descriptive analysis of the variables included in the analysis.

Table 1

Descriptive analysis of the variables in the frontier model

	Total full production (EGP)	Total commodity requirements (EGP)	Machinery and equipment (EGP)	Labor wages (EGP)
Mean	152,060,596	90,941,711	29,534,720	7,365,823
Standard Error	18,099,802	13,187,234	6,939,604	661,177
Median	4,100,000	1,020,290	135,000	586,761
Mode	10,444,928	1,338,592	-	216,000
Standard Deviation	978,561,715	712,964,853	375,188,131	35,746,371
Kurtosis	434	552	1,086	301
Skewness	18	21	30	14

Table 2

(continued). Descriptive analysis of the variables in the frontier model

	Service expenses during the year - operating expenses of third parties and subcontractors (EGP)	Service expenses during the year - maintenance expenses (EGP)	Service expenses during the year - research and experimental expenses (EGP)	Service expenses during the year - expenses for advertising, marketing (EGP)
Mean	852,601	719,862	50,986	930,920
Standard Error	303,181	123,018	11,568	182,318
Median	-	5,000	-	1,500
Mode	-	-	-	-
Standard Deviation	16,391,392	6,650,937	625,428	9,856,981
Kurtosis	1,468	418	565	355
Skewness	35	19	22	18

Empirical results

Maximum likelihood estimates (MLE) of the parameters of the stochastic frontier and technical inefficiency effects models (Eq. (1) and (2)) are estimated simultaneously using the computer program STATA 17. Table 2 shows the list of sectors included in the analysis. Table 3 presents the results of the specified frontier model for the SMEs of the selected sectors, which belong to three economic activities which are retailing, wholesaling, and manufacturing.

Table 3
Description of the sectors

Sector code	Sector title
10	Manufacture of food products
13	Manufacture of textiles
14	Manufacture of wearing apparel
20	Manufacture of chemicals and chemical products
21	Manufacture of basic pharmaceutical products and pharmaceutical preparations
22	Manufacture of rubber and plastics products
23	Manufacture of other non-metallic mineral products
27	Manufacture of electrical equipment
46	Wholesale trade, except of motor vehicles and motorcycles
47	Retail trade, except of motor vehicles and motorcycles

The results show that capital, labor and total commodity requirements have positive coefficients and are significant at the 5% level. Other input variables are statistically significant based on the nature of needed input per sector. All SMEs exhibit decreasing marginal returns to scale as the sum of the estimated input coefficients is lower than unity, except for food manufacturing and rubber and plastics products that exhibit constant and increasing economies of scale, respectively. While input elasticities differ among the economic activities, the elasticities of labor input in the stochastic production functions are much higher than capital input elasticities, which means they are more dependent on labor except for industry code (23), which has higher capital input elasticity, this indicates it is more dependent on capital. The estimated gamma for SMEs in different economic activities is less than 0.6, showing a low degree of technical inefficiency. Given that all industries are more labor intensive, it is relevant to distinguish between male and female effects on technical efficiency. The table also shows the estimated results of the technical inefficiency effects model. Negative coefficient signs of the independent variables indicate a positive effect on technical efficiency. The results demonstrate that at the level of management participation, whether female or male, gender diversity can either positively or negatively impact technical efficiency, depending on the specific economic sector of the SMEs. For example, in industry code (20), male specialists and technicians have more positive effects on technical efficiency than their female counterparts, while in the case of the retail sector, both male and female managers have similar positive effects on technical efficiency. In industry code (27), male

managers exhibit stronger effects compared to females, with female sales workers having a more positive impact on technical efficiency than their male counterparts.

The low technical efficiency performance of some industries could be attributed to the low dependence on capital. Furthermore, this is consistent with the problems identified in the Enterprise survey 2020 in Egypt, which are access to finance, practices of the informal sector, and the high tax rates and regulations. The manufacturing, textile, and chemicals industries are the two most technically efficient sectors, and they heavily rely on capital. The limited reliance on machinery and equipment (capital) input indicates a lack of capital investment, which hinders the ability to engage in high-value activities and produce distinctive, high-quality output that can effectively compete in marketplaces. There was a strong and positive relationship between skilled labor and the technological efficiency of all types of manufacturing and wholesale and retail SMEs. This highlights the need to consistently enhance the knowledge and abilities of the workers in small and medium-sized manufacturing enterprises by offering suitable educational and training opportunities. In the absence of a proficient labor force, the enhancement of technical efficiency in Egyptian SMEs would prove challenging, hindering their ability to partake in advanced knowledge, innovation, and high-value activities. Consequently, the economy will stay trapped in its middle-income status. Policy should prioritize the following areas. Firstly, enhancing the competencies of the workforce by providing enhanced educational and training resources to guarantee that labor skills are suitable and aligned with current business requirements.

