Innovation and Employment in Indian Manufacturing: The Role of Technological and Non-Technological Changes in Shaping Gender Diversity

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Abstract

Innovation plays a crucial role in shaping employment patterns in manufacturing enterprises. Innovations also affect aggregate employment and gender-based employment diversity through their compensation and displacement mechanisms. In this study, we investigate whether technological and non-technological innovations affect employment and promote gender-based employment diversity in a developing country context, using the case of manufacturing enterprises in India, a large developing economy. To this end, we use cross-sectional data from approximately 3,487 manufacturing enterprises, drawn from the World Bank Enterprise Survey (WBES) and the World Bank Innovation Survey Follow-up for India (2014). We employ Ordinary Least Squares (OLS), Instrumental Variables (IV)-based Two-Stage Least Squares (2SLS), and Generalized Methods of Moments (GMM) to evaluate it. Our analysis indicates that both technological innovation (particularly process innovation) and non-technological innovation (especially marketing innovation) contribute to overall employment growth via the compensation effect. However, technological innovation, particularly product innovation, promotes gender-based employment diversity by increasing female employment through compensation effects, especially in production-related occupations. These results show minor variations in enterprise sizes. Based on this, policymakers should actively foster research and innovation, particularly product innovation, and emphasize vocational training programs to enhance women's skills and support their labor market participation. Such measures can facilitate greater inclusion of women in technological and non-technological innovations, thereby advancing gender-based employment diversity. It will also help to achieve the Sustainable Development Goals (SDGs), particularly gender equality (SDG-5) and reduced inequalities (SDG-10), by fostering inclusive growth, enhancing female labor force participation, promoting gender diversity, and developing innovative policies that ensure fair and balanced employment outcomes.

Keywords: Gender-based employment, India, Non-Technological Innovation, Technological Innovation, Sustainable Development Goals.

JEL Classifications Codes: J4, J6, L6, O3

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1. Introduction

Innovation leads to the development of new ideas, processes, products, and services, increases efficiency, fosters competitiveness, and generates employment opportunities (Schumpeter, 1934; Dosi et al., 1988; Verspagen, 1992; M. van Dijk & Sandee, 2002; Fagerberg et al., 2005). Innovation can be broadly categorized into two types: technological and non-technological innovations. Technological and non-technological innovations impact employment by creating new job types and altering the nature of existing roles. These innovations can also reduce barriers for promoting gender-based employment diversity by supporting flexible work options, fostering inclusive work environments, and improving opportunities for skill advancement. In this context, gender-based employment diversity denotes the degree to which women are equitably represented across occupations, hierarchical levels, and forms of employment within firms or economies relative to men, capturing broader patterns of inclusion and equality in labor market participation. In turn, such inclusive employment practices enhance productivity, generate income, and foster economic independence, thereby contributing to broader economic and social development. It also enhances individual welfare and ensures social cohesion, underscoring why employment has always been a critical policy question worldwide. In India too, it remains a key concern, particularly with regard to female employment (Mahapatro, 2019). In India, female labor force participation has remained persistently low, despite steady economic growth over the past decades (Chatterjee & Vanneman, 2022). This enduring pattern reflects various structural and socio-cultural constraints that prevent females from engaging in formal employment, particularly in the manufacturing sector (Cooke, 2010; Abbasi, 2014; Mehtap et al., 2017; Islam et al., 2023). However, previous studies have only explained the association between technological innovation and employment, mainly at an aggregate level and with a limited focus on gender-based employment (Hall et al., 2008; Harrison et al., 2014; Vivarelli, 2014; Javaid et al., 2021). These studies did not reveal the association between technological and non-technological innovation on employment and gender-based employment diversity. Therefore, this study examines the impact of technological and non-technological innovation on aggregate employment in manufacturing enterprises in India. Additionally, it also analyses the impact of such innovations on gender-based employment diversity across production and non-production domains. The study's findings will provide policymakers and industry stakeholders with valuable insights into the effects of technological and non-technological innovations on overall and gender-based employment in the manufacturing sector. It will also help shape strategies to achieve the Sustainable Development Goals (SDGs), especially gender equality (SDG-5) and

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reduced inequalities (SDG-10), by fostering inclusive growth, enhancing female labor force participation, promoting gender diversity, and developing innovative policies that ensure fair and balanced employment outcomes.

Innovation improves technical efficiency and generates productivity gains (Reddy & Sasidharan, 2023). Industries' spending on Research and Development (R&D) results in technological and non-technological innovation. Product and process innovations are classified as technological innovations, whereas organizational and marketing innovations are considered non-technological, as shown in Table 1 (Schmidt & Rammer, 2007; Mothe & Thi, 2012). Product innovation enhances enterprises' technological competitiveness (Antonucci & Pianta, 2002; Bogliacino & Pianta, 2010). Enhanced technological competitiveness drives the introduction of new products and maximizes quality advantages to boost economic activity. This expansion in economic activity enlarges the market size for new products, generating more employment opportunities (Antonucci & Pianta, 2002). However, process innovation increases the enterprise's efficiency by implementing new or significantly improved production methods, including techniques, equipment, or software. An increase in enterprise efficiency enhances productivity by reducing production time and costs. It also leads to job loss, known as the displacement effect. A reduction in production costs lowers product prices, stimulating demand. This increase in market demand encourages enterprises to hire more workers, thereby generating employment, a phenomenon known as the compensation effect (Harrison et al., 2014; Zhu et al., 2021). As we know, the compensation effect can offset the displacement effect, or vice versa; the impact of process innovation on employment remains unclear and inconclusive (Avenyo et al., 2019). Additionally, organizational innovation involves adopting new managerial or organizational practices related to internal processes, workplace structures, or external partnerships. Organizational innovation also affects employment by reshaping work structures, decision-making processes, and coordination mechanisms (Edquist et al., 2001; Evangelista & Vezzani, 2011; Dosi & Mohnen, 2018). It can enhance an enterprise's productivity, improve working conditions, and increase demand for skilled labour. However, it may also reduce employment in routine tasks due to streamlined operations, requiring laborers to adapt through upskilling or role changes. Likewise, marketing innovation refers to introducing new marketing strategies, that is, a substantial change in product design or packaging, product placement, promotion, and pricing (OECD, 2005; Kam Sing Wong, 2013; Camisón & Villar-López, 2014; Medrano & Olarte-Pascual, 2016; Cruz-Ros et al., 2017; Geldes et al., 2017; Bortoluzzi et al., 2018; Ramirez et al., 2018). Marketing innovation can also influence employment by increasing product demand and expanding market reach. This

growth may create employment opportunities in sales, marketing, and customer service. However, it may also shift employment patterns, requiring workers with updated digital and communication skills.

Innovation also significantly influences female employment in the manufacturing sector by reorganizing manufacturing techniques, enhancing inclusivity, and generating new job opportunities for female laborers (Prabowo & Setiawan, 2021). In India's manufacturing sector, female employment is crucial for promoting gender diversity, fostering inclusive economic growth, and achieving gender equity in the labor market (Gupta, 2021). Integrating females into manufacturing broadens the labor force, enhances household incomes, and improves overall productivity. It also contributes to the economic empowerment of females, enabling greater autonomy and decision-making within households and communities. However, to the best of our understanding, existing studies have not explored the linkages between innovation and gender-based employment diversity. Therefore, the present study aims to bridge this gap and examine the impact of technological and non-technological innovation on gender-based employment diversity. To empirically investigate this, we used data from the World Bank Enterprise Survey (WBES) and the World Bank Innovation Survey Follow-up for Indian manufacturing enterprises (2014), as these sources offer detailed information on innovation and gender-based employment diversity. We employ the Ordinary Least Squares (OLS) and Instrumental Variable (IV) based Two-Stage Least Squares (2SLS) methods to analyze it. We also employed Instrumental Variable (IV)- based Generalised Method of Moments (GMM) for robustness, as these methods are powerful tools for addressing endogeneity and deriving causal estimates.

