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INNOVATION IN FIRMS REVIEW FROM A GENDER AND INTERNATIONALIZATION PERSPECTIVE. EVIDENCE FROM THE WORLD BANK'S WBES

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Abstract. Linear Discriminant Analysis (LDA) is used to identify the organizational, sectoral, innovation-related, and gender-based factors that best predict business investment in Research and Development (R&D) across a global sample of firms. Results show that variables related to product and process innovation, the Gender Equality in Governance Index (LGGGI), and the firm's sector play a key role in distinguishing companies that invest in R&D from those that do not.

Keywords: Linear Discriminant Analysis, R&D investment, WBES, Innovation, Woman CEO, Woman Owner

JEL Classifications: C25, L26, O32, J16

Introduction

Research and Development (R&D) investment has become a cornerstone of economic growth and business competitiveness (Jones, 1995; Bilbao-Osorio & Rodríguez-Pose, 2004, Paiva et al., 2020; Olaoye et. al, 2021; Ali & Anwar, 2021). However, the drivers of such investment vary across sectors and contexts. This study explores the role of sectoral affiliation, innovation indicators, productivity, institutional context, and gender representation in management and ownership to predict R&D investment (Wouters, 2020; Banelienė & Melnikas, 2020; Xie et al., 2020, Holh et al, 2021; Alexeeva-Alexeev, et al., 2025). A global dataset of companies from the World Bank Enterprise Survey is analyzed using Linear Discriminant Analysis (LDA) (Xanthopoulos et al., 2013; Izenman, 2013; Tharwat et al., 2017; Ghojogh & Crowley, 2019; Zhao et al., 2019).

R&D investment is widely recognized as a pivotal driver of firm-level innovation, national productivity, and long-term economic growth. It enables companies to develop new products, enhance production processes, and adapt to rapidly changing market conditions (Hall, et al., 2010, Alexeeva-Alexeev & Mazas-Perez-Oleaga, 2024). Traditional determinants of R&D investment—such as firm size, sector, and financial performance—have been extensively studied (Crespi & Zuniga, 2012; Zuniga & Crespi, 2013). However, growing attention has been directed toward understanding the role of more nuanced factors, including gender diversity in leadership, institutional quality, and internationalization strategies.

Gender diversity, particularly within senior management and ownership structures, is increasingly recognized as a critical enabler of innovation. Research suggests that heterogeneous leadership teams promote more effective problem-solving, greater creativity, and improved strategic decision-making, all of which are essential for fostering an innovation-friendly environment (Chen et al., 2016; Loukil & Yousfi, 2016; Ruiz-Jiménez et al., 2016; Xie et al., 2020). Furthermore, empirical evidence indicates that companies with higher female representation in leadership roles tend to display stronger

innovation outcomes, especially in industries characterized by rapid technological change (Post & Byron, 2015). Despite these findings, gender gaps in leadership persist globally, potentially limiting the innovative capacities of firms operating in less inclusive environments (Catalyst, 2020).

In parallel, the institutional context in which firms operate has profound implications for R&D investment decisions. Environments characterized by higher degrees of gender equality, political stability, and regulatory efficiency tend to provide more supportive conditions for innovation-driven activities (World Economic Forum, 2023). The Global Gender Gap Report has consistently shown that countries with higher gender parity scores also exhibit higher rates of technological readiness and innovation performance, suggesting a link between inclusive institutions and economic dynamism. Moreover, studies indicate that gender equality in governance frameworks can enhance firms' access to diverse talent pools, thereby strengthening their innovation capabilities (Noland, et al., 2016).

Internationalization is another critical dimension influencing firms' R&D behavior. Engaging with foreign markets exposes firms to new competitive pressures and technological standards, thereby incentivizing investment in R&D as a means to maintain or enhance their competitiveness (Cassiman & Golovko, 2011). Exporting firms, in particular, are often found to invest more heavily in R&D activities compared to their domestically-oriented counterparts (Love & Roper, 2015). This relationship is bidirectional; while innovation enables firms to successfully penetrate new markets, international exposure simultaneously stimulates further innovation through learning-by-exporting mechanisms.

