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An Integrated Analysis of the Impact of Gender Diversity on Innovation and Productivity in Manufacturing Firms

Prepared for the Institutions for Development Sector by:

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Abstract[*]

This paper presents evidence of the effects of gender diversity on firm innovation outcomes and their productivity in Colombian manufacturing firms, by extending a CDM model to include women's participation in science, technology and innovation (STI) activities and production processes. The paper makes a methodological contribution by taking into account potential endogeneity issues of women's participation in STI and innovation behavior. An upward bias of the impact of gender diversity on innovation might arise because more dynamic and innovative managers, knowing the value of gender diversity, may also hire more women in STI. The paper addresses the endogeneity concerns with a Tobit specification of the firm's decision to employ women in STI by instrumenting it with the share of total women in the workforce in the industry or the region where the firm is located. The main results indicate that firms with a larger share of women in the knowledge-creation and innovation process might increase their innovative behavior. It also presents evidence of a differentiated effect of gender diversity by type of innovation. Women's participation has a larger effect on technological innovation than on organizational innovation. Finally, gender diversity drives firm productivity, even after controlling for the effect of innovation on the production process. These results are important for developing countries where women's participation in STI activities is extremely low. In Colombia, for example, only 6 percent of STI employees are women, a very low figure compared with the 21 percent participation of women in industry and even lower compared with the 52 percent of women in Colombia's total work force. These figures and this paper's results should open up discussion on policies to promote women's participation in the labor force in manufacturing firms, specifically in the knowledge creation processes.

JEL codes: J16, J24, J82, O30, O31
Keywords: CDM, diversity, gender, innovation, women

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1. Introduction

Can the presence of women be a factor that contributes to a firm's productivity and propensity to innovate? Research on the impact of women's participation on firm performance and innovation has produced mixed results. Some studies that use employer-employee or firm-level datasets have found that women's participation in research and development (R&D) teams increases the likelihood that a firm innovates (Díaz, González, and Sáez, 2013; Fernández, 2015; García, Zouaghi and García, 2017; Østergaard, Timmermans, and Kristinsson, 2011; Teruel, Parra and Segarra, 2015). Other studies find that the empirical evidence of the impact of gender diversity on firm productivity is mostly negative (e.g., Parrotta, Pozzoli, and Pytlikova, 2014), although some (e.g., Garnero, Kampelmann, and Rycx, 2014) find a positive relationship. The involvement of women in knowledge creation and production processes within firms has interested both academics and experts. For example, renowned consulting companies such as McKinsey Global Institute (MGI) and specialized business magazines have recently called attention to the importance of women in the firms' labor force. MGI argues that advancing women's equality in the workplace could add as much as $12 trillion of additional global annual GDP worldwide by 2025, and a recent insight by Forbes (2015) concludes "... a diverse and inclusive workforce is necessary to drive innovation and foster creativity, and guide business strategy."

We present evidence about the effects of gender diversity on innovation outcomes and their productivity in Colombian manufacturing firms. Despite recent results on the virtuous relationship between innovation investments, innovative behavior, and productivity in developing economies, no research has delved into the extent to which having women involved in innovation activities might change the pace of both how firms innovate and their expected gains in productivity (Crespi and Zuñiga, 2012; Crespi, Taczir and Vargas, 2016; Gallego, Gutiérrez and Taborda, 2015). Specifically, we examine the impact of the presence of women involved directly in STI activity teams on the probability that a firm innovates. In addition, we link the predicted innovation behavior, controlling for women in STI activities and R&D expenditures, with gender diversity and labor productivity to emphasize the importance of women on productivity within firms. We argue that an integrated view is well-suited to capture the contribution of gender diversity both to the innovation and production processes.

The main results indicate that firms with a larger share of women in the knowledge creation and innovation process might increase their innovative behavior and, consequently, may exhibit greater labor productivity. An increase of six percentage points in the share of women in STI would increase the innovative behavior of firms by two percentage points. In addition, we find evidence of a differentiated effect of gender diversity by type of innovation: women's participation affects three times more *technological* innovation outcomes than *organizational* innovation. In particular, an increase of six percentage points would increase technological innovation by three percentage points and the organizational innovations of firms by less than one percentage point. In addition, we ran regressions where the mode of innovation is whether the firm achieved incremental or radical innovations (that is, innovations new to the market); interestingly, women's inclusion in STI activities has a similar effect on either type of innovations. As Page (2017) argues, the diversity premium is stronger in complex, non-routine, and cognitive tasks precisely the group problem-solving contexts. Technological innovation, specifically radical innovations, are by nature complex and based upon knowledge. The more cognitively diverse the teams, in our case in terms of gender, the stronger the effects. STI teams within firms obtain that premium if they are more diverse. Hence, the effect of diversity is stronger on technological than on non-technological innovation. These results are new evidence of the positive impact of having a more gender-diversified workforce on knowledge production processes in developing countries, whose economies exhibit low ratios of women in STI. In Colombia, for example, women's participation in manufacturing is only around 6 percent of the total number of employees in STI activities, a very low figure compared with 21 percent of the total workforce in industry and even lower compared with the 52 percent of the women in Colombia's total workforce.

