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Abstract

This study examines the relationships between gender, research and development (R&D), innovation, and productivity in Egyptian firms, leveraging panel data from 2013, 2016, and 2020. We explore whether female-led firms exhibit differences in productivity and innovation compared to their male-led counterparts. Going beyond most prior investigations, we allow for endogenous selection in innovation by incorporating instrumental variables within generalized structural equation models. Contrary to earlier findings, our results reveal that female-led firms are more likely to invest in R&D and innovate. Moreover, we show that female-led firms are as productive as male-led firms, challenging any notion of lower productivity among female-headed firms. In examining the links between R&D, innovation, and productivity, we determine that innovative and younger firms are more productive. Additionally, factors such as R&D expenditure, younger age, foreign technology adoption, and formal training provision increase the likelihood of innovation. Finally, firms adopting foreign technology and those with access to finance are more likely to invest in R&D.

Keywords: Gender, Productivity, Innovation, R&D, Instrumental variable, Generalized structural equation model, Egypt.
JEL Classifications: D24, J16, J24, O3.

ملخص

تبحث هذه الدراسة في العلاقات بين النوع الاجتماعي والبحث والتطوير والابتكار والإنتاجية في الشركات المصرية، والاستفادة من البيانات من 2013 و 2016 و 2020. نستكشف ما إذا كانت الشركات التي تقودها النساء تظهر اختلافات في الإنتاجية والابتكار مقارنة بنظيراتها التي يقودها الذكور. إذا تجاوزنا معظم الأبحاث السابقة، فإننا نسمح بالاختيار الداخلي في الابتكار من خلال دمج المتغيرات الأدائية ضمن نماذج المعادلة الهيكلية العامة. وعلى عكس النتائج السابقة، تكشف نتائجنا أن الشركات التي تقودها النساء من المرجح أن تستثمر في البحث والتطوير والابتكار. علاوة على ذلك، نظهر أن الشركات التي تقودها الإناث منتجة مثل الشركات التي يقودها الذكور، مما يتحدى أي فكرة عن انخفاض الإنتاجية بين الشركات التي ترأسها الإناث. وعند فحص الروابط بين البحث والتطوير والابتكار والإنتاجية، نصل إلى نتيجة هامة وهي أن الشركات المبتكرة والشابة أكثر إنتاجية. بالإضافة إلى ذلك، تزيد عوامل مثل الإنفاق على البحث والتطوير، والعمر الأصغر، واعتماد التكنولوجيا الأجنبية، وتوفير التدريب الرسمي من احتمالية الابتكار. أخيرًا، من المرجح أن تستثمر الشركات التي تعتمد التكنولوجيا الأجنبية وتلك التي لديها إمكانية الحصول على التمويل في البحث والتطوير.

1. Introduction

Technological innovations, whether manifesting as advancements in products or processes, have the power to either hinder or propel the growth trajectory of firms in the Middle East and North Africa (MENA) region. Despite the growth potential, Egyptian firms fall short of reaching their productivity frontier. In 2019, the value-added per worker in the industrial sector stood at USD 19,281, significantly below the global (USD 29,355) and MENA (USD 34,729) average. Similarly, the services sector in Egypt recorded USD 14,833 value-added per worker in 2019, less than half of the global average (USD 32,676) and notably lower than the MENA average (USD 25,268) (World Bank, 2023). The relatively low productivity levels observed may be attributed, at least in part, to firms' insufficient innovation efforts (Syverson, 2011), a challenge that may have been further exacerbated in female-led firms (Hoang et al., 2021).

This study examines the link between innovation and productivity in Egyptian firms, with a focus on the impact of gender on the propensity to innovate and its subsequent implications for productivity and overall firm performance. Specifically, our research strives to answer the following questions: (a) What firm-level factors drive research and development (R&D) and innovation in Egypt, and how does innovation affect labor productivity and overall firm performance? (b) Are female-headed firms in Egypt less inclined to spend on R&D and innovate, and do they exhibit lower productivity levels compared to their male-headed counterparts? (c) What determinants influence the likelihood of female-headed firms in Egypt spending on R&D and introducing process and product innovations? By unraveling these connections, our goal is to shed light on the nuanced dynamics at play and offer valuable insights into how gender factors into the innovation and productivity of Egyptian firms.

Several studies provide evidence supporting the positive impact of innovation on firm performance (e.g., Coad and Rao, 2008; Crowley and McCann, 2018; Friesenbichler and Peneder, 2016; Griffith et al., 2006; Hall and Kramarz, 1998; Hall et al., 2009; Parisi et al., 2006; Wadho and Chaudhry, 2018). These findings consistently indicate that both innovation and R&D efforts contribute to increased productivity, a correlation observed in numerous countries at both the firm and national levels.

While certain studies propose that male entrepreneurs play a pivotal role in driving firm innovation and productivity (Fairlie and Robb, 2009; Loscocco and Robinson, 1991; Marvel et al., 2015; Strohmeyer et al., 2017; Watson and Robinson, 2003), other research yields varied results concerning the relationship between gender, firm performance, and innovation (Brush, 1992; Eagly et al., 1995; Hoang et al., 2021; Lee and Marvel, 2014; Rosa et al., 1996). It is noteworthy that MENA countries, including Egypt, suffer from the largest gender gap worldwide with respect to women establishing and owning businesses (exceeding 40 percent), despite having some of the highest rates of entrepreneurial intentions for women (GEM, 2022).

Empirical evidence on the innovation, productivity, and gender relationship in middle-income countries, particularly in the MENA region, is limited (Crespi et al., 2016; Wadho and Chaudhry, 2018), and there exists a considerable gap in understanding how the gender of the firm head influences the likelihood of introducing innovations and its subsequent impact on productivity. This gap is particularly crucial in the MENA region, where women face substantial challenges in the labor market.