Despite the theoretical and empirical advances, gaps remain in the integrated analysis of how gender diversity, institutional frameworks, and internationalization interact to shape R&D investment decisions. Existing studies tend to focus on single-country contexts or specific industries, limiting the generalizability of their findings. To address this gap, this study employs a global dataset derived from the World Bank Enterprise Surveys (WBES) covering 118 countries over the period 2007–2023. Using Linear Discriminant Analysis (LDA), we identify the organizational, sectoral, innovation-related, and gender-based factors that best predict firms' decisions to invest in R&D.

By adopting a multidimensional perspective, this research seeks to contribute to a more comprehensive understanding of R&D investment behavior in the global economy. It aims not only to enrich the academic literature but also to provide valuable insights for policymakers and business leaders striving to foster innovation, promote gender equality, and enhance firms' competitiveness in increasingly interconnected markets.

Data and Methods

The data employed in this study are drawn from the World Bank Enterprise Surveys (WBES), a series of nationally representative surveys conducted at the firm level. These surveys provide rich and comprehensive information on a wide array of aspects characterizing the business environment, including firm-level attributes, access to finance, socio-economic conditions, firm performance metrics, labor market dynamics, and environmental practices. Innovation is a core area of inquiry within the WBES, captured through various indicators such as research and development (R&D) expenditure, the introduction of new or significantly improved products, and advancements in production technologies. Furthermore, the dataset incorporates detailed information on the participation of women in firm ownership and top management positions.

The WBES dataset has been widely adopted in prior empirical studies examining firm-level R&D behavior (Johri et al., 2024), gender disparities in entrepreneurship and corporate leadership (Shen & Zhang, 2024), and the internationalization of firms (Yan et al., 2024). Following a rigorous data-cleaning procedure, the final analytical sample comprises 107,027 firm-level observations from 118 countries, covering the period from 2007 to 2023.

For the purposes of this analysis, Linear Discriminant Analysis (Izenman, 2013; Tharwat et al., 2017) is employed as the primary statistical method. LDA is a supervised classification technique used to assign observations to predefined categorical groups based on a set of continuous or categorical predictor variables. The method is particularly suited for identifying which variables most effectively discriminate between groups and for developing a predictive model capable of classifying new

observations. Specifically, LDA estimates a discriminant function—a linear combination of the predictor variables—that maximizes the ratio of between-group variance to within-group variance, thereby enhancing the separation among the categories. In the case of two groups, the discriminant function can be expressed as:

$$D(X) = w_0 + w_1X_1 + w_2X_2 + \cdots + w_pX_p \ (1)$$

Where X_1, X_2,…, X_p are p explanatory variables (predictors), w_1, w_2,…, $w_p$are p coefficients or discriminant function weights and w_0 is a constant term.

The model assigns a new observation to the group whose discriminant function has the highest expected value. The objective is to determine the factors that determine whether a company invests in research and development, therefore, the discriminant function will use as a dependent variable the binary variable investment in R&D, which takes a value of 1 if the company has invested in R&D and 0 otherwise. Then, the LDA function was conducted with R&D investment as the dependent variable.

$$\begin{aligned} D(R\&D) = {} & w_0 + w_1\text{New Product} + w_2\text{New Product NM} + w_3\text{Improved Process} \\ & + w_4 Domestic\ Sales + w_5 Exports + w_6 lProductivity + w_7 Female\ CEO \\ & + w_8 Female\ Owner + w_9 lGGGI + w_{10} lPIB\ per\ capita + + w_{11} Size \\ & + w_{12} Sector \ (2) \end{aligned}$$

The set of independent variables incorporated into the LDA model presented in (1) is detailed as follows; variables *New Product*, *New Product NM*, and *Improved Process* capture distinct dimensions of firm-level innovation. According to the WBES coding scheme, these are specified as binary indicators: *New Product* assumes a value of 1 if the firm has introduced new or significantly enhanced products or services within the reference period, and 0 otherwise. *New Product NM* is coded as 1 if these innovations were launched in previously untapped markets. *Improved Process* equals 1 when the firm has adopted new or improved internal business processes; in the absence of such changes, it is coded as 0.

The gender-related variables include *Female CEO*, a dichotomous variable indicating whether the Chief Executive Officer of the firm is female (1 = female, 0 = otherwise), and *Female Owner*, which identifies female ownership using the same coding convention.