Furthermore, it is essential to carry out this action in parallel with increased investment in capital stock and the enhancement of technology. In order to promote and support the growth of SMEs in the economy, it is crucial for these two trends to occur simultaneously. This will enable and motivate SMEs to engage in activities that require advanced knowledge, skills, innovation, and the creation of greater value. This will also facilitate the production of superior and distinct goods, giving them a greater competitive advantage in both local and global markets. This issue holds significant importance for the country, as it could potentially hinder its ability to break free from the middle-income trap. It aligns with Egypt's vision for 2030, which aims to enhance product quality and improve both SME and labor productivity. Furthermore, it is crucial for policy to promote various types of entrepreneurial endeavors and SME ownership. This can be achieved by granting

SMEs more opportunities to participate in stock markets, which will enhance their ability to obtain capital, technology, and skilled labor. Additionally, this will enable SMEs to experience accelerated growth, take advantage of economies of scale and scope, and enhance their technical efficiency. Government support, such as subsidized loan programs, like the Central Bank of Egypt's 5% and 11% initiatives for SMEs is an example of enabling environment initiatives that give SMEs better access to finance as part of the financial inclusion strategy, as well as digital inclusion strategy. There is a significant expansion taking place inside Egypt's entrepreneurial ecosystem, which is exceeding the development of small and medium enterprises (SMEs). Egypt's ecosystem was rated 76th in 2018, according to the Global Entrepreneurship Index. This is a substantial improvement from its previous ranking of 91st in 2012 (Abdelmalak et al., 2021). To obtain more comprehensive and inclusive advantages for a wider spectrum of domestic SMEs, it is necessary to reassess current policy measures and fix any shortcomings (Ali et al., 2021).

Table 4
Maximum likelihood estimates for parameters of the stochastic frontier model and technical inefficiency effects model

Sector code	10	13	14	20	21	22	23	27	46	47
Sample size	381	200	751	85	70	123	60	67	276	513
Stochastic frontier model										
Capital	0.060**	0.028	0.094**	0.074	0.196**	0.165***	0.275**	0.059**	0.127**	-0.001
Labor	0.267**	0.324**	0.292**	0.310**	0.206	0.264**	0.143	0.239**	0.513**	0.256**
Total commodity requirements	0.673**	0.632**	0.510**	0.649**	0.586**	0.603**	0.492**	0.663**	0.298**	0.357**
Operating costs (subcontractors)	0.003	0.001	-0.001	0.002	-0.015	0.034	0.023	-0.024	-0.062**	0.026
Operating costs (maintenance)	0.004	0.004	0.006	-0.033	0.013	0.008	-0.011	-0.029	0.029	-0.028
Operating costs (research and experiments)	-0.011	0.007	0.011	0.001**	0.006	-0.018	-0.041	0.025	-0.004	0.043
Operating costs (marketing)	0.012	0.003	0.001	0.015**	0.002	-0.029**	0.001	0.018	0.004	0.041**
Constant	1.453**	1.475**	3.031**	1.101	1.227	1.004	3.302**	2.159	2.996	9.121
Technical inefficiency effects model										
Female managers	-0.823**	0.102	-0.094	0.595**	-0.529**	0.180	-0.390**	-0.182**	-0.827	-0.403**
Female specialists and technicians	-0.416	-0.184	-0.077	0.502**	0.491**	0.008	-0.127	-0.143	-0.729**	0.042
Female sales workers	0.017	0.203	-0.299**	0.376**	-0.107**	-0.478**	-0.065	-0.566**	0.067	0.029
Male managers	0.145	0.128	0.004	-0.383**	0.432**	0.307**	-0.056	-0.255**	-0.942**	-0.400**
Male specialists and technicians	0.973	-0.076	-0.121**	-0.324**	-0.642**	-0.499**	0.036	0.134	0.078	-0.222**
Male sales workers	0.899	-1.504	0.111	-0.350**	0.220**	0.218**	-0.074	0.321**	0.081	-0.195**
Constant	-50.605	-0.770	0.403	0.595	-0.062	0.081	0.780	0.140	0.500	2.514
Gamma	0.588**	0.407**	0.060	0.228**	0.174**	0.092**	0.040	0.062	0.147**	0.061
Return to scale	1.000	0.956	0.896	0.959	0.782	1.032	0.767	0.961	0.938	0.613
Mean technical efficiency	.683	.955	.939	.848	.974	.913	.672	.647	.751	.175

Conclusions

This paper has conducted a gender-based technical efficiency analysis of Egyptian manufacturing, wholesale, and retail SMEs. The findings are important for decision makers to develop policies and sectors' SMEs to improve performance to remain vital to future sustainable growth and employment generation in Egypt. The results show that most of the industries are more labor intensive, gender diversity effects are found to have a relevant effect on technical efficiency, where some sector female participation has a higher positive impact on technical efficiency, which is consistent with the literature. To date, government policy measures should encourage and address the improvement of SMEs technical efficiency and competitiveness. Policy emphasis should be focused on empowering females to participate in the workforce, enhancing SME capabilities and workers capacities by improving labor force and entrepreneurial quality, and upgrading capital stock and technology. Overall, policy focus needs to continue investing in capacity building programs that give workers the required skills to benefit from the new advancements; this makes sure the workforce can adapt effectively and succeed in a rapidly evolving business landscape.

Future research can look at regional effects (urban vs. rural), firm age and size (micro vs. small vs. medium), and compare type of ownership (public vs. private). Previous studies (i.e. Batra, 1995) established that SMEs, after investing in their workers' education, experience better productivity and innovations, two attributes that drive any firm's sustained competitive advantage within a market as dynamic as that of the given in in the analysis of this paper. More recently, technological advancement in SMEs like the adopting of industry 5.0 approach, in the areas of automation and quality control measures, has been seen to positively correlate with higher levels of operational performance. The future policy directions, thus, should target enhancing not only the capacity of the labor force but also providing a stronger enabling environment to encourage female participation and technology adoption by the SMEs. This dual approach would significantly enhance the resilience of Egyptian SMEs toward impacts from shocks while promoting sustainable practices of development in the local context. Human capital development along with technological advancement will then structure a solid base that enhances performance in the immediate term and places it forward for long-term growth in the context of an increasingly interconnected global economy.

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