Our study aims to bridge this literature gap by identifying the key determinants of innovation, estimating the impact of innovation on productivity, and examining how gender shapes the innovation-productivity relationship in Egyptian firms. Methodologically, departing from prior research in middle-income countries, our estimation strategy addresses endogeneity concerns, especially those stemming from omitted-variable bias, and considers endogenous selection into innovation when estimating its impact on productivity. Conceptually, we explore how the gender of the firm head mediates the R&D, innovation, and productivity relationship.

The paper is organized as follows. Section 1 provides the introduction to the analysis and reviews relevant literature. Section 2 outlines the employed methodology and robustness checks, while section 3 discusses data sources, constructed variables, and summary statistics. Section 4 presents the estimated results, and section 5 concludes.

2. Model and estimation method

2.1. Generalized structural equation model with instrumental variables

The productivity of a firm and its engagement in innovation and R&D activities can be jointly influenced by several factors, including firm size, firm age, and firm leadership. Additionally, there are other factors that remain unobservable. To navigate this complexity, we construct a generalized structural equation model that captures the interplay between R&D, innovation, and productivity at the firm level within a recursive framework, considering the gender of the firm's leader at every stage. This model addresses the inherent endogeneity in the relationships by introducing common, unobserved components into three equations for R&D, innovation, and productivity. Furthermore, the framework accounts for the endogenous self-selection in the innovation decision by incorporating instrumental variables into the analysis.

We formalize the model through three equations:

- Firms make decisions to invest in R&D, a choice that can be influenced by the gender of the firm leader (R&D spending equation).
- Innovations are generated as a result of this investment, alongside other inputs, and the decision to introduce innovations can also be impacted by the gender of the firm leader (innovation output equation).

- Output is produced with innovations as inputs, among others, yet productivity may be different for female-led firms (productivity equation).

For firm i, the system of these three equations can be expressed as the following model:

$$\Pr(RD_{it} = 1 \mid X_{it,RD}) = \Phi(\alpha_o + \boldsymbol{V}_{it,RD}\alpha_V + \alpha_F Female_{it} + \eta_i + \epsilon_{it,RD}) \tag{1}$$

$$IO_{it} = \beta_o + \beta_{RD}RD_{it} + \boldsymbol{W}_{it,IO}\beta_W + \beta_F Female_{it} + \xi_{it} + \eta_i + \epsilon_{it,IO} \tag{2}$$

$$y_{it} = \gamma_o + \gamma_{IO}IO_{it} + \boldsymbol{Z}_{it,y}\gamma_Z + \gamma_F Female_{it} + \gamma_\xi \xi_{it} + \eta_i + \epsilon_{it,y} \tag{3}$$

where:

$$\eta_i \sim N(0, \sigma_\eta)$$

$$\xi_{it} \sim N(0, 1)$$

$$\epsilon_{it,RD} \sim \text{Logistic}(0, \pi^2/3)$$

$$\epsilon_{it,IO} \sim N(0, \sigma_{IO})$$

$$\epsilon_{it,y} \sim N(0, \sigma_y)$$

RD_{it} is a dichotomous indicator of firm i's decision to acquire knowledge, specifically related to expenditures on R&D. IO_{it} represents the introduction of process and/or product innovations by firm i. The productivity of firm i is denoted by y_{it}, measured by value-added per worker and sales per worker in two model specifications.

In equation 1, $X_{it,RD}$ represents the set of all observed explanatory variables included on the right-hand side of the R&D spending equation. Φ denotes the cumulative logistic function. $\boldsymbol{V}_{it,RD}$ is a vector encompassing potential determinants influencing the firm's decision to invest in R&D. $\boldsymbol{W}_{it,IO}$ is a vector encompassing firm characteristics that influence the firm's decision to innovate, alongside RD_{it} and the gender of its leadership (equation 2). $\boldsymbol{Z}_{it,y}$ is a vector encompassing firm characteristics that impact firm productivity, alongside IO_{it} and the gender of its leadership (equation 3).

In all three equations, $Female_{it}$ takes on the value of one if firm i in year t is led by a female owner or manager and zero otherwise. η_i is the common, unobserved firm-level component that also affects innovation and productivity and gives rise to endogeneity. We introduce η_i as a "latent" variable in our system of equations to attenuate omitted-variable bias. It can be thought of as the firm-level effect.

IO_{it} is endogenous and affected not only by η_i but also by a time-varying unobserved component ξ_{it}, which also affects y_{it}. We posit that a subset of time-varying $\boldsymbol{W}_{it,IO}$ (specifically R&D, manager's experience, employee training, access to external knowledge, and demand-pull factors) affect IO_{it} but not y_{it}. The subset of variables that are unique to $\boldsymbol{Z}_{it,y}$ are considered exogenous. $\epsilon_{it,RD}$, $\epsilon_{it,IO}$, and $\epsilon_{it,y}$ are the error terms of equations 1, 2, and 3, respectively. The error processes of the equations are allowed to be correlated.

2.2. Maximum likelihood

Within the generalized structural equation modeling framework, we estimate our model by maximum likelihood as a recursive system of equations (1-3). Following Drukker (2014), we leverage Stata's *gsem* command, enabling the incorporation of generalized (non-continuous) responses and latent variables such as η_i and ξ_{it}. An important feature of our model is allowing the errors to be correlated across the three equations. Cross-equation residual correlations or contemporaneous correlations are accounted for in the joint estimation process, deviating from the three-step estimation routine adopted in prior studies.

The R&D spending equation (equation 1) draws on the full sample of firms, functioning as a selectivity equation capturing the likelihood of a firm engaging in R&D. In contrast, equations 2 and 3 focus on firms with observed innovation inputs and output. We address endogenous selection into innovation by introducing instrumental variables in equation 2 while excluding these variables from equation 3. These instruments are anticipated to influence innovation but not productivity.