Furthermore, we make a methodological contribution by including an *integrated* analysis of the effect of gender diversity on the relationship among innovation investments, innovation outcomes, and productivity in a CDM model (Crepón, Duguet, and Mairesse, 1998), taking into account potential endogeneity issues of women's participation in STI and innovation behavior. An upward bias of the impact of gender diversity on innovation might arise because more dynamic and innovative managers, knowing the value of gender diversity, will also hire more women for STI. We address the endogeneity concerns with a Tobit specification of the firm's decision to employ women in STI, by instrumenting it with the share of total women in the workforce in the industry and in the region where the firm is located. We then include the predicted women's participation in STI activities at the CDM model's second stage. By addressing the endogeneity of a firm's decision to hire (more) women in STI teams, we identify an unbiased effect of women on the knowledge equation of the CDM. Finally, in the third stage, we estimate a Cobb-Douglass production function augmented with gender diversity measures such as the share of women in the firm's total employees and two indicators (i.e., coefficient of variation and standard deviation) of women's participation in the different departments of the firm.

We also contribute to the current discussion about the function of team collaboration in knowledge creation. Innovation activities are complex processes that need, as the main input, a dedicated team of employees to perform very specialized tasks. A more diverse labor force may benefit firm performance if it encourages complementarities, but these beneficial effects can be offset by the potential communication costs that might arise (Lee and Farh, 2004; Prat, 2002). Our results show that the inclusion of gender diversity could produce value gains for manufacturing firms in Colombia, an industry with low female participation, and potential gains in terms of new products and higher productivity at the firm level.

The remainder of the article is organized as follows. Section 2 presents the analytical framework that guides this research as well as the working hypothesis. Section 3 provides details on the data, the sources of information and empirical methodology we employ to test our hypotheses. Section 4 presents the results, and Section 5 concludes.

2. Theoretical Framework and Hypotheses

We analyze an integrated view of the relationship between women's participation in the workplace and innovation and firm performance. This paper is related to two branches of literature: on innovation and productivity, and diversity. With respect to the former, researchers from different fields largely acknowledge that innovation is a key driver of firm performance and economic development (Fagerberg, Srholec, and Verspagen, 2010; Nelson, 2005). At the firm level, studies using the CDM structural framework have confirmed that enterprises that are more intensive in innovation investment have a higher propensity to be innovative and that firms that innovate more are also more productive (Crespi and Zuniga, 2012; Gallego, Gutiérrez and Taborda, 2015; Griffith et al., 2006). Most of this literature has identified key determinants of innovation efforts and innovation, but the inclusion of workforce diversity, specifically gender diversity, as a critical aspect in innovative behavior has been absent from an integrated analysis using the CDM model. However, studying the role of women in the workplace and whether their presence can be a factor that contributes to a firm's propensity to innovate and its productivity are relevant questions that we assess within the framework of CDM models. To the best of our knowledge, no research has followed this approach.

With regard to the role of diversity in the workplace, there is an extensive literature on the positive or negative consequences of having a more diversified labor force. The general idea is that firms seek to bring products and services to the firm or to markets and to implement production processes. These tasks are usually carried out by teams of workers or by specialized people instructed to perform them. Teams may be diverse in terms of age, gender, race, education, or nationality. These characteristics set in motion different economic and social forces that may affect the functioning of teams. Some scholars have argued that diversity in the labor force, and perhaps more so in specific teams, can be beneficial for firm performance if certain conditions are present and if there are complementary skills (Alesina and La Ferrara, 2005; Grund and Westergaard-Nielsen, 2008; Lazear 1999; Osborne, 2000; Parrotta, Pozzoli, and Pytlikova, 2014; Skirbekk, 2003). However, diversity may also have some disadvantages, since people may face greater communication and cooperation problems. In some cases, the costs of diversity outweigh the benefits (Lee and Farh, 2004; Prat, 2002).

One important dimension of workforce diversity is more equal participation of women in the workplace. In this respect, gender diversity has been considered a key factor not only in the production process but also in the knowledge creation process, with strong evidence in the case of developed economies. However, it is surprising that scant research has been done that provides evidence of whether women's involvement in firm *innovation endeavors* has positive or negative effects for emerging economies. There is even less evidence, if any, for any Latin American country.

Since our contribution is to explore women's participation in innovation and production processes in an integrated way, it is important to understand how the literature on gender diversity has assessed the role of women in innovation and production. Østergaard, Timmermans, and Kristinsson (2011) have studied how women's participation can affect the propensity of firms to innovate. Using an employer-employee dataset, the authors analyzed the effect of gender (and age) diversity and human capital on innovation in a sample of Danish firms using a diversity measure, the Shannon–Weaver entropy index. They found a strong *positive* and significant relationship between gender diversity and innovation, which indicates that a gender-diverse workforce composition is positively associated with the likelihood of introducing an innovation. Pfeifer and Wagner (2014) also found a positive correlation in their research on German manufacturing firms. They found that women's participation in a firm's labor force contributed to higher profits as well as more investment in R&D activities.

Using data on Spanish firms, researchers have studied the effect of gender diversity in R&D teams on innovation (Díaz, González, and Sáez, 2013; Fernández, 2015a; García, Zouaghi and García, 2017; Teruel, Parra, and Segarra, 2015). The focus of their research was to study the relationship between gender distribution of R&D groups and the propensity to achieve radical, incremental, or any type of innovation. In general, these studies found that diversity exerted positive effects on the probability of introducing any of those types of innovations. In developing countries, it would be important to analyze not only radical and incremental technological innovation, but also non-technological (i.e., organizational and marketing) innovation, since this type of innovation is particularly important in Latin American firms (Crespi and Zuñiga, 2012).

Finally, a recent study by Moore, Presbitero, and Rabelloti (2017) studied women ownership and the effect of having women in senior management positions on firms' innovation behavior using a sample of Caribbean small firms. They found that a firm's propensity to innovate increases if women are owners, but it decreases when they participate as senior managers. Based on the main insights in the literature, this paper stipulates the following hypotheses:

H1: There is a positive correlation between women's participation in STI activities and the likelihood that firms innovate.

