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ERF 30th Annual Conference

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ECONOMIC RESEARCH FORUM 30 years
منتدى البحوث الاقتصادية

2024

Beyond the Norms: Innovation, Productivity, and Gender in Egyptian Firms

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Abstract

This study examines the relationships between gender and R&D, innovation, and productivity within 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 into 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 identify that innovative and younger firms are more productive. 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 prone to invest in R&D.

Keywords. Gender, productivity, innovation, R&D, instrumental variable, generalized structural equation model, Egypt.
JEL Classification. D24; J16; J24; O3.

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 $19,281, significantly below the global average ($29,355) and the MENA average ($34,729). Similarly, the services sector in Egypt recorded a value added per worker of $14,833 in 2019, less than half of the global average ($32,676) and notably lower than the MENA average ($25,268) (World Bank, 2023). The relatively low productivity levels observed may be attributed, at least in part, to insufficient innovation efforts by firms (Syverson, 2011), a challenge that could have been further exacerbated in female-led firms (Hoang et al., 2021).

This study examines the links between innovation and productivity in Egyptian firms, with a specific focus on the impact of gender on the propensity to innovate and its subsequent implications for productivity and overall firm performance. 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 landscape of Egyptian firms.

Several studies provide evidence supporting the positive impact of innovation on firm performance (e.g., Coad & Rao, 2008; Crowley & McCann, 2018; Friesenbichler & Peneder, 2016; Griffith et al., 2006; Hall & Kramarz, 1998; Hall et al., 2009; Parisi et al., 2006; Wadho & Chaudhry, 2018). These findings consistently indicate that both innovation and research and development (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 & Robb, 2009; Loscocco & Robinson, 1991; Marvel et al., 2015; Strohmeyer et al., 2017; Watson & Robinson, 2003), other research yields varied results concerning the relationship between gender and firm performance and innovativeness (Brush, 1992; Eagly et al., 1995; Hoang et al., 2021; Lee & Marvel, 2014; Rosa et al., 1996). Additionally, it is noteworthy that MENA countries, including Egypt, suffers 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 & 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 confront 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 unfolds as follows: Section 1 provides the introduction to the analysis and reviews relevant literature; Section 2 outlines the employed methodology and robustness checks; 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 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 into the innovation decision by incorporating instrumental variables into the analysis.

We formalize the model through three equations: (i) 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); (ii) 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); and (iii) 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:

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

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

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

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 for 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 through 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 value 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 is 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 modelling 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 correlation 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 (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). A total of 1,172 firms were interviewed in 2013, 2016, and 2020 by the WBES. The dataset is designed to represent the population of firms in the manufacturing and services sectors.[1] One advantage of this data is that it is a panel one unlike most of the datasets of the Enterprise Survey. Panel observations of responses on the R&D spending, innovation output, and productivity questions of interest are available for all three waves in Egypt.

We provide detailed definitions of the variables used in this study in Table A.1 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,

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

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 the three equations for R&D spending, innovation output, and productivity.

3.1 R&D Determinants

As explanatory variables, in the R&D equation (1), we use four sets of determinants to explain the firm decision to do 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 positioned to benefit from economies of scale related to R&D production and to 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 (Alwis & Hartmann, 2008). Our fourth indicator of internal capabilities is product concentration as measured by the main product/service share of 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 & 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 located 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, through learning-by-doing, foreign-technology adoption can increase the odds of introducing innovations by firms in developing countries. Being located 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 enables, we include public support proxied by the percentage of firm owned by 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 firm's 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 a positive causal effect of training provision by German firms on innovation by facilitating access to cutting-edge knowledge. Building on these insights, Laursen & 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 (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 producing new products and services (Mohnen & 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 summary statistics for the pooled sample, and provides a breakdown by the gender of the firm lead.

TABLE 1
SUMMARY STATISTICS

		Pooled		Female-led		Male-led	
	Obs.	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
Productivity							
Value added per worker							
Sales per worker							
Innovation output							
R&D							
Labor							
Age							
Market share							
Diversification							
Export orientation							
International competition							
Foreign technology							
ICT							
Public support							
Access to finance							
Labor quality							
Capital intensity							
Energy intensity							

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)
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%, 5%, and 1% 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, strategically 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 prioritize operational efficiency over 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 towards 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 are essential to explain the specific factors influencing this divergence from prevailing evidence.

Finally, our R&D estimates indicate that firms whose main market is international 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, as mentioned, 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 through 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.

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 emerges 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, older firms, having established routines and business models, 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 they are successful, might become complacent with their current market position and may not feel the same urgency to innovate as newer entrants striving to establish themselves.

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%, 5%, and 1% levels, respectively. Labor and age variables are in logs.

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, prioritization of immediate market demands and competition, adherence to established business models, potential market saturation, complex regulatory environments, and logistical challenges.

4.3 Productivity

In Table 4, we list the results derived from the productivity equation (equation (3)). We report 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%, 5%, and 1% 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 of lower productivity among female-headed firms. The higher likelihood of women entrepreneurs to introduce process and product innovations in their firms likely 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 notably considerable both in significance and magnitude. A plausible explanation lies in the observation that these firms operate considerably 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 from 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 significantly 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 and Policy Implications

This paper estimates the impact of innovation on productivity and explore the interplay of gender within this dynamic among Egyptian firms. We examine the links between R&D, innovation, and firm productivity, specifically examining the gender dynamics within the Egyptian manufacturing sector. Key research questions include: (a) What factors at the firm level 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 the 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, financial measures such as subsidies and tax breaks, specifically tailored to foster the innovation capabilities of female entrepreneurs, can be introduced. Implementation of capacity-building programs, networking opportunities, as well as educational initiatives is vital to enhance the skills and resources available to female-headed firms, 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, addressing potential barriers. Overall, a coordinated and comprehensive approach is essential to create an environment that fosters the productivity of female-headed Egyptian firms.

References (In progress)

Abadie, A., Athey, S., Imbens, G., & 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., & 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., & 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

Baum, C. F., Lööf, H., Nabavi, P., & 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

Crespi, G., Tacsir, E., & 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., & 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., & 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

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

Friesenbichler, K., & 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.

Hoang, N., Nahm, D., & 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

Lee, I., & 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.

Mohnen, P., & Hall, B. H. (2013). Innovation and Productivity: An Update. *Eurasian Business Review, 3*(1), 47–65. https://doi.org/10.14208/bf03353817

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

Syverson, C. (2011). What Determines Productivity? *Journal of Economic Literature, 49*(2), 326–365. https://www.jstor.org/stable/23071619

Wadho, W., & 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

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

Appendix A

TABLE A.1
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 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