Considering the productivity equation (equation 3) in isolation, one could argue that IO_{it} is endogenous, potentially linked to the unobserved, firm-level component η_i. However, when viewed within the entire system of equations, we can introduce certain instruments. Specifically, we posit that RD_{it} and variables unique to $W_{it,IO}$ affect IO_{it} but not y_{it}. In this context, these variables can be treated as instruments, while the remaining factors are treated as exogenous covariates. Our system of equations encompasses unobserved components that can model random effects and endogeneity. The *gsem* framework further facilitates the estimation of each equation, drawing from the available observations for each respective equation.

To address the arbitrary metric of the latent variable ξ_{it}, its coefficient in equation 2 is normalized to one. This normalization allows the estimation of its magnitude in equation 3, where its variance is constrained to one.

We estimate the model two times, each for one measure of productivity. The obtained standard errors are clustered at the firm level to make them robust to heteroscedasticity and serial correlation (Abadie et al., 2017).

3. Data and Descriptive Analysis

We utilize panel data from the World Bank Enterprise Survey (WBES), which includes a total of 1,172 firms interviewed in 2013, 2016, and 2020. The dataset is designed to represent the population of firms in the manufacturing and services sectors.[3] One advantage is that this is panel data, unlike most of the Enterprise Survey datasets. Panel observations of responses on the R&D spending, innovation output, and productivity questions of interest are available for all three waves in Egypt. Detailed definitions of the variables used in this study are listed in Table A1 in the Appendix.

We use three dependent variables in the analysis. In the R&D spending equation, we utilize a binary variable to represent a firm's decision to engage in knowledge acquisition specifically through expenditure on R&D. In the innovation output equation, we use a continuous variable to indicate whether the firm has implemented either process and/or product innovation or both process and product innovations. Process innovation is measured by whether the firm has introduced new or significantly improved processes within the past three years. Similarly, product innovation is captured by whether the firm has introduced new products and/or services within the same timeframe. In the productivity equation, the dependent variable is firm performance, which is measured using two indicators: value-added per worker and sales per worker.

Our key explanatory variable is a dummy variable that switches on if the firm is led by a female owner and/or manager. We include this dummy variable in all three equations for R&D spending, innovation output, and productivity.

3.1. R&D determinants

As explanatory variables, in the R&D equation (equation 1), we use four sets of determinants to explain the firm's decision to initiate this effort: internal capabilities, demand-pull factors, technology-push factors, and outstanding barriers. To reflect a firm's internal capabilities, we include firm size (number of employees), manager's experience, firm age, and product concentration or diversification. The size of the firm has been consistently identified in the literature as a main determinant of knowledge generation activities as larger firms are better

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[3] A comprehensive description of the data and survey methodology is provided online at: www.enterprisesurveys.org.

positioned to benefit from economies of scale related to R&D production and appropriate external knowledge spillovers. We measure firm size as the (log) employment or specifically the (log) number of employees. We proxy human capital accumulation by the top manager's years of experience working in this sector. We include firm age to capture the impact of tacit knowledge that— through interactions with explicit knowledge—is essential to innovation management (Seidler-de Alwis and Hartmann, 2008). Our fourth indicator of internal capabilities is product concentration, measured by the main product/service share of a firm's total annual sales. We hypothesize that a firm's decision to invest in R&D decreases with product concentration since high product concentration reflects the narrow scope of the firm's production capability, which is likely to restrict the firm from operating easily in other industries, thereby worsening the expected returns to its R&D investments (Crespi et al., 2016).

We include two demand-pull factors: export orientation and competition intensity. Export orientation is measured as the exports' share of total sales and is expected to positively induce firm knowledge generation activities through "competition" and "learning" effects (Crespi and Zuniga, 2012). Competition intensity is measured by international competition, captured by whether the main market of the firm's main product is local/national or international.

For technology-push factors, access to external knowledge is facilitated by foreign technology adoption and being situated in a main business city. Foreign technology adoption is measured by whether the firm uses technology licensed from a foreign-owned company. We argue that adopting foreign technology can, through learning by doing, increase the likelihood of firms in developing countries introducing innovations. Being situated in a main business city is captured by a dummy variable. Previous research shows that agglomeration economies can raise the returns to R&D and innovation-related activities (e.g., Moretti, 2004).

As outstanding barriers or enablers, we include public support proxied by the percentage of firms owned by the government/state and access to finance proxied by having a line of credit or loan from a financial institution.

3.2. Innovation determinants

R&D is the key explanatory variable in the innovation output equation (equation 2). In addition to previously discussed internal capabilities, we introduce firms' training provision through a variable reflecting whether formal training programs were offered to employees. Effective training, even in the absence of R&D, is known to significantly enhance a firm's capacity to innovate or adeptly adopt innovations from elsewhere. Robust evidence supports the positive impact of employee training on firm innovation. Notably, a study by Dostie (2018) on Canadian firms establishes a correlation between higher employee training and increased process and product innovation. Bauernschuster et al. (2009) similarly find that training provided by German firms has a positive causal effect on innovation by enabling access to cutting-edge knowledge. Building on these insights, Laursen and Foss (2003) affirm the strong significance of both internal and external training in explaining the innovation performance of Danish manufacturing and non-manufacturing firms.

In the innovation output equation, we retain the demand-pull and technology-push factors from the R&D equation. However, internal capability variables (such as product concentration or diversification) and outstanding barriers or enablers are deemed irrelevant and are therefore excluded.

3.3. Productivity determinants

Innovation output is the key explanatory variable in the productivity equation (equation 3). Process innovation is anticipated to have a direct positive impact on productivity, given that newly introduced or significantly improved processes are typically adopted by firms to curtail production costs. Our hypothesis extends to product innovation, suggesting that it too can directly enhance productivity by generating new demand and fostering economies of scale in generating new products and services (Mohnen and Hall, 2013).