H1a: There is a differentiated effect of women's participation in STI on the mode of innovation (technological or non-technological).

From the large literature on workforce diversity and its positive effects on firm performance, only a few papers have studied the effect of gender diversity in the workforce on firm performance, measured in terms of sales, profits, or productivity. Hoogendoorn, Oosterbeek, and van Praag (2013) conducted a field experiment and found that teams with an equal gender mix perform better than male-dominated teams in terms of sales and profits. Garnero, Kampelmann, and Rycx (2014) made another key contribution to the subject (2014). Using a Belgian-linked employer-employee dataset, they studied the link between diversity measures and productivity and found that gender diversity generates significant gains in productivity in high-tech/knowledge-intensive sectors, but does not do so in more traditional industries. Stahl, Maznevski, Voigt, and Jonsen (2010) and Prat (2002) found similar results. However, other studies (e.g., Ilmakunnas and Ilmakunnas, 2011) show a negative impact of gender diversity on firm productivity (For a review of the literature on the negative effects of gender diversity on performance, see Garnero, Kampelmann and Rycx, 2016.) The ambiguity of the evidence calls for more country case studies that provide new empirical evidence of the relationship between women's participation and firm performance. Many of the mixed effects revealed in these studies may be due to the case-specific context of the country, period, or sample selection.

Given the mixed findings of the effects of gender diversity on firm performance, we propose to analyze a second hypothesis in our integrated study:

H2: In a structural model (specifically, in a CDM model) that controls for the innovation behavior on firm's productivity, women involvement in the firm *in general* offers a more diversified pool of skills and capabilities that can contribute to higher firm productivity.

Having posited those two hypotheses, we would like to call attention to the fact that *theoretical* advances in the research on how women's participation affects firm performance have been slow or poor in providing reliable guidance on what to expect from their contribution to firm outcomes. This study explores whether women's participation contributes to both firms' propensity to innovate and firm productivity. The way women's involvement is taken into account depends on whether they participate in knowledge creation or production processes. In the former case, we include a single measure of female participation in STI activities, because these activities are decided on a medium and long-term basis with less margin for job rotation among teams involved in innovation activities, and participation would be a sufficient measure of gender diversity. For the latter case, we can exploit the idea that women could participate in different departments in the overall production process of the firm, because in the short-run managers may have more flexibility to change the size and composition of the labor force (Robinson and Dechant, 1997). In the end, the reasons to include different types of measures are empirical. This study contributes by proposing a CDM framework that includes more suitable measures of gender diversity for each stage of the structural model: participation of women in STI for the knowledge creation process and measures of gender composition in the different units involved on the production.

3. Data and Sources of Information

The hypotheses are tested using data from two waves (2012 and 2014) of the Colombian Innovation Survey (Encuesta de Desarrollo e Innovación Tecnológica, or EDIT), conducted every two years by the Bureau of Statistics (Departamento Administrativo Nacional de Estadística, or DANE) in Colombia. The sampling methodology and the questionnaire follow to some extent the Organisation for Economic Co-operation and Development (OECD) Oslo Manual. The EDIT is an appropriate data source to answer the research questions for several reasons. First, the two waves of EDIT used in this study are the main data source at the firm level that has questions on the extent to which women are involved in STI activities among Colombian manufacturing firms. Second, as a database also collected and maintained by DANE, the EDIT has the advantage of having a large sample size, broad coverage of industries, and inclusion of firms with a variety of characteristics in terms of firm size, R&D intensity, innovation activities, innovation outcomes, and others. Using this dataset thus avoids the oversampling of large firms, which is common in other surveys, such as the World Ban's Enterprise Survey. The EDIT sample is a census of all manufacturing firms with ten or more employees. These aspects of the EDIT improve the robustness of the inference that can be made from analyzing it. Additional data on firm performance, physical investment, foreign capital, firm age, and the share of women participating in different vocational areas of the firm are drawn from the Colombian manufacturing survey (Encuesta Anual Manufacturera, or EAM), which has been used in important research papers on productivity at the firm level (Kugler and Verhoogen, 2009; 2012).

3.1 Empirical Framework

Our main methodological contribution is to present an integrated view of the role of women in innovation and production within the firm, taking advantage of the structural framework provided by the CDM model. We argue that an integrated view is well suited to capture the contribution of gender diversity to the innovation and production processes, since we first model women's participation in firm-sector-specific STI activities and then model the more general, or sector-specific, effect on firm productivity. The CDM model is well suited to address our hypothesis, that is, that women's participation contributes to a firm's propensity to innovate and that gender diversity directly contributes to productivity. The CDM model has three stages to deal with the sample selection and endogeneity problems on innovation efforts and outcomes. We built on the same structure by including women's participation at the second stage and distribution of women in the different units at the firm in the third stage. We control for the potential endogeneity of women's participation in STI by instrumenting the share of women at the second stage with an estimation of it as a function of the share of women in the industry in which the firm operates.