Internationalization and market orientation are captured through *Exports*, reflecting the proportion of total firm revenue derived from international sales, and *Domestic Sales*, which denotes the share of revenue generated from domestic transactions.

Firm-level efficiency is proxied by *lProductivity*, obtained as the ratio of total annual revenue to the number of full-time employees, in line with the methodology proposed by Muhammad et al. (2022). A natural logarithmic transformation is applied to this variable to address skewness and enhance statistical properties for modeling purposes.

Control variables include *Size*, measured by the total number of employees, and *Sector*, a binary variable equal to 1 if the firm operates in the service sector, and 0 if it belongs to the manufacturing industry.

At the macroeconomic level, two contextual variables are included: *lGGGI* and *lPIB per capita*. The Global Gender Gap Index (GGGI), as defined by Bertrand et al. (2022), evaluates gender equality across four domains—economic participation, educational attainment, health outcomes, and political empowerment—on a continuum ranging from 0 (complete inequality) to 1 (full parity). This index is logarithmically transformed to facilitate interpretation and statistical analysis. Similarly, *lPIB per capita* is employed as a widely accepted proxy for national economic development (Minniti, 2010) and is also subjected to logarithmic transformation for consistency and improved model performance.

The descriptive statistics of the above variables are summarized in Tables 1 and 2.

Table 1. Descriptive statistics, discrete variables

	Yes		No		Total
	N	%	N	%	
R&D Investment	88251	82,46%	18776	17,54%	107027
New product	34736	32,46%	72291	67,54%	107027

New Product NM	23108	21,59%	83919	78,41%	107027
Improved Process	31627	29,55%	75400	70,45%	107027
Woman Owner	31418	29,36%	75609	70,64%	107027
Woman Ceo	15407	14,40%	91620	85,60%	107027
	Services		**Manufacturing**		**Total**
	N	**%**	**N**	**%**	
Sector	62208	58,12%	44819	41,88%	107027

Source: own elaboration

Table 2. Descriptive statistics, continuous variables

	lPIB per capita	lProductivity	lGGGI	Size	Domestic Sales	Exports
Mean	3.70	4.42	-0.386	93.1	87.9	8.76
Median	3.56	4.42	-0.377	21	100	0
Std. Deviation	0.518	0.817	0.0847	433	26.9	23.1
Min	2.41	-2.12	-0.667	1	0	0
Max	5.07	10.7	-0.184	64000	100	100
N	107027	107027	107027	107027	107027	107027

Source: own elaboration

The performance of the Linear Discriminant Analysis (LDA) model is assessed using two confusion matrices (train and test) to determine how effective the model is at distinguishing between companies that invest in R&D and those that do not. The training test considered is 70% of the whole sample.

Results

The purpose of the study is to determine which factors best define and classify the decision of a company to invest in R&D. First of all, some conclusions can be drawn using the group averages shown in Table 3 that shows the mean (average) values for each explanatory variable, separated by whether the firm does not invest (Group 0) or does invest (Group 1) in Research and Development (R&D). This comparison allows us to identify patterns and characteristics that distinguish companies based on their R&D investment status.

Table 3. Group Means

Group Means (R&D Investors vs. Non-Investors)		
Variable	**No R&D**	**R&D Investors**
lGGGI	-0.391	-0.362
Female CEO	0.145	0.134
New Product	0.246	0.701
New Product NM	0.154	0.511
Improved Process	0.220	0.657
lProductivity	4.376	4.644
Domestic Sales	89.922%	78.476%
Exports	7.081%	16.714%
Size	73.993	174.802
Female OWNER	0.278	0.357
lPIB per capita	3.682	3.783
Sector	0.552	0.716

Source: own elaboration

According to the results in Table 2, it can be determined that some variables show different values for those companies that invest in R&D, for example in the *New product* (0.246 vs 0.701) indicates that firms that invest in R&D report, on average, a 70.1% probability of having introduced a new product, in contrast, only 24.6% of non-investors did so that new product development is strongly associated with R&D investment. This makes sense as R&D activities often result in new or improved

offerings. Refering the variable, *New Product NM* (0.154 vs. 0.511) is closely related to R&D investment, because among R&D investors, 51.1% introduced a product in a new market, compared to only 15.4% of non-investors, and then R&D enables firms to expand beyond current markets—indicating that innovation supports strategic market diversification. Regarding *Improved Process* (0.220 vs. 0.657), about 65.7% of R&D investors report improved internal processes, versus only 22% of non-investors, this means that process innovation, like automation or operational improvements, is more prevalent in firms investing in R&D, highlighting the broader organizational impact of R&D beyond just product development.