The productivity equation incorporates additional inputs for the production function, encompassing firm size (labor), labor quality, firm age, capital intensity, and fuel intensity. Human capital accumulation is proxied by the proportion of skilled labor force. Physical capital or capital intensity, measured as the (log) deflated replacement value of machinery, vehicles, and equipment (per employee), is included to reflect a firm's internal capability. Finally, fuel intensity assumes significance in the productivity equation as an identified outstanding barrier.

3.4. Descriptive analysis

Table 1 presents the summary statistics of the pooled sample and provides a breakdown by the gender of the firm lead. The statistics provide initial indications that firms led by women are not less productive than those led by men; furthermore, they are more likely to innovate and invest in R&D compared to their male-led counterparts.

Table 1. Summary statistics

	Obs.	Pooled Mean	Pooled Standard Deviation	Female-led Mean	Female-led Standard Deviation	Male-led Mean	Male-led Standard Deviation
Productivity							
Value-added per Worker	4,259	8.820	1.223	8.900	1.190	8.792	1.223
Sales per Worker	6,757	9.421	1.338	9.535	1.359	9.378	1.327
Innovation Output	7,759	0.170	0.446	0.241	0.521	0.144	0.409
R&D	7,757	0.057	0.232	0.093	0.290	0.047	0.212
Labor	7,641	96.493	267.496	124.139	346.276	85.636	233.901
Age	7,720	21.649	16.403	25.023	17.583	20.860	16.111
Manager Experience	7,728	21.498	11.448	22.488	12.066	21.165	11.287
Main Business City	7,786	0.424	0.494	0.474	0.500	0.416	0.493
Market Share	6,433	0.797	24.945	0.483	0.875	0.855	27.626
Diversification	7,630	9.604	17.760	9.662	18.462	9.310	17.355
Export Orientation	7,736	5.936	18.871	7.316	20.082	5.405	18.187
International Competition	7,090	0.057	0.232	0.080	0.272	0.051	0.220
Foreign Technology	7,088	0.082	0.274	0.111	0.315	0.074	0.261
Public Support	7,749	0.616	6.265	0.897	7.514	0.547	5.972
Access to Finance	7,632	0.096	0.295	0.156	0.363	0.082	0.274
Employee Training	7,754	0.123	0.329	0.152	0.360	0.106	0.308
Labor Quality	4,713	75.350	26.671	74.895	25.453	75.727	26.834
Capital Intensity	4,344	8.898	1.673	8.910	1.628	8.892	1.666
Energy Intensity	6,130	1.479	2.786	1.536	2.896	1.361	2.753

4. Empirical Results and Discussion

4.1. R&D spending

Table 2 presents the results derived from the R&D equation (equation 1). We report both the GSEM correlated random effects with IVs estimators (column 2) and the GSEM correlated random effects baseline estimators (column 3).

Table 2. GSEM estimation of the R&D spending equation

Dependent variable: R&D

	GSEM Correlated Random Effects with IVs	GSEM Correlated Random Effects
Female	0.622***	0.617***
	(0.198)	(0.211)
Labor	0.539***	0.535***
	(0.051)	(0.054)
Manager Experience	0.010	0.010
	(0.008)	(0.008)
Firm Age	-0.083	-0.085
	(0.104)	(0.113)
Market Share		
Monopolistic Competition	0.694**	0.686**
	(0.307)	(0.320)
Oligopoly	0.210	0.212
	(0.172)	(0.179)
Monopoly	-0.299	-0.307
	(0.575)	(0.665)
Diversification	-0.006	-0.006
	(0.004)	(0.005)
Demand Pull		
Export Orientation	0.004	0.004
	(0.005)	(0.005)
International Competition	0.145	0.146
	(0.716)	(0.692)

Table 2. GSEM estimation of the R&D spending equation (continued)

	GSEM Correlated Random Effects with IVs	GSEM Correlated Random Effects
Technology Push		
Foreign Technology	1.369***	1.358***
	(0.201)	(0.200)
Main Business City	-0.307*	-0.310*
	(0.169)	(0.179)
Credit		
Public Support	0.005	0.005
	(0.008)	(0.008)
Access to Finance	0.362*	0.360*
	(0.198)	(0.206)
M1[panelid]	1.000	
	(constrained)	
Latent Variable (L)		-0.166
		(1.257)
Constant	-5.527***	-5.475***
	(0.332)	(0.362)
Observations	4,520	4,520

*Robust standard errors clustered at the firm level are reported in parentheses. *, **, and *** denote statistical significance at the 10 percent, five percent, and one percent levels, respectively. Labor and age variables are in logs.*

Contrary to existing evidence, the obtained estimates reveal a significant tendency for female-led firms to allocate resources to R&D, irrespective of the chosen estimation methodology. The observed tendency could be attributed to a potential selection bias. If women face higher barriers to entry or advancement in entrepreneurial roles, those who do assume such positions may be exceptionally talented, skilled, or resourceful, contributing to the competitiveness of their firms. Overcoming gender-related challenges, these female entrepreneurs may possess entrepreneurial qualities and strategic vision, purposefully prioritizing R&D as part of their business strategy. Successful female firm heads may also have better access to financial resources, mentorship, and networks, enabling them to invest more substantially in R&D compared to their male counterparts. This strategic focus on innovation might be driven by a recognition of the importance of R&D for market differentiation and responding to consumer demands. Further research is needed, however, to confirm and elaborate on these potential factors contributing to the observed trend.