Since our main correlations are in the second and third stages, we will skip the details of the first stage and describe the econometric methods involved in the second and third stages. The second stage estimates a knowledge production function (See Crespi and Zuñiga, 2013, Gallego Gutiérrez, and Taborda, 2015, for Colombia; Griffith et al., 2006) augmented by introducing *women's participation* in STI (*sw_STI*). As we mentioned above, EDITs 2011-2012 to 2013-2014 asked about the number of women who directly participated in STI activities. Having this information allows us to test the *direct* contribution of women on a firm's propensity to innovate (hypothesis 1).

$$INN_{i,t} = \gamma\widehat{R\&D} + \vartheta\, \widehat{sw\_STI}_{i,t} + x_{i,t}\delta + u_{i,t} \qquad (1)$$

where $INN_{i,t}$ is knowledge output, that is, whether the firm obtained any mode of innovation (i.e., technological innovation –TI or organizational and marketing innovation –NTI). The variable $\widehat{R\&D}_{i,t}$ is the predicted innovation effort by firm *i* at time *t*. The gender indicator is captured by the predicted value of the share of women in STI, $\widehat{sw\_STI}_{i,t}$. In equation (1), ϑ is the key parameter of interest (i.e., whether women's share in innovation activities contributes to increase firms' propensity to innovate), γ is the classical parameter of the standard CDM in which the impact of R&D efforts on innovation outcomes is observed. This specification controls for other factors that are common in this framework, $x_{i,t}$ (i.e., size, human capital, exporter dummy, ownership, and modes of cooperation in innovation), and their impacts are captured by the vector δ. Finally, $u_{i,t}$ is an error term.

When analyzing the effect of women on the likelihood that a firm innovates, endogeneity concerns arise because of omitted unobservable firm characteristics. With respect to the relationship between gender diversity and innovation, it is plausible, for example, that some firms have managers interested in both gender diversity and innovation, but we do not observe the types of managers that are running the firm. To take account of this potential endogeneity issue, we first run a Tobit model and get an estimate of sw_STI, *i.e.*, $\widehat{sw\_STI}$, which we introduce in equation (1) instead of the direct measure. As for the IV, one way to control for this endogeneity is to use the share of women working in firms that belong to a given four-digit manufacturing industry (Adams and Ferreira, 2009; Campbell and Mínguez, 2008; Reguera, de Fuentes, and Laffarga, 2017; Srinidhi, Gul and Tsui, 2011). We include in the Tobit regressions controls for firm characteristics such as size, exporting behavior, and foreign ownership.

In the last stage, the standard CDM model relates innovation to productivity by augmenting a Cobb-Douglas production function with the predicted innovation outcomes from the second stage, the common inputs (i.e., labor, capital, and a measure of human capital), and the variable of interest that measures the gender distribution of the workforce at different units of the firm and the share of women working on the production process *ws*. The final specification is:

$$y_{i,t} = \pi_1 k_{i,t} + \pi_2 l_{i,t} + \delta HC_{i,t} + \rho ws_{i,t} + \pi_2 \widehat{INN_{\iota,t}} + v_{i,t} \qquad (2)$$

where $y_{i,t}$ stands for labor productivity (log of value added per worker), $k_{i,t}$ is the log of physical capital per worker, $l_{i,t}$ is total employees, $HC_{i,t}$ is the share of employees with a bachelor's degree or more, $\widehat{INN_{\iota,t}}$, is the corresponding predicted innovation output, and $ws_{i,t}$ is the measure of gender diversity on the production process of the firm. ρ is our main parameter of interest since it shows how gender diversity directly affects firm labor productivity. We approach gender diversity by using three measures: the ratio of women to total employees in the firm, the coefficient of variation (CV), and the standard deviation coefficient (SD) of the distribution of women across different areas of the firm.

The CV conceptualizes diversity as disparity. We use this measure because disparity can be viewed as an increase in both separation and variety. Distance of women and men within a group can be approached in terms of prestige, power, or pay. CV is defined as follows:

$$CV = \frac{\sqrt{\frac{\sum_i^n (D_i - D_{mean})^2}{n}}}{D_{mean}}$$

where D_i is the number of female (male) employees who work in the same area (occupation). To calculate this measure (and the other diversity one), we use the EAM, which splits the overall workforce into three vocational areas: (i) total employees working directly and only in production and who had a professional or technical degree; (ii) total employees working in production with no technical degree, plain blue collar workers; and (iii) white collar workers who may be in sales and management areas of the firm, and additionally for the whole work force. We account for n=6 different groups, D_i, three types of occupations for each gender group. The second chosen measure of gender dispersion is the standard deviation index that follows the traditional calculation. Finally, we use women's participation as a standard measure of gender contribution to the production process.

In all regressions of the three stages of our CDM specification, the analysis includes a set of two-digit industry level dummies, a year dummy, and region dummies. Following standard procedures, we also control for firm size in all equations except the intensity of innovation equation, since the indicator is already scaled for size.

3.2. Descriptive Statistics for the Gender Contribution to the Nexus Innovations-Productivity

Table 1 summarizes the definitions of the main variables, dependents, and covariates used in the CDM empirical exercise below. From 2011 to 2014, 20 percent of firms were innovative, and technological innovations (18 percent) were more common than non-technological ones (9 percent). These figures are much smaller than those found in Crespi et al. (2016). That study found that 70 percent of Latin American firms surveyed were technological innovators, while for Colombian manufacturing firms, that percentage is only 20 percent, or almost three and a half times lower. One potential explanation of that huge difference may be that the Colombian data include a larger number of small and medium firms, while the study by Crespi et al. 2016 includes mainly large firms. Another fact is the amount of money invested in R&D—on average, around 104,000 Colombian pesos per employee. Only 6 percent of firms, most of them very large, undertook R&D activities. One final indicator of innovation performance is the percentage of firms that had a patent during the period of study. The figure was a negligible 0.3 percent, an indication of the patenting behavior of Colombian manufacturing firms.