Although existing theoretical frameworks provide some understanding of the link between innovation and gender diversity, they are often narrow in scope and do not fully address the complexity of the relationship. Many theories concentrate either on the economic impact of innovation or on the structural dimensions of gender inequality, but rarely integrate both perspectives. Consequently, they offer only a limited explanation and overlook important mechanisms, such as compensation and displacement effects, through which innovation can affect gender-based employment diversity. Given this theoretical gap, the present study primarily adopts an empirical approach to explore these relationships. Moreover, this paper makes three contributions to the literature. First, to the best of our knowledge, it is the first empirical study to investigate the impact of both technological and non-technological innovation on gender-based employment diversity. By examining the impact of technological and non-technological innovations on the gender composition of production and non-

production roles, the study offers valuable insights into the broader implications of innovation on the nature of employment and workplace inclusion. Second, the study reinforces the critical role of innovation in shaping gender-based employment diversity in the labor force. The findings contribute to a more nuanced understanding of how innovation affects labor market dynamics, including the distribution and characteristics of employment across gender lines. This perspective is crucial in assessing the nature of employment and its inclusiveness in an evolving industrial landscape. Third, the insights gained from the analysis offer practical value for policymakers and stakeholders. By highlighting the gendered effects of innovation, the study can inform the development of innovation-driven employment policies that promote equitable labor outcomes. Furthermore, the results can support efforts to recalibrate employment structures to enhance job quality and inclusivity, thereby fostering a more balanced and sustainable labor market development in the country.

This study will have two limitations. First, while existing theories offer partial explanations for the relationship between innovation and gender-based employment diversity, they are not comprehensive. Therefore, we rely primarily on empirical analysis to explore and better understand these associations. Although the empirical approach provides meaningful insights, it also poses a limitation, as the absence of a comprehensive theoretical framework may restrict the study's wider applicability and limit the depth of interpretation of its findings. Second, limitations of secondary databases, such as response bias, regional underrepresentation, and the exclusion of informal enterprises, can affect the study, resulting in an incomplete or skewed picture.

The rest of the paper is structured as follows. Section 2 reviews the theories, channels, and empirical studies. Section 3 outlines the data sources and methodology employed. Section 4 represents the econometric results and provides a detailed discussion. Finally, Section 5 concludes with key insights and policy implications.

2. Theories, Channels, and Empirical Studies

2.1. Innovation and Employment: A Theoretical Framework

The association between innovation and employment remains at the centre of theoretical and empirical economic research. This field of inquiry has been extensively explored within the framework of contemporary economic theories. It begins with classical economist Ricardo’s notion of technological unemployment, progressing through Keynes’s vision of “mankind solving the economic problem," and culminating in modern evaluations of the labor market consequences of automation and robotics across various occupations. As Dosi (1982)

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metaphorically describes, the multifaceted character of technological progress functions both as an engine and a thermostat. As an engine, it determines the pace at which new technological paradigms are introduced and evolve along their trajectories. As a thermostat, it regulates the extent and pattern of technological diffusion across different sectors.

These theories are also an exploration of contrasting theoretical frameworks, broadly categorized into equilibrium-based approaches, such as Neoclassical analyses, and disequilibrium-based approaches, including Evolutionary, Keynesian, Structuralist, and Regulationist theories (Calvino & Virgillito, 2017). The primary divergence between these perspectives lies in their assumptions regarding the presence of an automatic self-adjustment mechanism induced by innovation. From an equilibrium perspective, innovation through technological advancement enhances productivity, thereby stimulating economic growth. This, in turn, is expected to generate employment gains through increased aggregate output and potential wage adjustments. Conversely, disequilibrium perspectives suggested that the employment effects of innovation are far less predictable, emphasizing the complexity and context-dependent nature of technological change. This question has been debated since the beginnings of political economy, with thinkers from the Mercantilists to Ricardo, Marx, Keynes, and Chris Freeman often expressing disbelief in the economy's automatic adjustment mechanisms. In contrast, economists such as Say, Schumpeter, and supporters of general equilibrium theory have held a more optimistic view of the market's ability to self-adjust.

Evaluating whether innovation is ultimately conducive to employment creation or leads to employment destruction, and whether compensation mechanisms exist to offset these opposing dynamics, remains a central concern in policy discourse, particularly in the current economic scenario. The impact of innovation, given its diverse forms and inherent complexity, on the employment mechanism has proven difficult to clearly identify. Consequently, a comprehensive examination that contextualizes the nexus between innovation and gender-based employment diversity is both theoretically and empirically essential.

2.2. Innovation and Employment: Their Definitions and Channels

Innovation and employment are interrelated through multiple channels. The debate over the association between innovation and employment centers on two conflicting perspectives. The first perspective suggests that innovation aimed at saving labor leads to job loss, resulting in technological unemployment. On the contrary, the second perspective clearly distinguishes the type of innovation and its impact on labour employment. As per Pavitt's taxonomy (1984), product and process innovation (Schumpeterian view) are the two patterns of technological

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innovation in the manufacturing industry. Product innovation refers to the manufacturing of a product with a totally new or substantial upgrade in its functional or user characteristics (OECD, 2005). Process innovation is defined as the use of new or improved production methods to manufacture the same product (Hervas-Oliver et al., 2017). It increases flexibility (Edquist et al., 2001) and reduces production costs (Pianta & Vivarelli, 2003). Moreover, critics of the traditional focus on product and process innovations emphasize the need to more clearly distinguish between technological and non-technological innovations to capture the diverse forms of innovation within enterprises, as shown in Table 1 (Geldes et al., 2017). Recent literature has increasingly recognized the critical role of non-technological innovations, particularly marketing and organizational innovations, in driving innovative performance within enterprises (Mothe & Thi, 2010, 2012; Gunday et al., 2011; Geldes et al., 2017).

Technological innovation, particularly product innovation, has a significantly complex role in employment at the enterprise level. Introducing new products will expand the market by increasing demand from existing customers of old products and from new customers making their first attempt (Fosfuri & Giarratana, 2009). Various new products reduce competitors' market share (Champsaur & Rochet, 1989; Kekre & Srinivasan, 1990; Mahajan et al., 1993). Therefore, enterprises hire more workers to meet the demand for new products. The indirect effect of product innovation also affects the demand for the old product (Harrison et al., 2014). If the new product is a substitute for the old product, then more workers will be employed to produce the new product than to produce the old one. Whereas, if the new product is a complementary good for the old product, then product innovation generates employment opportunities in production for old and new products.

In contrast, process innovations increase the enterprise's competitiveness and raise its production efficiency, which can lead to job losses, known as ‘displacement effects.’ Increasing production efficiency can reduce production costs and lower consumer prices in competitive markets. It stimulates market demand for products, generating new employment opportunities, known as the 'compensation effect.' The magnitude of the compensation effect depends on factors such as demand elasticity for the enterprise's behavior (brand), the enterprise's products, and competition from other enterprises (Harrison et al., 2014; Avenyo et al., 2019).

Unlike technological innovations, non-technological innovations (organizational and marketing innovations) enhance an enterprise’s ability to adapt to market dynamics, improve internal efficiency, and support the successful implementation of new products or processes (March, 1991; Huber, 1991; Thornhill, 2006; Garcia & Calantone, 2002). Organizational innovation enhances internal processes and structures, while marketing innovation improves

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how companies reach and engage customers. Organizational innovation refers to the introduction and implementation of new management or organizational practices that impact an enterprise's internal operations, workplace arrangements, or external collaborations (Evangelista & Vezzani, 2011). Organizational innovation may also involve changes in how tasks are structured, how teams are organized, or how the organization interacts with external partners. The primary objective of organizational innovation is to enhance overall organizational performance. It aims to enhance operational efficiency, streamline communication within and across departments, and facilitate more informed decision-making processes. It also helps organizations to become more adaptable, responsive, and competitive in a changing business environment.

Table 1: Classification of Innovation and its activities

Types of Innovation	Subtypes of innovation	Activities
Technological Innovation	Product Innovation	• Introducing new or significantly improved products or services.
	Process Innovation	• Introducing any innovative methods of manufacturing products or offering services. • Introducing any innovative logistics, delivery, or distribution methods for inputs, products, or services. • Introducing any innovative supporting activity for processes, such as maintenance systems or operations for purchasing, accounting, or computing.
Non-technological Innovation	Organizational Innovation	• Introducing any new or significantly improved organizational structures or management practices. • Introducing any change in the method of hiring processes.
	Marketing Innovation	• Introducing new or significantly improved marketing methods (e.g., Packaging, Branding, logo, name, or trademark, products' appearance, excluding packaging or branding, advertising methods, etc).