In alignment with existing literature, a firm's internal capabilities, as indicated by its size, play a role in determining the likelihood of R&D expenditure. Larger firms in Egypt exhibit a higher propensity to engage in R&D activities. Furthermore, factors related to technology push, such as the adoption of foreign technologies, significantly raise the probability of R&D spending. When Egyptian firms embrace foreign innovations, they are more inclined to allocate resources to R&D initiatives. This is likely driven by the benefits of accessing advanced technologies, improving global competitiveness, facilitating knowledge transfer, meeting evolving market demands, and fostering collaboration opportunities. In parallel, access to finance emerges as a notable factor influencing a firm's decision to invest in R&D. The availability of adequate funds seems to influence firms to engage in innovative activities by providing the necessary capital for hiring skilled personnel, acquiring technology, and conducting experiments. Access to finance is particularly significant for mitigating the inherent risks associated with R&D activities, enabling firms to adopt a long-term perspective and commit to innovation despite potential uncertainties.

Conversely, being situated in a main business city appears to have a discouraging effect on the inclination to invest in R&D. This trend can be attributed to factors such as elevated operational costs, heightened competition, and a market structure that favors operational efficiency over innovation. Further investigation is necessary to pinpoint the specific reasons driving this observed reluctance to invest in R&D in main business cities in Egypt.

Contrary to prevailing evidence, export orientation does not demonstrate a significant impact on the likelihood of R&D expenditure. Possible explanations for this deviation include unique market dynamics, resource allocation priorities that rank operational efficiency above innovation, barriers to entry in international markets, industry structures that may not heavily emphasize differentiation through R&D, as well as perceived risks associated with global competition. The cautious approach toward R&D spending in favor of immediate and predictable strategies, combined with potential government policies that are not strongly aligned with R&D incentives for export-oriented firms, may contribute to this atypical pattern. Further research of the Egyptian export landscape is needed to help explain the specific factors influencing this divergence from prevailing evidence.

Finally, our R&D estimates indicate that firms that primarily operate in international markets do not exhibit a distinct propensity for R&D compared to those targeting local or national markets. One plausible interpretation is that, in the context of intense global competition, firms might perceive R&D investments as riskier and more costly. The pressure to remain competitive in international markets may lead companies to prioritize cost-effective strategies and short-term gains over longer-term, riskier investments in innovation. The observed trend aligns with recent experimental evidence, which suggests that increased competition can have a negative impact on R&D investments, particularly for firms facing challenges or lagging behind in the short term (Aghion et al., 2018). This underscores the complex interplay of market dynamics, competition, and perceived risks that shape the strategic decisions of firms in Egypt, especially when navigating international markets where the stakes and competition are high.

4.2. Innovation output

Table 3 summarizes the results derived from the innovation output equation (equation 2). We report the GSEM correlated random effects with IVs estimators (column 2) and the GSEM correlated random effects baseline estimators (column 3).

Diverging from prior research (e.g., Hoang et al., 2021), the reported estimates demonstrate that female-led firms in Egypt are significantly more likely to introduce process and product innovations regardless of the employed estimation methodology. In the context of female entrepreneurs in the Egyptian manufacturing sector, it is possible that those who have risen to leadership positions have demonstrated resilience, strong leadership skills, and a high level of entrepreneurial acumen. If female entrepreneurs in this sector have successfully navigated historical gender-related challenges and emerged as owners and/or managers, they may indeed be exceptionally strong and resourceful. This could contribute to a greater willingness to take risks, invest in R&D, and drive innovation within their firms. This self-selection hypothesis aligns with the idea that those who break through gender barriers to become leaders may possess attributes that set them apart and position them as innovative and forward-thinking entrepreneurs. Additional research is required to obtain additional insights into the motivations, challenges, and leadership characteristics of female owners and managers in the Egyptian manufacturing sector.

Table 3. GSEM estimation of the innovation output equation

Dependent variable: innovation output

	GSEM Correlated Random Effects with IVs	GSEM Correlated Random Effects
Female	0.075***	0.070***
	(0.026)	(0.023)
R&D	0.523***	0.499***
	(0.070)	(0.055)
Labor	0.010*	0.011**
	(0.006)	(0.005)
Manager Experience	0.001	0.002**
	(0.001)	(0.001)
Employee Training	0.193***	0.188***
	(0.044)	(0.037)
Firm Age	-0.019**	-0.020**
	(0.009)	(0.009)
Demand Pull		
Export Orientation	-0.000	0.000
	(0.001)	(0.001)
International Competition	0.031	0.033
	(0.045)	(0.044)
Technology Push		
Foreign Technology	0.112***	0.112***
	(0.040)	(0.035)
Main Business City	-0.065***	-0.065***
	(0.015)	(0.012)
M1[panelid]	1.000	
	(constrained)	
Latent Variable (L)	1.000	-0.440***
	(constrained)	(0.167)
Constant	0.121***	0.113***
	(0.028)	(0.026)
Observations	4,520	4,520

*Robust standard errors clustered at the firm level are reported in parentheses. *, **, and *** denote statistical significance at the 10 percent, five percent, and one percent levels, respectively. Labor and age variables are in logs.*

In alignment with the CDM estimates by Crépon et al. (1998), our R&D coefficients exhibit positive and highly significant associations. In the Egyptian manufacturing sector, access to external knowledge through the adoption of foreign technology and skills development through on-the-job training emerge as two key determinants of innovation. Firms that embrace foreign technology and implement formal training programs for their employees are significantly more likely to introduce both process and product innovations. This could be attributed to the fact that incorporating advanced technologies from international sources provides a competitive edge, enhances knowledge transfer, and stimulates innovation in both processes and products within the Egyptian manufacturing sector. The positive correlation between skills development and innovation could be attributed to the enhanced skills and knowledge of the workforce, increased adaptability, knowledge transfer within the firm, increased employee engagement, and the competitive advantage gained through a well-trained and innovative workforce.