Table 1. Main Variables Used in the Empirical Exercises

Definition		Observations	Mean	Minimum	Maximum
Related to innovation activities					
Innovative firm	(0/1) if firm introduced product, process, organizational or marketing innovation	17070	0.20	0	1
Technological innovation	(0/1) if firm introduced a product or process innovation	17070	0.18	0	1
Non-technological innovation	(0/1) if firm introduced an organizatinal or marketing innovation	17070	0.09	0	1
Women's participation in STI and overall workforce					
Share of women in STI (ws_STI)	% of women working in STI activities	17070	0.06	0	1
Share of women in firm's workforce	% of women in firm's laborforce	17070	0.21	0	1
Gender diversity measures					
Coefficient of variation	Definition in the text	17070	0.50	0	3.3
Standard deviation	Definition in the text	17070	0.42	0	155.8
Intensity of innovation and determinants of innovation					
R&D dummy (RD_D)	(0/1) if firm invested in R&D activities	17070	0.06	0	1
R&D per worker	(000000 COL$ of 2008) R&D Expenditures per worker	17070	104	0.54	474171
R&D department	(0/1) if firm reported to have an R&D department	17070	0.03	0	1
Patent	(0/1) if firm reported to have patented	17070	0.003	0	1
Public	(0/1) if firm reported to have obtained public support	17070	0.01	0	1
Cooperation (CO)	(0/1) if firm reported to have cooperated with any of its stakeholders	17070	0.09	0	1
INFO 1	(0/1) if firm reported to have obtained information from external sources related to non-research centers or market sources	17070	0.17	0	1
INFO 2	(0/1) if firm reported to have obtained information from external sources related to research centers or scientific sources	17070	0.05	0	1
INFO 3	(0/1) if firm reported to have obtained information from external sources related to public sources	17070	0.16	0	1
Age	(years) firm age	17070	23	1	205
FDI	(0/1) if firm had 10% or more of foreign ownership	17070	0.04	0	1
Human capital (HC)	% of workers with bachelor's degree	17070	0.30	0	1
Employment	Total workforce	17070	84	1	8501
Exports per worker	(000 COL$ of 2008) Exports per worker	17070	256	0	416520
Market Share	% of firm's market share	17070	0.01	0	0.95
Performance					
Labor productivity (VA)	(000000 COL$ of 2008) Value added per worker	17070	533	0.006	254977
Physical capital stock	(000000 COL$ of 2008) Physical capital stock per worker	17070	69643	0.002	$2,4*10^{7}$

Source: Authors' calculation based on EAM and EDIT data.

Other important factors that affect innovation activities relate to firm age and human capital. Firm age captures the tacit knowledge accumulated at the firm. The average age of firms in the sample was 23 years old. Human capital, measured as the share of employees who have at least a bachelor's degree, was close to 30 percent. Additional factors that help explain firms' decisions to conduct R&D refer to public support (Crespi et al 2016; Czarnitzki and Lopes 2013; Hall 2010; Hall and Lerner, 2010), engagement in collaborative projects (Becker and Dietz, 2004; Temel, Mention, Torkkeli, 2013 for studies of Germany and Turkey, respectively), and sources of information used (Gómez, Salazar, and Vargas, 2016). Evidently, public support was not used for all firms: fewer than 1.0 percent of firms obtained some financing from public sources. Firms seemed to be reluctant to enter into cooperative arrangements with any of their stakeholders, including clients, suppliers, and competitors, with only 9 percent of firms implementing cooperation mechanisms. Finally, 16 percent of firms made use of external public sources of information, while only 5 percent approached research centers or used scientific sources to find information for their innovation activities.

Table 1 presents the main statistics of women's participation in STI, the whole workforce, and the two diversity measures. First is direct women's involvement in STI activities, which was surprisingly low. It only amounted to 6.0 percent of the total employees on STI activities. However, women's involvement in the entire manufacturing workforce averaged 21 percent. Both indicators, especially the first one, clearly show that there is ample room for firm managers to hire more women. The means of the coefficient of variation and standard deviation coefficient are 0.5 and 0.42, respectively. These two last indicators confirm that the gender distribution in manufacturing firms is still unequal.

4. Results

This section provides empirical evidence of the relationship of having a diversified gender workforce in Colombian manufacturing industries on the likelihood that a firm innovates and on the value-added per worker. In this way, we will test the two hypotheses proposed above.

4.1. How Women's Involvement in STI Activities Contributes to Innovation

As was shown in Table 1, the share of women working in STI areas is relatively low (6 percent compared to 21 percent in the overall labor force at the industry, on average) but their contribution to a firm's propensity to innovate can only be assessed empirically. We will focus our analysis on our main variables of interest and on the predicted R&D. The results of the other coefficients are presented in Table 2. Table 2 presents four panels, each of them presenting the marginal effects of explanatory variables on the propensity of innovate in: (i) any mode, (ii) technological innovations, (iii) non-technological types, (iv) radical innovations, and (v) imitation ones. Furthermore, in each panel, we first present the results of the second stage of the CDM model assuming non-endogeneity of our variable of interest by including directly the share of women working in STI activities, followed by the results when we instrument that variable.