Source: Adapted from Oslo Manual (OECD, 2005) and World Bank Innovation Survey Follow-up for India (2014)

Likewise, marketing innovation strategy refers to adopting and implementing new marketing methods or approaches (Shergill & Nargundkar, 2005; Naidoo, 2010; Kafetzopoulos & Psomas, 2016). It involves making significant changes to how various marketing strategies are implemented to improve their efficiency and effectiveness. These strategies help enterprises to gain a competitive edge and increase shareholder value. Specifically, it can enhance shareholder value by extending customer lifetime value, improving customer engagement,

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boosting positive word of mouth, and encouraging customers to contribute ideas for new products and services. Additionally, focusing on internet banking, emphasizing relationship marketing, adopting a customer co-creation orientation, recognizing alternative marketing methods, and prioritizing alliance-based marketing are the key dimensions of marketing innovation strategy. A significant amount of research highlights the importance of marketing innovation as a key factor in achieving competitive advantage for businesses (O'Dwyer et al., 2009; Ren et al., 2009). It is considered essential for gaining and maintaining a competitive edge, which ultimately contributes to improved business performance (Bhaskaran, 2006; Naidoo, 2010). It also enables enterprises to expand into new products and services, thereby increasing customers' willingness to pay for innovative offerings (Schubert, 2010). While considerable advancements have been made in the development of new products and process innovations, organizational and marketing innovations have not received the same level of attention in research and practice (Claudy et al., 2015; Geldes et al., 2017).

2.3. Empirical Studies

Empirical studies have shown an association between innovation and enterprise-level employment (Pianta, 2006; Harrison et al., 2014; Vivarelli, 2014). The potential impact of innovation on enterprise-level employment depends on technological innovation, specifically product and process innovation (Pianta, 2006; Hall et al., 2008; Harrison et al., 2014; Paola, 2024). Additionally, the theoretical impact of innovation on employment depends on the magnitude of compensation and the displacement effect of product and process innovation. Process innovation may eliminate jobs, while product innovation can offset this by generating new employment opportunities and maintaining overall employment (Petit, 1995; Spiezia & Vivarelli, 2002; Pianta, 2006; Vivarelli, 2013, 2014; Ugur et al., 2017; Calvino & Virgillito, 2017). However, there is an interdependence between product and process innovation (Antonucci & Pianta, 2002; Mairesse & Mohnen, 2010; Mohnen & Hall, 2013). The majority of the literature suggests that product innovation results in a net increase in employment, with a stronger compensation effect than displacement effects (Piva et al., 2005; Hall et al., 2008; Peters, 2008; Harrison et al., 2014; de Elejalde et al., 2015; Van Roy et al., 2018; Cirera & Sabetti, 2019; Crespi et al., 2019; Dosi & YU, 2018). Moreover, product innovation fosters the growth of the skilled labor force, particularly in manufacturing enterprises (de Elejalde et al., 2015; Crespi et al., 2019), and creates both skilled and unskilled jobs in the economy (Dutz et al., 2011; de Elejalde et al., 2015). On the other hand, the impact of process innovation on employment remains unclear, as the compensation effect could offset the displacement effect

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or vice versa (Avenyo et al., 2019). It also found that innovation increases employment opportunities, but process innovation has a greater impact on employment than product innovation (Blanchflower & Burgess, 1998; Lachenmaier & Rottmann, 2011). Moreover, evidence from the Norwegian Community Innovation Survey (CIS) 2008 indicates that the combined impact of product and process innovation has a more consistent effect on employment than either innovation alone (Herstad & Sandven, 2019). As a result, the impacts of product and process innovations on employment within enterprises remain theoretically unclear and inconclusive (Antonucci & Pianta, 2002; Hall et al., 2008; Lachenmaier & Rottmann, 2011).

On the contrary, non-technological innovation, including organizational and marketing innovations, also plays a crucial role in shaping employment patterns and enhancing enterprise competitiveness. Organizational innovation can enhance efficiency, promote employee engagement, and improve job design. It often increases demand for skilled labor (the compensation effect) and facilitates task reallocation, though it may reduce the number of routine jobs (the displacement effect). Likewise, marketing innovation can expand market reach and stimulate demand, thereby generating new job opportunities in sales, marketing, and customer support through a compensation mechanism. Marketing innovation can also reduce employment by automating tasks, reducing labor demand, and displacing workers through advanced technologies or efficient processes, a phenomenon known as the displacement effect. These innovations impact employment through multiple channels, including market expansion, operational restructuring, skill upgrading, and enhanced organizational responsiveness. Unlike technological innovations that often focus on automation, non-technological innovations frequently support inclusive growth by emphasizing human capital, adaptability, and effective service delivery. As a result, they contribute to employment generation, improve job quality, and enhance organizational agility in a competitive environment.

These innovations also play a vital role in improving overall performance and employment dynamics in India's manufacturing sector (Schroeder et al., 1989; Evangelista et al., 1997). It contributes to increased productivity by streamlining processes, reducing production costs, and enabling the creation of higher-quality, more varied products (Ghobadian et al., 2020). These improvements enhance the global competitiveness of Indian manufacturing enterprises, facilitating their growth and expansion into new markets. In the manufacturing sector, employment is also crucial for economic growth, poverty reduction, and industrial development. Female employment, in particular, promotes gender equality, empowers women economically, and contributes to inclusive development. Increasing female participation in

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manufacturing boosts household incomes, helps diversify the workforce, and enhances overall productivity and innovation in the sector.

However, the literature lacks empirical analysis of the association between innovation and gender-based employment diversity. To fill this gap, this paper empirically examines whether technological and non-technological innovation affect gender-based employment diversity in Indian manufacturing enterprises across different enterprise sizes. Considering the existing theoretical and empirical literature, we investigate how compensation and displacement mechanisms affect the influence of technological and non-technological innovation on gender diversity. Based on this framework, we propose four hypotheses to empirically investigate these associations, as outlined below:

Hypothesis 1: Product innovation does not exert a significant effect on gender-based employment diversity within firms, either through compensation effects or displacement effects.

Hypothesis 2: Process innovation does not have a significant impact on gender-based employment diversity within firms, whether through compensation mechanisms or displacement effects.

Hypothesis 3: Organizational innovation does not produce a significant effect on gender-based employment diversity within enterprises, either via compensation channels or displacement mechanisms.

Hypothesis 4: Marketing innovation does not exert a significant influence on gender-based employment diversity within firms, either through compensation effects or displacement mechanisms.

3. Data and Methods

3.1. Data Description

To test the above-mentioned hypothesis, we use enterprise-level data from the Enterprise Survey and Innovation Survey Follow-up for India conducted by the World Bank (2014). Business owners or top managers provided these data through in-person interviews. The enterprise survey provides a representative overview of a country's private non-agricultural sector, focusing on registered enterprises with at least five employees. It uses standardized tools to collect data on various aspects of the business environment, including access to finance, crime, infrastructure, corruption, labor conditions, growth constraints, market competition, and business performance indicators. Additionally, the Innovation Survey Follow-up gathers information on various types of innovation activities. We merged two datasets: the World Bank

Enterprise Survey (2014) and the World Bank Innovation Survey Follow-up (2014) for India, as the variables of interest were available in the questionnaires. We use cross-sectional data from approximately 3,487 enterprises in India, collected from both surveys. The WBES database has certain limitations, including potential response bias due to self-reported data, limited coverage in some regions, and difficulties in accurately capturing informal-sector activities and small enterprises. Despite these limitations, we have used WBES because it provides nationally representative, firm-level data with standardized measures of innovation, employment, and gender composition. Its rich cross-sectional coverage enables systematic analysis of technological and non-technological innovation and their association with gender-based employment diversity in Indian manufacturing firms.

3.2. Empirical Strategy

To assess the effects of technological and non-technological innovation on gender-based employment diversity, this study estimates two regression models. The first model assesses the impact of technological and non-technological innovations on overall employment, whereas the second model analyzes how these innovations influence gender-based employment diversity across permanent production and non-production job categories. Based on this, we estimate the following regression equation:

$$\ln \mathrm{TL}_{\mathrm{i}} = \alpha_0 + \alpha_1 \mathrm{INN}_{\mathrm{i}} + \beta_1 \mathrm{EPLF}_{\mathrm{i}} + \mathrm{EC}_{\mathrm{i}} + \varepsilon_{\mathrm{i}} \quad (1)$$

$$\mathrm{GBE}_{\mathrm{i}} = \alpha_0 + \alpha_1 \mathrm{INN}_{\mathrm{i}} + \beta_1 \mathrm{EPLF}_{\mathrm{i}} + \mathrm{EC}_{\mathrm{i}} + \varepsilon_{\mathrm{i}} \quad (2)$$

Here, the subscript *i* denotes the enterprise. The dependent variable *TL* and *GBE* captures employment outcomes (defined below). The key independent variables include *INN*, which reflects the types of innovation (defined below); *EC*, a vector of enterprise-level control variables; and ε, the conventional error term.