The variables related to gender equality are also related to investment in R&D, for example the indicator *lGGGI* (Gender Equality Index: -0.391 vs. -0.362) shows that firms operating in countries with greater gender equality in leadership roles are slightly more likely to invest in R&D, hinting at a favorable institutional environment for innovation. Moreover, female ownership (0.278 vs. 0.357) reveals that among R&D investors, 35.7% of firms include female owners, compared to 27.8% among non-investors so that there is a positive relationship between female representation in ownership and R&D investment. This could reflect broader inclusiveness and innovation-oriented governance.

On the other hand, the characteristics and business performance of companies are also key in R&D investment, the export share (7.08% vs. 16.71%) indicates that exporting firms are more likely to invest in R&D; so that R&D investors export more than double the share of their output compared to non-investors. International orientation seems to drive innovation. Firms that compete globally may feel more pressure to differentiate and innovate. The firm size (74 vs. 175) is also relevant, on average, R&D-investing firms are more than twice as large as non-investors in terms of size (employees or another measure). Larger firms may have more resources, infrastructure, or absorptive capacity to support R&D activities.

To sum up, the group means clearly show that R&D investment is closely associated with higher levels of innovation (product and process), greater international exposure (exports), larger firm size, more inclusive ownership, and operating in the services sector. These variables are not only statistically different between the groups but also theoretically aligned with what we expect from firms that prioritize innovation and strategic development.

To complement the previous analysis, a LDA has been carried out. This function is a weighted combination of independent variables designed to maximize the separation between groups, in this case, firms that invest in R&D (group 1) and those that do not (group 0). Two key outputs are analyzed here:

- Coefficients of Linear Discriminant Function– these represent the weight or contribution of each variable to the discriminant function.
- Normalized Loadings – these represent the correlation between each variable and the discriminant function (standardized). They help us understand which variables are most aligned with the function's direction.

The results from LDA estimation are shown in Table 4.

Table 4. LDA coefficients and normalized loadings

Variable	Coefficient (LDA)	Normalized Loading	Interpretation
Improved_process	1.19579	0.61390	Very strong
LGGGI	1.09466	0.56198	Very strong
New Product	0.83985	0.43117	Strong
New Product NM	0.52726	0.27069	Moderate
Sector	0.36026	0.18495	Moderate
Lproductivity	0.19858	0.10195	Weak
LGDP per capita	0.04005	0.02056	Very weak
Female OWNER	0.03521	0.01808	Very weak
Exports	0.00446	0.00229	Very weak
Domestic Sales	-0.00438	-0.00225	Very weak

Size	0.000427	0.000219	Very weak
Female CEO	-0.10247	-0.05261	Very weak

Source: own elaboration

Results suggest that some of the explanatory variables act as major discriminants among the companies that invest in R&D and have a greater influence in favor of companies that invest in R&D. The variable *Improved Process*, is the most powerful variable in distinguishing R&D investors, so that firms that improve internal processes are much more likely to invest in R&D (Carboni & Medda, 2020**)** This result may imply that process innovation reflects internal capabilities and R&D as a continuous effort to enhance efficiency. Firms should see R&D not just as product-focused, but as a tool to upgrade operations. Similarly, Rocha et al. (2020) found that firms located near the technological frontier derive greater benefits from R&D investment, reinforcing the idea that internal efficiency and innovation capabilities are key drivers of R&D engagement. This evidence supports the notion that R&D should not be confined to product development but also be strategically leveraged to enhance operational performance and long-term competitiveness. Another influential variable is the equality indicator, *lGGGI*, that is a strong signal that firms in countries with more gender-inclusive institutions are more prone to R&D investment. Businesses in countries with supportive social and governance frameworks may have more incentives and better conditions to invest in innovation (Tonoyan, & Boudreaux, 2023). The last variable that has a high degree of discrimination towards R&D investment is the introduction of new products that strongly correlates with R&D investment. This means that product development and R&D go hand in hand. Companies should strategically align product roadmaps with R&D agendas to stay competitive. As cited in Cooper (2019) there is an intense relationship between R&D investment and the firm's drive for new product development.