Table 2. The Knowledge Production Function - Biprobit Regressions - Marginal Effects (Stage 2)

Variable	INN		TI		NTI		Radical		Imitation	
	Naive	IV	Naive	IV	Naive	IV	Naive	IV	Naive	IV
RD_p (Predicted R&D expenditure per employee)	0.079***	0.102***	0.14***	0.175***	0.08***	0.097***	0.06***	0.07***	0.071***	0.09***
	(0.044)	(0.033)	(0.005)	(0.0063)	(0.003)	(0.004)	(0.003)	(0.004)	(0.012)	(0.0032)
Size	0.02***	0.003	0.022***	0.012	0.009***	-0.007	0.012***	-0.011	0.011***	-0.014
	(0.0013)	(0.009)	(0.002)	(0.0012)	(0.002)	(0.007)	(0.0013)	(0.010)	(0.0012)	(0.012)
Log_export per employee	-0.033***	-0.054***	-0.064***	-0.095***	-0.038***	-0.053***	-0.022***	-0.037***	-0.026***	-0.042***
	(0.0056)	(0.0045)	(0.0063)	(0.008)	(0.0063)	(0.005)	(0.006)	(0.006)	(0.0033)	(0.005)
Human capital	0.0072	0.0018	0.031	0.0025	0.011	0.016	0.019**	0.023***	0.026	0.002
	(0.0085)	(0.0013)	(0.012)	(0.0015)	(0.013)	(0.017)	(0.008)	(0.01)	(0.018)	(0.011)
Cooperation	-0.0088	-0.0053	-0.021**	-0.018	-0.038***	-0.035***	-0.012	-0.01	-0.017**	-0.02
	(0.0084)	(0.006)	(0.0094)	(0.014)	(0.0085)	(0.010)	(0.009)	(0.0097)	(0.026)	(0.011)
Foreign ownership > 10%	-0.034***	-0.04***	-0.056***	-0.067***	-0.026***	-0.0302***	-0.029***	-0.033***	-0.03***	-0.035***
	(0.0067)	(0.0084)	(0.0095)	(0.01)	(0.0063)	(0.0057)	(0.0065)	(0.006)	(0.010)	(0.011)
sw_STI	0,203***		0,26***		0,15***		0,11***		0,13***	
	(0.0115)		(0.011)		(0.007)		(0.007)		(0.006)	
sw_STI_hat		0,106***		0,16***		0,075***		0,10**		0,11**
		(0.038)		(0.049		(0.025)		(0.047)		(0.04)
Constant										
Observations	17055	17055	17051	17051	17050	17050	17020	17020	17055	17055

Source: Authors' elaboration.
Notes: Bootstrapping errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1.
All regressions include dummies controlling for region, year, and ISIC-2 digits.

One outstanding result across all variables through what we call naive specification, or the IV regressions that control for potential sources of endogeneity of women's participation in STI activities, is that regardless of the mode of innovation, firms with greater women's participation in STI activities ($\widehat{sw\_STI}$) had a higher propensity to innovate.[1] It confirms hypothesis 1, which states that gender diversity increases the likelihood of being innovative. We also provide evidence of a *differentiated* effect of gender diversity by type of innovation, as was stated in hypothesis 1a. Women's participation has a positive and statistically significant effect on *technological* innovation outcomes that doubles the effect found in non-technological ones. In our data, that type of innovation includes both radical and incremental innovations, which were also found to be positive and significantly affected by gender diversity in another empirical context (Díaz, González, and Sáez, 2013; Fernández, 2015a and 2015b; García, Zouaghi and García, 2017; Teruel, Parra and Segarra, 2015).[2] Not controlling for potential endogeneity issues of women's participation in STI activities led to an overestimation of the effect of that participation. The overestimation effects were greater proportionally for non-technological innovation regressions. These results provide

[1] The results of the Tobit regression used to control for the potential endogeneity of the gender variables are presented in Table A2 (see Annex). In Table A3 (see Annex), we also present results for regressions checking the validity of our instrument. It runs the effect of our instrument the women share on STI and the industry and region level on the three types of firm innovation. Clearly, after controlling for sector, industry and year effect, women share at industry region level does not affect any mode of firm's innovation outcomes.

[2] The EDIT survey allows separating the measure of technological innovation between those innovations that were introduced by the firm as new to the firm and new to the market.

new evidence of the positive impact of having a more gender-diverse workforce in knowledge production undertakings in developing countries, whose economies exhibit low ratios of women working in STI activities.

To further explore the robustness of these findings, we ran regressions where the mode of innovation is whether the firm achieved incremental or radical innovation. The findings are presented in Table 2. Interestingly, the inclusion of women in STI activities seems to affect similarly either mode of innovation. As Page (2017) argues, the diversity premium is stronger in complex, non-routine, cognitive tasks, which are the group problem-solving contexts. In more cognitively diverse teams, the effect of diversity, in this case gender diversity, is stronger. STI teams within firms gain their bonus if they are more diverse. Hence, the effect is stronger on technological than on non-technological innovation.

Finally, Table 2 confirms the importance of the (predicted) intensity of R&D investment. The results show a positive and significant correlation between R&D investment and the probability that a firm innovates, even after controlling for gender diversity. Of the remaining control variables, human capital has a positive sign for any type of innovation, but it is only statistically significant for radical innovations.

The presence of foreign ownership and whether a firm cooperated with internal and external partners both have a negative impact on the likelihood that a firm innovates. In the first variable, foreign companies undertake innovation efforts at their headquarters, which may explain their nil impact. With respect to the second variable, more research is warranted. Being an exporting firm decreases the chances of innovating. This result calls for more exploration of the way the indicator is built; for example, the geographic destination or R&D intensity of goods (Crespi and Zuñiga, 2012) should be considered. Last, the effect of size was not statistically significant in any of the IV-controlled regressions.

How do the findings of gender diversity compare to those found in the literature? This result is in the same vein with the findings of recent research that have tested whether having gender diversity is beneficial for getting more innovation. We have found a similar positive effect in an integrated analysis, despite using direct women's share in STI activities instead of a *diversity* index. For example, Díaz et al. (2013) found that gender diversity in R&D team contributes positively to a firm's achievement of radical innovations. Fernández (2015a and 2015b) found a positive contribution of gender diversity on four modes of innovations. Finally, Teruel et al. (2015) and García et al. (2017) also found a positive contribution of greater gender diversity on a firm's propensity to innovate either in product, process, marketing, or organizational innovations, or to make incremental or radical innovations.[3] Consequently, we have shown that for a developing economy, having (more) women directly employed in STI activities brings ideas, insights, and creativity that enhance a firm's propensity to be more innovative.