TL and GBE are our primary explained variables. TL demonstrates the overall employment, defined as the total number of laborers in the enterprise. On the other hand, GBE refers to gender-based employment, defined as the ratio of female to male employment. It also captures the extent of feminization or defeminization in the workforce and indicates the level of gender-based employment diversity. Gender-based employment diversity is captured in four different ways: (i) FMTW, (ii) FMPW, (iii) FMPPW, and (iv) FMPNW. Where FMTW defines the share of female workers to male workers at an aggregate level. FMPW refers to the share of female permanent workers to male permanent workers. FMPPW shows the proportion of

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female permanent production workers to male permanent production workers. FMPNW denotes the proportion of female permanent non-production workers to male permanent non-production workers.

Likewise, our primary explanatory variable is INN, representing innovation, which we use to test all the hypotheses. Innovation is classified into two categories: (i) technological innovation, and (ii) non-technological innovation. Technological innovation represents (a) product innovation (PDI) and (b) process innovation (PCI), while non-technological innovation demonstrates (a) organizational innovation (OI) and (b) marketing innovation (MI). Moreover, PDI represents product innovation, which is when an enterprise introduces new or improved products or services. PCI shows that process innovation occurs when an enterprise introduces a new or improved process. OI signifies organizational innovation by reducing the number of direct reporting layers from the Top Manager to the lowest-level employee. MI refers to marketing innovation, which occurs when an enterprise introduces new or significantly enhanced marketing methods.

In addition, extensive research literature suggests that employment is closely associated with specific enterprise characteristics. Therefore, this study incorporates various enterprise-specific indicators as control variables, including whether the enterprise is part of a larger firm (EPLF), the enterprise's age (Age), internationally recognized quality certification (IRQC), capacity utilization (CU), fixed asset purchases (FAP), Inadequately educated workforce (IEW), and the total labor-force (TL) (Çağatay & Berik, 1990; Blanchflower & Burgess, 1998; Ozler, 2000; Bloom & Van Reenen, 2002; Villarreal & Yu, 2007; Iwaro & Mwasha, 2012; Chen et al., 2013; Islam & Amin, 2015; Ali & Shabir, 2017; Islam et al., 2018; Avenyo et al., 2019; Gallego & Gutiérrez Ramírez, 2021; Amin & Islam, 2023; Amin & Khalid, 2023; Kamal, 2024). Moreover, Table 2 presents the summary statistics for the variables used in this study, providing a detailed overview of each variable, including its mean, standard deviation, minimum, and maximum values. The analysis is based on a sample comprising 3,487 manufacturing enterprises operating in India, offering a comprehensive representation across various enterprise sizes and sectors.

Furthermore, we employ Ordinary Least Squares (OLS) and the Instrumental Variable (IV)- based Two-Stage Least Squares (2SLS) methods to analyze it, and use the IV-based Generalized Method of Moments (GMM) for robustness. The IV-based 2SLS method is a powerful tool for addressing endogeneity and deriving causal estimates. However, this method depends mainly on the validity and quality of the instruments. Likewise, the IV-based GMM method is commonly used in economics to address endogeneity, omitted-variable bias, and

measurement error. It allows for efficient estimates, leveraging more instruments to improve precision (Wooldridge, 2010).

Table 2. Summary statistics.

Variable	Description	Obs	Mean	Std. Dev.	Min	Max
FMTW	Female/male total workers	2,501	0.26	1.21	0	34
FMPW	Female/male permanent workers	2,518	0.21	1.05	0	34
FMPPW	Female/male permanent production workers	2,490	0.09	0.47	0	15
FMPNW	Female/male permanent non-production workers	2,372	0.25	0.79	0	20
PDI	Establishment introduces new or improved products or services	2,499	0.62	0.49	0	1
PCI	Establishment introduces any new or improved process	2,501	0.71	0.45	0	1
OI	Reducing the number of direct reporting layers from the Top Manager to the lowest-level employee	1,787	0.36	0.48	0	1
MI	Establishment introduces new or significantly enhanced marketing methods	2,497	0.57	0.50	0	1
EPLF	Whether the enterprise is part of larger firms (1=yes; 0=otherwise)	2,501	0.23	0.42	0	1
Age	Age of the enterprise in years	2,501	20.98	14.73	1	151
IRQC	Internationally-recognized quality certification (1=yes; 0=otherwise)	2,501	0.57	0.50	0	1
CU	Proportion of the maximum achievable output by the enterprise	2,501	0.82	0.16	0.05	1
FAP	Purchasing any new or second-hand fixed assets (1=yes; 0=otherwise)	2,501	0.34	0.47	0	1
IEW	Inadequately educated workforce (1=yes; 0=otherwise)	2,476	0.62	0.49	0	1
TL	Total number of laborers in the enterprise	2,501	131.93	322.55	5	8000

Source: Authors' estimation

4. Results

4.1. Baseline regression

We represent our baseline results in Tables 3.1, 3.2, 3.3, and 3.4. We employ OLS and the IV-based 2SLS method to obtain more consistent and reliable results. A potential simultaneity issue arises, as the primary explanatory variables may be endogenously determined by gender-based employment diversity, suggesting a bidirectional causal relationship.

To address potential endogeneity in the product innovation variable, we use the "Market Success" (MS) variable as an instrumental variable. MS is defined as the share of an establishment's total sales derived from newly introduced products or services. This variable effectively captures the scope of product innovation. It shows a greater share of sales from newly introduced products, indicating both the enterprise's active participation in innovation and the market success and depth of those activities. Moreover, while product innovation may influence employment outcomes, the sales composition itself, that is, the proportion of revenue generated from innovative products (MS), is unlikely to directly affect employment, particularly when enterprise-specific controls are included. This supports the validity of the

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exclusion restriction, making MS a theoretically and empirically appropriate instrument for product innovation.

Furthermore, to address potential endogeneity bias in the process innovation variable, we use "Innovative Methods of Manufacturing" (IMM) as an instrumental variable. IMM is defined by whether the establishment introduced any innovative or significantly improved methods for manufacturing products or offering services. This variable corresponds well with the underlying construct of process innovation, as it reflects the enterprise's actual implementation of innovation in production or service processes. It serves as a valid determinant for process innovation, which is often operationalized through enhancements in production or offering service techniques. Additionally, the instrument is plausibly exogenous, as the adoption of such innovative methods is unlikely to directly influence employment outcomes, except through its effect on process innovation itself. Thus, the exclusion restriction underlying instrumental variable techniques is upheld.

To control for endogeneity in the organizational innovation variable, we use "Change in Hiring" (CH) as an instrumental variable. This instrumental variable indicates whether the establishment implemented changes in its hiring practices for non-managerial and non-supervisory employees. This instrument is conceptually valid, as adjustments in hiring approaches often reflect underlying organizational transformation, particularly in workplace systems and personnel management. This instrument is also plausibly exogenous, given that such changes are unlikely to have a direct impact on employment outcomes beyond their influence through organizational innovation. The omission of managerial and supervisory roles from this variable reinforces the validity of the exclusion restriction by limiting potential bias from direct employment decisions.

We use the "New Approach" (NA) as an instrumental variable to address potential endogeneity in the marketing innovation variable. This instrument variable captures whether the establishment allowed employees time to develop or experiment with new ideas related to products or services, business processes, enterprise management, or marketing. This variable also serves as a proxy for an innovation-supportive environment, which is a key enabler of marketing innovation. Enterprises encouraging employee experimentation are more likely to introduce novel strategies in areas such as advertising, brand positioning, and customer outreach. Therefore, the instrument aligns well with theoretical expectations, as it is expected to be strongly associated with the adoption of marketing innovation. Moreover, it is plausibly exogenous to employment outcomes, since the internal allocation of time for idea generation is not expected to directly influence employment. Its impact on employment is transmitted

exclusively through marketing innovation, which supports the exclusion restriction required for a valid instrumental variable. Consequently, this variable is both a theoretically justified and empirically appropriate instrument for estimating the causal effect of marketing innovation on employment.