On the contrary, Table 3 indicates that older firms exhibit a lower propensity for innovation compared to younger firms. Several factors may contribute to this trend. Firstly, with established routines and business models, older firms may be more risk-averse than younger and more agile startups. Innovation often involves taking risks, and established firms may be more hesitant to deviate from proven strategies. Secondly, older firms may face more challenges in adapting to change due to organizational inertia. Established structures, processes, and cultures may hinder the ability to embrace and implement innovative practices. Thirdly, older firms may allocate a significant portion of their resources to maintaining existing operations, leaving limited resources for experimentation and innovation. This resource allocation pattern can impact the firm's willingness to invest in new ideas. Lastly, older firms, especially when successful, might become complacent with their current market position and not feel the same urgency to innovate as the newer entrants striving to establish themselves.

Finally, mirroring the results from the R&D estimations, firms located in main business cities in Egypt are significantly less likely to innovate. This pattern, akin to the R&D trend, could be shaped by various factors, including higher operational costs, the prioritization of immediate market demands and competition, adherence to established business models, potential market saturation, complex regulatory environments, and logistical challenges.

4.3. Productivity

Table 4 lists the results derived from the productivity equation (equation 3). It also reports the GSEM correlated random effects with IVs estimators (columns 2 and 4) and the GSEM correlated random effects baseline estimators (columns 3 and 5).

Table 4. GSEM estimation of the productivity equation

Dependent variable: value-added/sales per worker

	Value-added per Worker		**Sales per Worker**	
	GSEM Correlated Random Effects with IVs	**GSEM Correlated Random Effects**	**GSEM Correlated Random Effects with IVs**	**GSEM Correlated Random Effects**
Female	0.044	0.031	0.056	0.056
	(0.098)	(0.067)	(0.102)	(0.071)
Innovation	0.455**	0.227***	0.556***	0.256***
	(0.202)	(0.074)	(0.212)	(0.076)
Labor	0.047*	0.057***	0.054**	0.068***
	(0.026)	(0.018)	(0.027)	(0.019)
Labor Quality	-0.000	-0.001	-0.000	-0.000
	(0.002)	(0.001)	(0.002)	(0.001)
Firm Age	-0.096**	-0.100***	-0.093**	-0.101***
	(0.038)	(0.026)	(0.040)	(0.027)
Capital Intensity	0.282***	0.263***	0.346***	0.322***
	(0.026)	(0.015)	(0.028)	(0.017)
Energy Intensity	-0.196***	-0.185***	-0.211***	-0.200***
	(0.022)	(0.014)	(0.022)	(0.014)
M1[panelid]	1.000		1.000	
	(constrained)		(constrained)	
Latent Variable (*L*)	4.104***	1.000	4.354***	1.000
	(0.139)	(constrained)	(0.146)	(constrained)
Constant	6.398***	6.552***	6.370***	6.580***
	(0.296)	(0.171)	(0.313)	(0.177)
Observations	4,520	4,520	4,520	4,520

*Robust standard errors clustered at the firm level are reported in parentheses. *, **, and *** denote statistical significance at the 10 percent, five percent, and one percent levels, respectively. Labor and age variables are in logs.*

The reported estimates indicate that female-led firms in Egypt are as productive as male-led firms, refuting any argument for lower productivity among female-headed firms. The higher likelihood of women entrepreneurs introducing process and product innovations in their firms possibly mitigates the impact of barriers and gender stereotypes in the Egyptian manufacturing sector, which might have otherwise lowered their productivity. Through active involvement in innovation, women-led businesses not only demonstrate resilience in the face of challenges but also contribute to reshaping perceptions about gender roles in the sector. However, a more in-depth analysis is needed to understand the specific dynamics at play in the Egyptian context.

In line with existing evidence, innovative firms are significantly more productive. The impact of innovation on firm productivity is considerable both in significance and magnitude. A plausible explanation lies in the observation that these firms operate markedly below their technological and productivity frontiers, suggesting that substantial gains in productivity can be achieved in the Egyptian manufacturing sector through the introduction of incremental innovations.

Mirroring the results of the innovation output estimations, older firms are significantly less productive.

Finally, Table 4 shows that capital intensity has a significant positive impact on productivity, while fuel intensity has a significant negative impact on productivity. The observed positive impact of capital intensity on productivity suggests that Egyptian firms benefit considerably from increased investment in capital assets such as machinery. This relationship is likely attributed to the efficiency gains achieved through automation and advanced technologies, resulting in faster and more precise production processes. Additionally, larger production capacities associated with capital-intensive methods contribute to economies of scale, reducing average production costs per unit and enhancing overall productivity. In parallel, the significant negative impact of fuel intensity on productivity suggests that firms relying heavily on fuel-related inputs in their production processes face challenges that hinder overall efficiency. Higher fuel intensity often implies increased operational costs, vulnerability to energy price volatility, and potential difficulties in complying with environmental regulations.

5. Conclusion

This paper estimates the impact of innovation on productivity and explores the interplay of gender within this dynamic among Egyptian firms. We examine the links between R&D, innovation, and firm productivity, specifically observing the gender dynamics within the Egyptian manufacturing sector. Our key research questions include: (a) What firm-level factors drive R&D and innovation in Egypt, and how does innovation affect labor productivity and overall firm performance? (b) Are female-headed firms in Egypt less inclined to spend on R&D and innovate, and do they exhibit lower productivity levels compared to their male-headed counterparts? (c) What determinants influence the likelihood of female-headed firms in Egypt spending on R&D and introducing process and product innovations?

To explore these dynamics, we employ a generalized structural equation model to estimate the relationships among R&D, innovation output, productivity, and the influence of the gender of the firm head on this nexus, leveraging panel data spanning the years 2013, 2016, and 2020. This framework accommodates selectivity in reporting R&D expenditure and innovation output within a subset of firms and addresses the endogeneity inherent in the R&D-innovation-productivity relationship. Incorporating a “latent” variable helps capture the effects of unobserved factors underlying the relationships, further mitigating concerns related to endogeneity.