4.2. Women's Contribution to Productivity

We have found that women's engagement in STI activities within the Colombian manufacturing firms contributed importantly to the propensity of firms to innovate. But can women's participation in the whole firm, i.e., within any functional domain, also be a contributing factor to enhancing firm productivity (our second hypothesis)? This question is answered in Table 3, which shows the result of the econometric specification of equation (2). We recall that equation (2) is an augmented Cobb-Douglas production function that includes common inputs, capital, labor, human capital, plus a measure of gender diversity in the overall firm labor force and the predicted innovation results obtained in stage 2.

Before presenting and analyzing the main findings, some explanations about Table 3 are in order. First, the estimation of the production function is the third stage of a structural model in which we first estimate the intensity of R&D investment (reported in Table A1 in the Annex), followed by introduction of the predicted value into the knowledge production function, which in turn is calculated for three measures of innovations, that is, the innovative firm (INN), the realization of technological innovations (TI), and the achievement of non-technological innovations (NTI) (Table 2). The estimation of these three innovation measures was made using the gender variable of interest at stage 2, that is, women's participation in STI activities. These predicted values, plus the standard inputs of a production function, led to the results in Table 3. To illustrate, columns 1 to 4 present the results of the standard CDM augmented by the predicted innovation variable –$\widehat{INN}$, plus the *direct* contribution of three measures of women's participation in firm productivity (Columns 2 to 4). Columns 5 to 7, and columns 8 to 10, replace the $\widehat{INN}$ variable with $\widehat{TI}$ and then with $\widehat{NTI}$ plus the contribution of the main variables of interest (women's participation in the overall workforce of the firm, the coefficient of variation, and the standard deviation).

[3] Most papers use the Blau Index as a measure of gender diversity because it accounts for the distribution of women on different teams involved on STI activities (Harrison and Klein, 2007). The information about the distribution of women on different teams on innovation activities is not available on the EDIT survey in Colombia. We measure the role of women on innovation outcomes by the ratio of women participating in STI.

Table 3. Impact of Innovation and Gender on Labor Productivity

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Capital stock per employee	0,185***	0,186***	0,185***	0,185***	0,185***	0,185***	0,185***	0,185***	0,185***	0,185***
	(0.008)	(0.010)	(0.010)	(0.009)	(0.010)	(0.009)	(0.009)	(0.008)	(0.010)	(0.010)
Size	0,122***	0,120***	0,121***	0,119***	0,111***	0,113***	0,111***	0,114***	0,115***	0,113***
	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.006)
Age	-0,0459***	-0,0453***	-0,0444***	-0,0458***	-0,0499***	-0,0495***	-0,0500***	-0,0509***	-0,0506***	-0,0510***
	(0.012)	(0.011)	(0.012)	(0.010)	(0.011)	(0.014)	(0.010)	(0.014)	(0.011)	(0.011)
Human capital	0,476***	0,480***	0,475***	0,477***	0,480***	0,476***	0,477***	0,444***	0,442***	0,444***
	(0.039)	(0.043)	(0.050)	(0.036)	(0.050)	(0.042)	(0.041)	(0.044)	(0.050)	(0.037)
Share_women in firm		0,048***			0,041**			0,041**		
		(0.017)			(0.018)			(0.019)		
Coefficient of variation			0,022**			0,079***			0,0070	
			(0.006)			(0.008)			(0.009)	
Standard deviation				0,0094**			0,0086**			0,0085***
				(0.004)			(0.004)			(0.004)
INN (Predicted)- sw_STI	0.437***	0.437***	0.383***	0.405***						
	(0.042)	(0.037)	(0.049)	(0.045)						
TI (Predicted) - sw_STI					0.102***	0.096***	0.095***			
					(0.009)	(0.015)	(0.011)			
NTI (Predicted) - sw_STI								0.147***	0.14***	0.137***
								(0.01)	(0.02)	(0.02)
Constant	3.28***	3,27***	3,28***	3,29***	3.45***	3.44***	3.45***	3.54***	3.54***	3.54***
	(0.09)	(0.09)	(0.10)	(0.09)	(0.10)	(0.10)	(0.10)	(0.09)	(0.12)	(0.11)
Observations	17055	17055	17055	17055	17067	17067	17067	17067	17067	17067
R-squared	0.223	0.223	0.224	0.224	0.224	0.224	0.225	0.224	0.224	0.225

Source: Authors' elaboration.
Notes: Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1.
All regressions include dummies controlling for region, year, and ISIC-2 digits.

We begin by focusing on our variables of interest, that is, the share of women in the overall labor force of a firm, and the two diversity measures. First, regardless of the mode of (predicted) innovation obtained by firms, the higher the share of women in the overall labor force of a firm, the greater its labor productivity. Second, regarding the two gender diversity measures, only the standard deviation seems to contribute to increased labor productivity, and the results do not depend on the mode of innovation achieved by the firm. When we utilize the coefficient of variation instead of the standard deviation, we find that this diversity measure impacts productivity when the innovation outcome is defined broadly, that is, either type of innovation. No (significant) effect of this indicator on firm's labor productivity was found when we only used technological or non-technological innovation.