To this end, Tables 3.1 and 3.3 present the results of our analysis on the impact of technological innovation on gender-based employment diversity in Indian manufacturing enterprises. Our findings indicate that technological innovation, particularly process innovation, increases overall employment (Blanchflower & Burgess, 1998; Lachenmaier & Rottmann, 2011). In contrast, process innovation is associated with declining female employment, particularly among permanent non-production workers. Moreover, at the aggregate level, product innovation is associated with increased female employment, notably for permanent production female workers (Ugur et al., 2017; Calvino & Virgillito, 2017). Product innovation is linked with promoting gender-based employment diversity through various mechanisms. First, introducing new products drives the demand for roles in design, quality control, and coordination domains in which female participation tends to be higher (Crespi et al., 2019; Dosi & YU, 2018). Second, product innovation generally requires support activities such as documentation, regulatory compliance, and customer service, which tend to employ more females (Harrison et al., 2014; de Elejalde et al., 2015). Third, enterprises involved in product innovation may implement inclusive recruitment strategies to align with diverse consumer preferences or comply with global standards (Van Roy et al., 2018; Cirera & Sabetti, 2019). These factors, combined, support the creation of secure job opportunities for women in production roles through product innovation.

In contrast, introducing process innovation generally entails implementing advanced technologies, automation, and optimized production methods to boost operational efficiency and reduce labor costs (Edquist et al., 2001; Harrison et al., 2014; Avenyo et al., 2019). This may decrease female employment, particularly among permanent non-production workers, through various mechanisms. First, process innovation often reduces the need for routine administrative and support functions, areas where female employment is generally concentrated (Mohnen & Hall, 2013; Calvino & Virgillito, 2017). Second, improvements in efficiency through process innovation often prompt enterprises to streamline operations, leading to reductions in middle-management and clerical roles (Edquist et al., 2001; Mairesse & Mohnen, 2010). Third, process innovation often increases the demand for higher technical skills, and women may be underrepresented due to systemic disparities in access to education and vocational training programs (Hervas-Oliver et al., 2017). These factors collectively reduce

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the creation of secure job opportunities for females in stable and non-production roles in the manufacturing sector through process innovation.

Likewise, Tables 3.2 and 3.4 represent the results of the impact of non-technological innovation on gender-based employment diversity in Indian manufacturing enterprises. Our analysis reveals that non-technological innovation, particularly marketing innovation, increases overall employment. Additionally, organizational innovation reduces female employment at the aggregate level. Moreover, marketing innovation is also associated with a decline in permanent non-production employment for females. Organizational innovation is associated with decreased female employment via several channels. First, the shift toward lean management and organizational restructuring mainly involves downsizing administrative and support functions, areas where females are largely concentrated (Evangelista & Vezzani, 2011; Gunday et al., 2011). Second, increased reliance on outsourcing and contract-based employment tends to displace permanent positions with temporary ones, adversely affecting women, who are more represented in such roles (Calvino & Virgillito, 2017). Third, focusing on technical and managerial skills in such innovations may disadvantage women, who have traditionally encountered systemic obstacles to acquiring these skills (Thornhill, 2006; Garcia & Calantone, 2002).

On the other hand, marketing innovation leads to a decline in permanent non-production female employment in the manufacturing sector through multiple channels. First, an increase in digital marketing and e-commerce use diminishes the need for conventional marketing posts, such as sales administration and customer service, which are generally staffed by females (Shergill & Nargundkar, 2005; Naidoo, 2010). Second, marketing functions are increasingly being outsourced or managed through contract-based employment structures, resulting in a reduction in permanent in-house positions within the organization (Calvino & Virgillito, 2017). Third, as enterprises increasingly rely on data analytics and digital strategies, the required skill sets may be less accessible to females, reflecting existing gender inequalities in technical education and skill development (O'Dwyer et al., 2009; Ren et al., 2009). These transformations lower the share of females in permanent non-production jobs and further exacerbate the overall decrease in female employment.

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Table 3.1. The impact of technological innovation on gender-based employment diversity in Indian Manufacturing Enterprises (with OLS method)

OLS	Product Innovation					Process Innovation				
	TL	FMTW	FMPW	FMPPW	FMPNW	TL	FMTW	FMPW	FMPPW	FMPNW
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
PDI	0.28*** (0.05)	0.10* (0.05)	0.13*** (0.04)	0.01 (0.02)	0.10*** (0.03)					
PCI						0.16*** (0.05)	-0.15*** (0.05)	-0.14*** (0.05)	-0.02 (0.02)	-0.22*** (0.04)
EPLF	0.70*** (0.05)	-0.02 (0.06)	-0.06 (0.05)	0.03 (0.02)	-0.09** (0.04)	0.70*** (0.05)	-0.01 (0.06)	-0.05 (0.05)	0.03 (0.02)	-0.07* (0.04)
ln Age	0.12*** (0.03)	0.09*** (0.03)	0.08*** (0.03)	0.03** (0.01)	0.02 (0.02)	0.13*** (0.03)	0.08** (0.03)	0.08*** (0.03)	0.02** (0.01)	0.01 (0.02)
IRQC	0.67*** (0.05)	-0.18*** (0.05)	-0.18*** (0.05)	-0.05** (0.02)	-0.004 (0.03)	0.69*** (0.05)	-0.18*** (0.05)	-0.17*** (0.05)	-0.05** (0.02)	0.01 (0.03)
CU	0.76*** (0.14)	-0.07 (0.15)	0.05 (0.13)	0.03 (0.06)	0.003 (0.10)	0.82*** (0.14)	-0.07 (0.15)	0.06 (0.13)	0.03 (0.06)	0.01 (0.10)
FAP	0.49*** (0.05)	0.003 (0.05)	-0.02 (0.05)	-0.01 (0.02)	0.11*** (0.04)	0.50*** (0.05)	0.02 (0.05)	-0.0003 (0.05)	-0.01 (0.02)	0.13*** (0.04)
IEW	-0.05 (0.05)	0.20*** (0.05)	0.14*** (0.04)	0.005 (0.02)	0.05 (0.03)	-0.03 (0.05)	0.21*** (0.05)	0.15*** (0.04)	0.01 (0.02)	0.06* (0.03)
ln TL		0.03 (0.02)	0.02 (0.02)	0.12*** (0.01)	0.05*** (0.01)		0.04* (0.02)	0.03* (0.02)	0.12*** (0.01)	0.06*** (0.01)
Constant	2.16*** (0.16)	-0.12 (0.18)	-0.19 (0.15)	-0.45*** (0.07)	-0.11 (0.12)	2.12*** (0.16)	0.01 (0.18)	-0.07 (0.16)	-0.44*** (0.07)	0.06 (0.12)
Observation	2,474	2,474	2,491	2,463	2,346	2,476	2,476	2,493	2,465	2,348
R^2	0.23	0.0144	0.0167	0.0984	0.0202	0.2212	0.0162	0.0169	0.0987	0.0319

Source: Authors' estimation
Notes: Standard errors are in parentheses. ***, **, * are significant at 1%, 5%, and 10% respectively.

Table 3.2. The impact of non-technological innovation on gender-based employment diversity in Indian Manufacturing Enterprises (with OLS method)

	Organizational Innovation					Marketing Innovation				
	TL	FMTW	FMPW	FMPPW	FMPNW	TL	FMTW	FMPW	FMPPW	FMPNW
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
OI	-0.05 (0.05)	-0.12** (0.06)	-0.05 (0.05)	0.001 (0.03)	-0.13*** (0.05)					
MI						0.15*** (0.05)	-0.01 (0.05)	-0.02 (0.04)	0.02 (0.02)	-0.06* (0.03)
EPLF	0.55*** (0.05)	-0.01 (0.07)	-0.05 (0.06)	0.03 (0.03)	-0.11** (0.05)	0.69*** (0.05)	-0.02 (0.06)	-0.06 (0.05)	0.03 (0.02)	-0.08* (0.04)
ln Age	0.16*** (0.03)	0.11** (0.04)	0.11*** (0.04)	0.02 (0.02)	0.03 (0.03)	0.12*** (0.03)	0.09*** (0.03)	0.08*** (0.03)	0.03** (0.01)	0.02 (0.02)
IRQC	0.39*** (0.05)	-0.17*** (0.06)	-0.18*** (0.05)	-0.04* (0.03)	0.01 (0.05)	0.69*** (0.05)	-0.18*** (0.05)	-0.17*** (0.05)	-0.05** (0.02)	0.001 (0.03)
CU	0.86*** (0.15)	0.02 (0.19)	0.17 (0.16)	0.02 (0.08)	0.14 (0.14)	0.78*** (0.14)	-0.05 (0.15)	0.08 (0.13)	0.03 (0.06)	0.03 (0.10)
FAP	0.41*** (0.05)	0.04 (0.06)	0.02 (0.05)	-0.01 (0.03)	0.15*** (0.05)	0.51*** (0.05)	0.01 (0.05)	-0.01 (0.05)	-0.01 (0.02)	0.12*** (0.04)
IEW	-0.04 (0.05)	0.22*** (0.06)	0.14*** (0.05)	0.01 (0.03)	0.09** (0.04)	-0.05 (0.05)	0.20*** (0.05)	0.16*** (0.04)	0.002 (0.02)	0.07** (0.03)
ln TL		0.01 (0.03)	0.0004 (0.03)	0.17*** (0.01)	0.01 (0.02)		0.04 (0.02)	0.03 (0.02)	0.12*** (0.01)	0.06*** (0.01)
Constant	2.76*** (0.17)	-0.10 (0.24)	-0.18 (0.20)	-0.69*** (0.10)	0.01 (0.17)	2.20*** (0.16)	-0.10 (0.18)	-0.17 (0.15)	-0.45*** (0.07)	-0.08 (0.12)
Observation	1,766	1,766	1,773	1,748	1,675	2,472	2,472	2,489	2,461	2,344
R^2	0.1664	0.0151	0.0146	0.1084	0.0167	0.2222	0.013	0.0133	0.0989	0.0176