With a moderate discriminatory effect we have variables such as *New product NM*, and *Sector*. Introducing a new product in a new market is moderately associated with R&D investment, then, international and cross-market innovation appears to drive R&D. Firms expanding into new markets may require stronger R&D backing to localize or differentiate offerings. In addition, operating in the services sector is positively linked to R&D, so that innovation is increasingly service-driven (e.g., fintech, edtech, digital health, etc.). Firms in services should explore R&D strategies aligned with intangible assets, and platforms.

In third place are variables that have a weak discriminatory effect, either positive or negative. With a weak positive capacity are the variables productivity, *lPIB per cápita*, *Exports* and *Domestic Sales*. Productivity has a small but positive relationship which implies that more productive firms might be slightly more likely to invest in R&D, but this is not a key determinant. R&D may not directly depend on current productivity but rather long-term strategic orientation. Similar results are given by *lPIB per cápita*. While higher national income is often linked to innovation, it does not seem to heavily differentiate R&D-investing firms. Other factors, like firm-specific strategy, matter more. The *Female Owner* implies that gender-inclusive ownership alone does not strongly influence R&D investment, though it may correlate with broader values or governance culture. Finally, *Exports* behavior alone does not significantly separate R&D investors from non-investors—though it may be more of an outcome than a cause of R&D. Although the influence of the Exports and Domestic Sales variables is not very relevant, the normalized loadings of the LDA function are in tune with the results of a study conducted by Peters et al. (2022) in German companies, which shows that, on the one hand, R&D leads to higher rates of product and process innovation among exporting companies and, on the other hand, there is a higher economic profitability of innovation in export markets than in the domestic market. Moreover, the positive sign of the normalized loadings of The Exports and Lproductivity variables indeed shows a relationship between productivity, which reinforces the relationship between R&D activities and exports, as found in Falk and Figueira de Lemos (2019).

Weak negative relationship is shown by *Female CEO* and *Domestic Sales* variables. For the first one, this result should be interpreted with caution. It may reflect structural biases or underrepresentation of women in top positions, particularly in sectors that dominate R&D. It does not suggest that female leadership is a barrier, but rather highlights existing disparities. Surprisingly, firm size is not a major

driver. This suggests small and large firms alike may invest in R&D depending on strategy and sector, not scale. This result is pointed out in a study by Foster et al. (2020) on a firm-level sample from 1992 to 2013 in the United States in which it is observed that most R&D is performed by large manufacturing firms that export, but the composition of firms performing R&D is gradually shifting towards smaller non-manufacturing firms.

Finally, the validation of the model is carried out by means of the confusion matrix that reports an accuracy in training of 87.3% and accuracy in testing of 85.9%. Therefore, the model shows good predictive power. However, there is an expected bias towards the majority class (non-investing companies), as has been documented in studies with unbalanced classes.

Conclusions

This global analysis identifies key factors that differentiate companies that invest in R&D. Innovation activity, institutional gender equality, and sectoral context are all essential elements. These insights can inform public policy and business strategies aimed at fostering R&D investment and promoting gender equity in organizations. Some of the most relevant findings are that innovation is central; product and especially process innovation are the most predictive features of R&D investment, the institutional gender equality matters, companies in more inclusive environments are more R&D active. On the other hand, R&D is sector-sensitive; services firms are increasingly embracing R&D, possibly in response to tech and digital disruption. It is also interesting to highlight the participation of women in the management and ownership of companies; gender representation in leadership and ownership are not major drivers individually, but they may signal broader organizational culture factors. However, as has been shown in the analysis of the, firm size and GDP per capita**,** while often assumed to predict R&D, have limited discriminative power here.

For future research, the performance of the minority class will be considered using class matching methods and alternative classifiers.

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