Our second hypothesis says that a more gender diverse workforce, or a labor force in which more women participate, can offer a broader pool of skills and capabilities which can manifest itself in greater productivity. Thus, the main variable of interest in Table 3 is women's overall participation within the firm (Columns 2, 5, and 8 in Table 3). Consequently, we are assuming that regardless of the functional area where women work, their impact as a whole should be positive. Indeed, this is what we found in those three columns. This result is contrary to some results found in the labor research of the impact of gender on productivity (and wages). For example, Ilmakunnas and Ilmakunnas (2011) found that the influence of women's participation in total factor productivity had a negative sign but had become insignificant in fixed effects estimation. However, in their GMM specification, the effect is definitely negative. On the other hand, Garnero et al. (2014), in their study of Belgian companies, found that the *diversity index* of gender was negatively related to both average labor productivity and average wages when taking the whole industry into account, while gender diversity increased productivity when looking only at high-tech industries. In our case, we only tested the effect of women's participation in all manufacturing sectors. Contrary to Ilmakunnas and Ilmakunnas (2011) and Garnero, Kampelmann, and Rycx (2014), the result was that women's participation supports productivity. Hypothesis two is therefore accepted.

Furthermore, the positive contribution of either mode of innovation achieved by firms to firm labor productivity is consistent with findings in related research for both industrialized and emerging economies. The effects are large and significant. Finally, two results that are worth highlighting refer to the coefficients of human capital and age. The first one is positive, meaning that the higher the skills of the (overall) labor force of a firm, the higher its productivity. The second one is negative, meaning that younger firms, when controlling for innovation and women's participation, are more productive than mature firms.

5. Concluding Remarks

This study has tested two hypotheses regarding the contribution of women's presence in a firm's labor force and has found a positive relationship between measures of gender diversity and innovation and productivity. Using data from two innovation surveys and performance surveys for Colombian manufacturing firms for the period 2011–2014 and studying the role of women using an integrated view of a CDM framework as the econometric technique, we found some robust evidence of a positive contribution of women's participation in STI activities to firm innovation outcomes. Hypothesis 1 is accepted, since it established a positive association between women's engagement in STI activities and firms' achievement of innovations. The results in Table 2 also confirm hypothesis 1a, that is, that women's participation in STI activities impacts differentially the mode in which firms innovate. It has a positive and significant contribution to the likelihood that firms introduce technological innovations but seems not to affect firms' propensity to achieve non-technological innovation. Furthermore, using the same data and model, we found a positive contribution of women's share in overall personnel and of gender diversity measures to labor productivity. In this case, hypothesis 2 is also accepted.

The results of this research clearly show that women's participation in the manufacturing labor force, and in scientific, technological, and innovation activities is of foremost importance. The results also bolster the case made by McKinsey about the value women's participation can add to annual GDP growth. This value could be greater for developing countries that face the challenge of providing better living conditions and more sustainable growth and development and where women's involvement in STI activities is low.

In terms of the cost to firms that do not have (more) women in the workplace, our research can indirectly provide some insights. It is well known that innovation is the key driver of firm productivity, and that for firms to keep or increase their market share, they will begin, or continue, to be more innovative. Since technological innovations (product and process ones) move a firm's marginal cost function to the right, that is, a reduction of cost for each unit of good produced, innovation can result in larger gains. Finally, we found evidence that a more gender-diverse labor force enhances firm productivity. Thus, firms have lower labor productivity when their labor force tends to be less diverse. Future research can provide us with more accurate results and with them to see the costs that a firm incurs from not having a more balanced labor force. These calculations are left for future research.

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Annex

Table A1. First Stage: Heckman Model

Variable	ln_RD_empl	RD_D
Size		0.182***
		(0.0183)
Export_dummy	0.435***	0.123**
	(0.125)	(0.0489)
Foreign	0.261	-0.0251
	(0.188)	(0.0830)
Human capital	0.0883	0.264**
	(0.300)	(0.105)
Age	0.0916	0.0478
	(0.0933)	(0.0343)
PATENT	1.360***	0.541**
	(0.495)	(0.231)
CO	0.800***	0.502***
	(0.153)	(0.0567)
INFO1	0.588***	0.692***
	(0.195)	(0.0706)
INFO2	0.585***	0.416***
	(0.142)	(0.0644)
INFO3	0.687***	0.481***
	(0.164)	(0.0700)
part	7.308**	0.536
	(3.441)	(1.060)
Constant	1.476**	-2.952***
	(0.635)	(0.139)
Rho		0.886***
		(0.122)
Observations	17,067	17,067
p-value LR test	0	0

Source: Authors' elaboration.
Notes: Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1
All regressions include dummies controlling for region, year, and ISIC-2 digits.

Table A2. Tobit Model to Control for Potential Endogeneity of Women in STI Activities

Variable	Model
sw_firm ISC_4	0.292***
	(0.0578)
Size	0.245***
	(0.00862)
Export_dummy	0.0907***
	(0.0251)
Foreign	0.0135
	(0.0425)
Constant	-1.774***
	(0.0539)
sigma	0.815***
	(0.0165)
Observations	17,070

Source: Authors' elaboration.
Notes: Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1
All regressions include dummies controlling for region, year, and ISIC-2 digits. The IV is ISIC_4 that refers to the share of women in firms belonging to a common industrial standard four-digit classification.

Table A3. Test of Exclusionary Restriction

Variable	INN	TI	NTI
sw_STI	-0.627	-0.0139	-0.0094
	(0.47)	(0.03)	(0.02)
Constant	0.726	0.257	0.158
	(0.31)	(0.02)	(0.01)
Observations	17070	17070	17070
R_squared	0.002	0.032	0.015

Source: Authors' elaboration.
Notes: Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1
All regressions include dummies controlling for region, year and ISIC-2 digits.