Source: Authors' estimation
Notes: Standard errors are in parentheses. ***, **, * are significant at 1%, 5%, and 10% respectively.

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Table 3.3. The impact of technological innovation on gender-based employment diversity in Indian Manufacturing Enterprises (with IV-based 2SLS method)

2 SLS Estimation	Product Innovation					Process Innovation				
	TL	FMTW	FMPW	FMPPW	FMPNW	TL	FMTW	FMPW	FMPPW	FMPNW
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
PDI	-1.00 (1.14)	3.11** (1.58)	2.38* (1.33)	1.22* (0.66)	1.49 (1.21)					
PCI						0.23*** (0.06)	-0.15** (0.07)	-0.14** (0.06)	-0.01 (0.02)	-0.23*** (0.04)
EPLF	0.85*** (0.18)	-0.42* (0.25)	-0.29 (0.21)	-0.08 (0.10)	-0.14 (0.17)	0.69*** (0.05)	-0.01 (0.06)	-0.05 (0.05)	0.03 (0.02)	-0.07* (0.04)
ln Age	0.10 (0.08)	-0.01 (0.11)	0.02 (0.09)	-0.02 (0.05)	-0.02 (0.07)	0.13*** (0.03)	0.08** (0.03)	0.08*** (0.03)	0.02** (0.01)	0.01 (0.02)
IRQC	0.77*** (0.12)	0.07 (0.19)	-0.03 (0.16)	0.06 (0.08)	0.10 (0.13)	0.68*** (0.05)	-0.18*** (0.05)	-0.17*** (0.05)	-0.05** (0.02)	0.01 (0.03)
CU	0.95** (0.38)	-0.20 (0.52)	-0.12 (0.44)	-0.07 (0.21)	-0.44 (0.33)	0.81*** (0.14)	-0.07 (0.15)	0.06 (0.13)	0.03 (0.06)	0.01 (0.10)
FAP	0.48*** (0.12)	-0.16 (0.16)	-0.10 (0.14)	-0.01 (0.07)	-0.12 (0.10)	0.49*** (0.05)	0.02 (0.05)	-0.001 (0.05)	-0.01 (0.02)	0.14*** (0.04)
IEW	0.03 (0.14)	-0.01 (0.20)	-0.05 (0.17)	-0.05 (0.09)	-0.07 (0.14)	-0.03 (0.05)	0.21*** (0.05)	0.15*** (0.04)	0.01 (0.02)	0.06* (0.03)
ln TL		-0.03 (0.07)	-0.02 (0.06)	0.10*** (0.03)	-0.02 (0.05)		0.04* (0.02)	0.03* (0.02)	0.12*** (0.01)	0.06*** (0.01)
Constant	3.03*** (0.60)	-1.58** (0.79)	-1.28* (0.68)	-1.10*** (0.33)	-0.23 (0.54)	2.07*** (0.16)	0.003 (0.18)	-0.07 (0.16)	-0.44*** (0.07)	0.06 (0.12)
Observation	615	615	615	612	582	2475	2,475	2,492	2,464	2,347
R^2	0.1142	-	-	-	-	0.2211	0.0162	0.0169	0.0985	0.0319

Source: Authors' estimation
Notes: Standard errors are in parentheses. ***, **, * are significant at 1%, 5%, and 10% respectively.

Table 3.4. The impact of non-technological innovation on gender-based employment diversity in Indian Manufacturing Enterprises (with IV-based 2SLS method)

2 SLS Estimation	Organizational Innovation					Marketing Innovation				
	TL	FMTW	FMPW	FMPPW	FMPNW	TL	FMTW	FMPW	FMPPW	FMPNW
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
OI	-0.22 (0.34)	-0.75* (0.45)	-0.46 (0.38)	-0.10 (0.18)	0.03 (0.31)					
MI						0.58*** (0.09)	0.12 (0.09)	0.11 (0.08)	-0.01 (0.03)	- 0.17*** (0.06)
EPLF	0.56*** (0.05)	0.01 (0.07)	-0.03 (0.06)	0.04 (0.03)	-0.12** (0.05)	0.61*** (0.06)	-0.04 (0.06)	-0.08 (0.05)	0.03 (0.02)	-0.06 (0.04)
ln Age	0.16*** (0.04)	0.07 (0.06)	0.08* (0.05)	0.02 (0.02)	0.04 (0.04)	0.12*** (0.03)	0.09*** (0.03)	0.08*** (0.03)	0.03** (0.01)	0.02 (0.02)
IRQC	0.39*** (0.05)	-0.17** (0.07)	-0.18*** (0.05)	-0.05* (0.03)	0.02 (0.05)	0.69*** (0.05)	-0.18*** (0.05)	-0.17*** (0.05)	-0.05*** (0.02)	-0.0002 (0.03)
CU	0.83*** (0.15)	0.03 (0.20)	0.17 (0.16)	0.02 (0.08)	0.12 (0.14)	0.72*** (0.14)	-0.07 (0.15)	0.06 (0.13)	0.03 (0.06)	0.05 (0.10)
FAP	0.40*** (0.05)	0.04 (0.07)	0.02 (0.05)	-0.01 (0.03)	0.15*** (0.05)	0.50*** (0.05)	0.01 (0.05)	-0.01 (0.05)	-0.01 (0.02)	0.12*** (0.04)
IEW	-0.03 (0.05)	0.27*** (0.07)	0.18*** (0.06)	0.02 (0.03)	0.08 (0.05)	-0.12** (0.05)	0.18*** (0.05)	0.13*** (0.05)	0.01 (0.02)	0.09** (0.04)
ln TL		-0.0004 (0.03)	-0.01 (0.03)	0.17*** (0.01)	0.01 (0.02)		0.03 (0.02)	0.03 (0.02)	0.12*** (0.01)	0.06*** (0.01)
Constant	2.86*** (0.25)	0.27 (0.35)	0.06 (0.29)	-0.64*** (0.14)	-0.07 (0.24)	2.08*** (0.16)	-0.13 (0.18)	-0.20 (0.16)	-0.45*** (0.07)	-0.07 (0.12)
Observation	1754	1,754	1,761	1,736	1,663	2466	2,466	2,483	2,455	2,342
R^2	0.1617	-	-	0.1003	0.0096	0.1946	0.0104	0.0097	0.0981	0.0129

Source: Authors' estimation
Notes: Standard errors are in parentheses. ***, **, * are significant at 1%, 5%, and 10% respectively.

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4.2. Heterogeneity concern

The issue of heterogeneity may arise from differences in enterprise size. We identify enterprise-size heterogeneity by segregating the full sample into enterprise-size subsamples and re-estimating the results. We report the estimated results on the impact of technological and non-technological innovation on gender-based employment diversity for different enterprise sizes in Tables 4.1, 4.2, 4.3, and 4.4, respectively. We employ the World Bank Enterprise Survey (WBES) classification of enterprise sizes: Micro (<5 laborers), Small (>=5 and <=19 laborers), Medium (>=20 and <=99 laborers), and Large (>=100 laborers). Additionally, we excluded micro-sized enterprises from the analysis due to the absence of available observations following the merger of the Innovation Follow-up Survey with the World Bank Enterprise Survey (WBES) database.