Our findings align with prior research, revealing a significant positive impact of R&D on innovation and of innovation on productivity. In a departure from existing evidence, our results indicate that female-headed firms are more likely to invest in R&D and introduce process and product innovations. However, when adjusting for innovation output, the analysis suggests no significant variation in productivity levels between female-headed and male-headed firms.

This analysis of the R&D-innovation-productivity relationship in Egypt, along with insights into the gender gap in R&D, innovation, and firm performance, provides valuable evidence for shaping policies that enhance firm performance and foster economic growth. Additionally, it presents targeted recommendations to support female entrepreneurs in their business pursuits. Policymakers are encouraged to promote gender-inclusive innovation policies, recognizing and supporting the engagement of female-headed firms in R&D activities. To incentivize R&D investments, it may be beneficial to introduce financial measures such as subsidies and tax breaks specifically tailored to foster the innovation capabilities of female entrepreneurs. The implementation of capacity-building programs, networking opportunities, and educational initiatives is vital to enhancing the skills and resources available to female-headed firms, thereby ensuring a supportive ecosystem for their active participation in innovation. Furthermore, policies should prioritize improving access to funding and resources for female entrepreneurs engaged in R&D and innovation in order to address potential barriers. A coordinated and comprehensive approach is essential to creating an environment that fosters the productivity of female-headed Egyptian firms.

References

Abadie, A., Athey, S., Imbens, G., and Wooldridge, J. (2017). When Should You Adjust Standard Errors for Clustering? NBER Working Paper No. 24003. https://doi.org/10.3386/w24003

Aghion, P., Bechtold, S., Cassar, L., and Herz, H. (2018). The Causal Effects of Competition on Innovation: Experimental Evidence. *Journal of Law, Economics, and Organization, 34*(2), 162-195. https://doi:10.1093/jleo/ewy004

Atalay, M., Anafarta, N., and Sarvan, F. (2013). The Relationship between Innovation and Firm Performance: An Empirical Evidence from Turkish Automotive Supplier Industry. *Procedia - Social and Behavioral Sciences, 75*(75), 226-235. https://doi.org/10.1016/j.sbspro.2013.04.026

Bauernschuster, S., Falck, O., and Heblich, S. (2009). Training and Innovation. *Journal of Human Capital, 3*(4), 323-353. https://doi.org/10.1086/653713

Baum, C., Lööf, H., Nabavi, P., and Stephan, A. (2016). A New Approach to Estimation of the R&D-Innovation-Productivity Relationship. *Economics of Innovation and New Technology, 26*(1-2), 121-133. https://doi.org/10.1080/10438599.2016.1202515

Brush, C. (1992). Research on Women Business Owners: Past Trends, a New Perspective and Future Directions. *Entrepreneurship Theory and Practice, 16*(4), 5-30. https://doi.org/10.1177/104225879201600401

Coad, A. and Rao, R. (2008). Innovation and Firm Growth in High-Tech Sectors: A Quantile Regression Approach. *Research Policy, 37*(4), 633-648. https://doi.org/10.1016/j.respol.2008.01.003

Crespi, G. and Zuniga, P. (2012). Innovation and Productivity: Evidence from Six Latin American Countries. *World Development, 40*(2), 273-290. https://doi.org/10.1016/j.worlddev.2011.07.010

Crespi, G., Tacsir, E., and Vargas, F. (2016). Innovation Dynamics and Productivity: Evidence for Latin America. *Firm Innovation and Productivity in Latin America and the Caribbean,* 37-71. https://doi.org/10.1057/978-1-349-58151-1_2

Crépon, B., Duguet, E., and Mairessec, J. (1998). Research, Innovation and Productivity: An Econometric Analysis at the Firm Level. *Economics of Innovation and New Technology, 7*(2), 115-158. https://doi.org/10.1080/10438599800000031

Crowley, F. and McCann, P. (2018). Firm Innovation and Productivity in Europe: Evidence from Innovation-Driven and Transition-Driven Economies. *Applied Economics, 50*(11), 1203-1221. https://doi.org/10.1080/00036846.2017.1355543

Dostie, B. (2018). The Impact of Training on Innovation. *ILR Review, 71*(1), 64-87. https://doi.org/10.1177/0019793917701116

Drukker, D. (2014). Some Stata Commands for Endogeneity in Nonlinear Panel-Data Models, German Stata Users Group Meeting (13 June 2014), https://www.stata.com/meeting/germany14/abstracts/materials/de14_drukker_gsem.pdf

Eagly, A., Karau, S., and Makhijani, M. (1995). Gender and the Effectiveness of Leaders: A Meta-Analysis. *Psychological Bulletin, 117*(1), 125-145. https://doi.org/10.1037/0033-2909.117.1.125.

Fairlie, R. and Robb, A. (2009). Gender Differences in Business Performance: Evidence from the Characteristics of Business Owners Survey. *An Entrepreneurship Journal, 33*(4), 375-395. https://doi.org/10.1007/s11187-009-9207-5.

Friesenbichler, K. and Peneder, M. (2016). Innovation, Competition and Productivity Firm-Level Evidence for Eastern Europe and Central Asia. *The Economics of Transition, 24*(3), 535-580. https://doi.org/10.1111/ecot.2016.24.issue-310.1111/ecot.12100.