These findings can be explained by differences in the nature and skill demands of innovations. In small enterprises, product innovation often expands output and market reach, generating additional labor demand and creating opportunities for permanent female employment, particularly through compensation effects. In contrast, process innovation typically emphasizes cost reduction and efficiency, often through mechanization or task reorganization, which may substitute routine or support functions where women are relatively more concentrated, especially in non-production roles, through displacement effects. Organizational and marketing innovations, meanwhile, tend to reallocate tasks rather than substantially expand or contract employment, resulting in no significant gender-differentiated employment effects.

In medium-sized enterprises, product innovation typically expands output, diversifies product lines, and opens new markets, thereby increasing overall labor demand and benefiting female workers in both production and non-production roles through compensation effects. In contrast, process innovation prioritizes efficiency and automation, which can disproportionately displace female workers if they are concentrated in routine or less technology-intensive tasks. Furthermore, organizational innovation often involves restructuring, multitasking, or managerial consolidation, which may reduce employment opportunities for women due to gendered role segmentation and weaker job security. However, marketing innovation emphasizes market expansion, branding, and customer engagement, creating demand for labor-intensive production adjustments and coordination activities that can increase permanent female employment, particularly in production roles.

In large enterprises, product innovation is often incremental and capital-intensive, relying more on technology and on existing male-dominated skilled workforces, thereby

generating limited additional demand for female labor. On the other hand, process, organizational, and marketing innovations typically emphasize efficiency, automation, and managerial rationalization, which can disproportionately displace permanent female workers who are more concentrated in routine, administrative, and support (non-production) roles. Moreover, large enterprises possess greater capacity to internalize adjustments through labor-saving technologies and restructuring, intensifying displacement effects for women relative to men, particularly in non-production employment categories.

Table 4.1. Robust results of the impact of product innovation on gender-based employment diversity in Indian Manufacturing Enterprises at different enterprise sizes (with OLS method)

OLS	FMTW			FMPW			FMPPW			FMPNW		
	Small (1)	Medium (2)	Large (3)	Small (4)	Medium (5)	Large (6)	Small (7)	Medium (8)	Large (9)	Small (10)	Medium (11)	Large (12)
PDI	0.12 (0.08)	0.14* (0.08)	-0.06 (0.11)	0.15* (0.08)	0.13* (0.08)	0.07 (0.06)	0.002 (0.004)	0.01** (0.005)	0.01 (0.07)	0.09** (0.04)	0.10** (0.05)	0.13 (0.09)
EPLF	-0.12 (0.12)	-0.14 (0.10)	0.15 (0.10)	-0.12 (0.12)	-0.14 (0.09)	0.03 (0.06)	0.02*** (0.01)	-0.02*** (0.01)	0.08 (0.07)	-0.04 (0.06)	-0.06 (0.06)	-0.11 (0.08)
ln Age	0.01 (0.05)	0.14** (0.05)	0.10 (0.07)	0.02 (0.05)	0.13** (0.05)	0.07* (0.04)	-0.0003 (0.002)	-0.001 (0.003)	0.06 (0.04)	0.01 (0.02)	-0.01 (0.03)	0.08 (0.05)
IRQC	-0.20** (0.09)	-0.26*** (0.08)	-0.09 (0.12)	-0.18** (0.08)	-0.24*** (0.07)	-0.11 (0.07)	-0.01** (0.004)	-0.02*** (0.005)	-0.07 (0.08)	-0.09** (0.04)	-0.003 (0.05)	0.04 (0.10)
CU	-0.23 (0.23)	0.18 (0.24)	-0.39 (0.35)	-0.10 (0.22)	0.12 (0.23)	0.18 (0.20)	-0.001 (0.01)	-0.002 (0.01)	0.10 (0.22)	-0.07 (0.10)	-0.01 (0.14)	0.12 (0.28)
FAP	-0.12 (0.10)	0.002 (0.08)	0.08 (0.10)	-0.11 (0.09)	0.004 (0.08)	0.02 (0.06)	-0.001 (0.004)	0.004 (0.01)	-0.03 (0.07)	-0.003 (0.04)	0.08 (0.05)	0.26*** (0.08)
IEW	0.15* (0.08)	0.26*** (0.08)	0.16 (0.10)	0.14* (0.08)	0.20*** (0.08)	0.06 (0.06)	0.003 (0.004)	0.01** (0.005)	0.07 (0.07)	-0.04 (0.04)	0.02 (0.05)	0.17** (0.08)
ln TL	0.07 (0.07)	0.01 (0.06)	-0.003 (0.06)	0.08 (0.06)	-0.01 (0.06)	-0.01 (0.04)	0.03*** (0.003)	0.05*** (0.004)	0.37*** (0.04)	0.14*** (0.03)	0.07* (0.04)	-0.02 (0.05)
Constant	0.13 (0.31)	-0.36 (0.35)	0.24 (0.49)	-0.09 (0.30)	-0.23 (0.33)	-0.12 (0.28)	-0.07*** (0.01)	-0.15*** (0.02)	-2.02*** (0.32)	-0.20 (0.14)	-0.02 (0.21)	-0.23 (0.40)
Observation	648	1,150	676	654	1,157	680	653	1,147	663	608	1,091	647
R^2	0.0233	0.0258	0.0123	0.0227	0.0221	0.0125	0.2	0.1443	0.1265	0.053	0.0117	0.0288

Source: Authors' estimation
Notes: Standard errors are in parentheses. ***, **, * are significant at 1%, 5%, and 10% respectively.

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Table 4.2. Robust results of the impact of process innovation on gender-based employment diversity in Indian Manufacturing Enterprises at different enterprise sizes (with OLS method)

OLS	FMTW			FMPW			FMPPW			FMPNW		
	Small (1)	Medium (2)	Large (3)	Small (4)	Medium (5)	Large (6)	Small (7)	Medium (8)	Large (9)	Small (10)	Medium (11)	Large (12)
PCI	-0.02 (0.08)	-0.23*** (0.08)	-0.15 (0.12)	-0.04 (0.08)	-0.20** (0.08)	-0.19*** (0.07)	-0.003 (0.004)	-0.01** (0.01)	-0.06 (0.08)	-0.07* (0.04)	-0.17*** (0.05)	-0.51*** (0.10)
EPLF	-0.12 (0.13)	-0.12 (0.10)	0.16 (0.10)	-0.12 (0.12)	-0.13 (0.09)	0.05 (0.06)	0.02*** (0.01)	-0.02** (0.01)	0.09 (0.07)	-0.04 (0.06)	-0.05 (0.06)	-0.07 (0.08)
ln Age	0.02 (0.05)	0.13** (0.05)	0.09 (0.07)	0.03 (0.05)	0.12** (0.05)	0.06 (0.04)	-0.0003 (0.002)	-0.001 (0.003)	0.05 (0.04)	0.01 (0.02)	-0.02 (0.03)	0.06 (0.05)
IRQC	-0.19** (0.09)	-0.26*** (0.08)	-0.09 (0.12)	-0.16** (0.08)	-0.24*** (0.07)	-0.11 (0.07)	-0.01** (0.004)	-0.02*** (0.005)	-0.07 (0.08)	-0.08* (0.04)	-0.003 (0.05)	0.05 (0.09)
CU	-0.24 (0.23)	0.21 (0.23)	-0.39 (0.34)	-0.11 (0.22)	0.14 (0.22)	0.21 (0.20)	-0.002 (0.01)	-0.0003 (0.01)	0.11 (0.22)	-0.09 (0.10)	0.003 (0.14)	0.21 (0.28)
FAP	-0.11 (0.10)	0.03 (0.08)	0.09 (0.10)	-0.09 (0.09)	0.02 (0.08)	0.03 (0.06)	-0.0003 (0.004)	0.005 (0.01)	-0.03 (0.07)	0.01 (0.04)	0.10* (0.05)	0.28*** (0.08)
IEW	0.16* (0.08)	0.28*** (0.08)	0.15 (0.10)	0.15* (0.08)	0.22*** (0.08)	0.06 (0.06)	0.003 (0.004)	0.01*** (0.005)	0.07 (0.07)	-0.04 (0.04)	0.04 (0.05)	0.18 (0.08)
ln TL	0.07 (0.07)	0.01 (0.06)	0.001 (0.06)	0.08 (0.06)	-0.02 (0.06)	-0.002 (0.04)	0.03*** (0.003)	0.05*** (0.004)	0.37*** (0.04)	0.14*** (0.03)	0.07* (0.04)	0.003 (0.05)
Constant	0.19 (0.31)	-0.09 (0.35)	0.32 (0.50)	-0.01 (0.30)	-0.002 (0.34)	0.003 (0.28)	-0.07*** (0.01)	-0.13*** (0.02)	-1.98*** (0.32)	-0.12 (0.14)	0.16 (0.22)	0.10 (0.39)
Observation	649	1,151	676	655	1,158	680	654	1,148	663	609	1,092	647
R^2	0.0201	0.0297	0.0143	0.0174	0.0246	0.0213	0.2004	0.1455	0.1274	0.0488	0.0174	0.0658

Source: Authors' estimation

Notes: Standard errors are in parentheses. ***, **, * are significant at 1%, 5%, and 10% respectively.