Global Entrepreneurship Monitor (GEM) (2022). GEM 2023/2024 Global Report. Available at: https://www.gemconsortium.org/reports/latest-global-report
Griffith, R., Huergo, E., Mairesse, J., and Peters, B. (2006). Innovation and Productivity Across Four European countries. *Oxford Review of Economic Policy, 22*(4), 483-498. https://doi.org/10.1093/oxrep/grj028.
Hall, B. and Kramarz, F. (1998). The Effects of Technology and Innovation on Firm Performance, Employment, and Wages. Special Issue, *Economics of Innovation and New Technology, 5*(2), 109-343. https://doi.org/10.1080/10438599800000001.
Hall, B., Lotti, F., and Mairesse, J. (2009). Innovation and Productivity in SMEs: Empirical Evidence for Italy. *Small Business Economics, 33*(1), 13-33. https://doi.org/10.1007/s11187-009-9184-8.
Hoang, N., Nahm, D., and Dobbie, M. (2021). Innovation, Gender, and Labor Productivity: Small and Medium Enterprises in Vietnam. *World Development, 146,* 105619. https://doi.org/10.1016/j.worlddev.2021.105619
Laursen, K. and Foss, N. (2003). New Human Resource Management Practices, Complementarities and the Impact on Innovation Performance. *Cambridge Journal of Economics, 27*(2), 243-263. https://doi.org/10.1093/cje/27.2.243.
Lee, I. and Marvel, M. (2014). Revisiting the Entrepreneur Gender–Performance Relationship: A Firm Perspective. *An Entrepreneurship Journal, 42*(4), 769-786. https://doi.org/
10.1007/s11187-013-9497-5.
Loscocco, K. and Robinson, J. (1991). Barriers to Women's Small-Business Success in the United States. *Gender & Society, 5*(4), 511-532. https://doi.org/10.1177/089124391005004005.
Marvel, M., Lee, I., and Wolfe, M. (2015). Entrepreneur Gender and Firm Innovation Activity: A Multilevel Perspective. *IEEE Transactions on Engineering Management, 62*(4), 558-567. https://doi.org/10.1109/TEM.1710.1109/TEM.2015.2454993.
Mohnen, P. and Hall, B. (2013). Innovation and Productivity: An Update. *Eurasian Business Review, 3*(1), 47-65. https://doi.org/10.14208/bf03353817
Moretti, E. (2004). Workers' Education, Spillovers, and Productivity: Evidence from Plant-Level Production Functions. *American Economic Review, 94*(3), 656-690. https://doi.org/10.1257/0002828041464623
Oudgou, M. (2021). Financial and Non-Financial Obstacles to Innovation: Empirical Evidence at the Firm Level in the MENA Region. *Journal of Open Innovation: Technology, Market, and Complexity, 7*(1), 28. https://doi.org/10.3390/joitmc7010028
Parisi, M., Schiantarelli, F., and Sembenelli, A. (2006). Productivity, Innovation and R&D: Micro Evidence for Italy. *European Economic Review, 50*(8), 2037-2061. https://doi.org/10.1016/j.euroecorev.2005.08.002.
Rosa, P., Carter, S., and Hamilton, D. (1996). Gender as a Determinant of Small Business Performance: Insights from a British Study. *An International Journal, 8*(6), 463-478. https://doi.org/10.1007/BF00390031.
Seidler-de Alwis, R. and Hartmann, E. (2008). The Use of Tacit Knowledge within Innovative Companies: Knowledge Management in Innovative Enterprises. *Journal of Knowledge Management, 12*(1), 133-147. https://doi.org/10.1108/13673270810852449
Strohmeyer, R., Tonoyan, V., and Jennings, J. (2017). Jacks-(and Jills)-of-All-Trades: On Whether, How and Why Gender Influences Firm Innovativeness. *Journal of Business Venturing, 32*(5), 498–518. https://doi.org/10.1016/j.jbusvent.2017.07.001.
Syverson, C. (2011). What Determines Productivity? *Journal of Economic Literature, 49*(2), 326-365. https://www.jstor.org/stable/23071619

Wadho, W. and Chaudhry, A. (2018). Innovation and Firm Performance in Developing Countries: The Case of Pakistani Textile and Apparel Manufacturers. *Research Policy, 47*(7), 1283-1294. https://doi.org/10.1016/j.respol.2018.04.007

Watson, J. and Robinson, S. (2003). Adjusting for Risk in Comparing the Performances of Male- and Female-Controlled SMEs. *Journal of Business Venturing, 18*(6), 773-788. https://doi.org/10.1016/S0883-9026(02)00128-3.

World Bank (2023). World Development Indicators. Retrieved from: https://databank.worldbank.org/source/world-development-indicators

Appendix A

Table A1. Definition of the variables

Variable	Definition
Key Outcomes	
Value-added per Worker	(log) deflated value added per worker
Sales per Worker	(log) deflated sales per worker
Product Innovation	=1 if the firm introduced new products and/or services in last three years
Process Innovation	=1 if the firm introduced new/significantly improved process in last three years
Innovation	=1 if the firm introduced new products and/or services and/or introduced new/significantly improved process in last three years, =2 if the firm introduced both
R&D Spending	=1 if the firm spent on R&D in last fiscal year
Gender	
Female	=1 if firm is led by a female owner or manager
Internal Capabilities	
Labor	(log) number of permanent full-time production employees at the end of last fiscal year
Labor Quality	Percentage of full-time production workers who were skilled at the end of last fiscal year
Manager Experience	Number of years of experience working in this sector top manager has
Employee Training	=1 if the firm provided formal training programs for its permanent full-time employees in last fiscal year
Firm Age	(log) number of years of firm operation
Capital Intensity	(log) capital intensity = (log) deflated replacement value of machinery, vehicles, and equipment, divided by the number of permanent full-time employees in last fiscal year
Diversification	(Product concentration) Main product/service share (percentage) of total annual sales
Demand Pull	
Export Orientation	Direct exports share (percentage) of sales
International Competition	Whether the main market for the firm's main product is local/national or international
Technology Push	
Foreign Technology	=1 if the firm uses technology licensed from a foreign-owned company
Main Business City	=1 if the firm is located in a main business city
Other	
Market Share	Number of competitors the firm's main product faced in the last fiscal year for the main market in which this firm sold its main product
Public Support	Percentage of the firm owned by government/state
Access to Finance	=1 if the firm has a line of credit or loan from a financial institution
Energy Intensity	Proxied by fuel intensity = fuel cost as a fraction of sales