Table 4.3. Robust results of the impact of organizational innovation on gender-based employment diversity in Indian Manufacturing Enterprises at different enterprise sizes (with OLS method)

OLS	FMTW			FMPW			FMPPW			FMPNW		
	Small (1)	Medium (2)	Large (3)	Small (4)	Medium (5)	Large (6)	Small (7)	Medium (8)	Large (9)	Small (10)	Medium (11)	Large (12)
OI	-0.12 (0.07)	-0.16** (0.08)	-0.05 (0.11)	-0.06 (0.05)	-0.09 (0.08)	0.03 (0.06)	-0.06 (0.05)	-0.01 (0.005)	0.03 (0.07)	-0.23 (0.35)	-0.07 (0.05)	-0.23*** (0.09)
EPLF	-0.14 (0.11)	-0.18* (0.10)	0.16 (0.10)	-0.13 (0.08)	-0.15 (0.10)	0.04 (0.06)	-0.01 (0.07)	-0.02*** (0.01)	0.10 (0.07)	-0.27 (0.49)	-0.10 (0.06)	-0.10 (0.09)
ln Age	0.03 (0.05)	0.14** (0.06)	0.09 (0.07)	0.05 (0.04)	0.14** (0.06)	0.08* (0.04)	0.04 (0.03)	-0.002 (0.004)	0.04 (0.05)	0.48** (0.21)	-0.01 (0.04)	0.06 (0.06)
IRQC	-0.05 (0.07)	-0.23*** (0.08)	-0.10 (0.13)	-0.05 (0.06)	-0.21*** (0.07)	-0.11 (0.07)	0.01 (0.05)	-0.02*** (0.005)	-0.06 (0.08)	-0.51 (0.35)	0.01 (0.05)	0.04 (0.10)
CU	-0.16 (0.18)	0.24 (0.23)	-0.42 (0.36)	-0.06 (0.14)	0.17 (0.22)	0.22 (0.21)	-0.08 (0.12)	-0.001 (0.01)	0.12 (0.23)	-0.49 (0.80)	0.06 (0.15)	0.24 (0.29)
FAP	0.02 (0.08)	0.003 (0.08)	0.08 (0.11)	-0.01 (0.06)	0.02 (0.08)	0.02 (0.06)	-0.01 (0.05)	0.004 (0.01)	-0.03 (0.07)	-0.26 (0.43)	0.08 (0.05)	0.27*** (0.09)
IEW	0.08 (0.08)	0.26*** (0.08)	0.17 (0.11)	0.05 (0.06)	0.20*** (0.08)	0.07 (0.06)	0.06 (0.05)	0.01** (0.005)	0.07 (0.07)	-0.27 (0.35)	0.02 (0.05)	0.23** (0.09)
ln TL	0.06 (0.04)	0.05 (0.07)	-0.004 (0.07)	0.07** (0.03)	0.01 (0.06)	-0.01 (0.04)	0.08*** (0.03)	0.05*** (0.004)	0.39*** (0.04)	0.30* (0.17)	0.06 (0.04)	-0.03 (0.05)
Constant	0.01 (0.25)	-0.42 (0.35)	0.25 (0.53)	-0.20 (0.19)	-0.28 (0.34)	-0.12 (0.30)	-0.29* (0.16)	-0.15*** (0.02)	-2.14*** (0.34)	-1.08 (1.11)	0.04 (0.23)	-0.07 (0.42)
Observation	37	1,080	649	36	1,087	650	36	1,078	634	31	1,026	618
R^2	0.2468	0.0273	0.0125	0.3154	0.02	0.0115	0.4313	0.1439	0.1294	0.3897	0.0099	0.0373

Source: Authors' estimation

Notes: Standard errors are in parentheses. ***, **, * are significant at 1%, 5%, and 10% respectively.

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Table 4.4. Robust results of the impact of marketing innovation on gender-based employment diversity in Indian Manufacturing Enterprises at different enterprise sizes (with OLS method)

OLS	FMTW			FMPW			FMPPW			FMPNW		
	Small (1)	Medium (2)	Large (3)	Small (4)	Medium (5)	Large (6)	Small (7)	Medium (8)	Large (9)	Small (10)	Medium (11)	Large (12)
MI	-0.01 (0.08)	-0.03 (0.08)	0.03 (0.11)	0.02 (0.08)	-0.07 (0.07)	-0.01 (0.06)	0.001 (0.004)	0.01* (0.005)	0.07 (0.07)	0.05 (0.04)	-0.04 (0.05)	-0.19** (0.09)
EPLF	-0.12 (0.13)	-0.14 (0.10)	0.14 (0.10)	-0.13 (0.12)	-0.14 (0.10)	0.04 (0.06)	0.02*** (0.01)	-0.02*** (0.01)	0.07 (0.07)	-0.05 (0.06)	-0.06 (0.06)	-0.07 (0.08)
ln Age	0.02 (0.05)	0.14** (0.06)	0.10 (0.07)	0.03 (0.05)	0.13** (0.05)	0.07* (0.04)	-0.0003 (0.002)	-0.001 (0.003)	0.06 (0.04)	0.02 (0.02)	-0.01 (0.03)	0.09 (0.05)
IRQC	-0.19** (0.09)	-0.26*** (0.08)	-0.09 (0.12)	-0.17** (0.08)	-0.24*** (0.07)	-0.11 (0.07)	-0.01** (0.004)	-0.02*** (0.005)	-0.07 (0.08)	-0.08** (0.04)	-0.004 (0.05)	0.05 (0.10)
CU	-0.24 (0.23)	0.24 (0.24)	-0.41 (0.34)	-0.11 (0.22)	0.18 (0.23)	0.21 (0.20)	-0.001 (0.01)	-0.0004 (0.01)	0.09 (0.22)	-0.08 (0.10)	0.03 (0.14)	0.20 (0.28)
FAP	-0.11 (0.10)	0.01 (0.08)	0.09 (0.10)	-0.10 (0.09)	0.01 (0.08)	0.02 (0.06)	-0.001 (0.004)	0.004 (0.01)	-0.02 (0.07)	-0.001 (0.04)	0.08 (0.05)	0.25*** (0.08)
IEW	0.16* (0.09)	0.28*** (0.08)	0.15 (0.10)	0.14* (0.08)	0.22*** (0.08)	0.07 (0.06)	0.002 (0.004)	0.01** (0.005)	0.06 (0.07)	-0.05 (0.04)	0.04 (0.05)	0.20** (0.08)
ln TL	0.07 (0.07)	0.02 (0.06)	-0.005 (0.06)	0.08 (0.06)	-0.01 (0.06)	-0.01 (0.04)	0.03*** (0.003)	0.05*** (0.004)	0.37*** (0.04)	0.14*** (0.03)	0.07* (0.04)	-0.01 (0.05)
Constant	0.18 (0.31)	-0.32 (0.35)	0.21 (0.50)	-0.03 (0.30)	-0.18 (0.33)	-0.11 (0.28)	-0.07*** (0.01)	-0.15*** (0.02)	-2.05*** (0.32)	-0.17 (0.14)	0.01 (0.21)	-0.18 (0.40)
Observation	649	1,148	675	655	1,155	679	654	1,145	662	609	1,089	646
R^2	0.0201	0.0232	0.012	0.0172	0.0201	0.0108	0.1995	0.145	0.1279	0.0457	0.0081	0.0339

Source: Authors' estimation

Notes: Standard errors are in parentheses. ***, **, * are significant at 1%, 5%, and 10% respectively.

4.3. Robustness tests

We perform a robustness check to ensure the consistency and reliability of our empirical findings. The primary explanatory variables may exhibit a bidirectional causal relationship with gender-based employment diversity, thereby posing a potential simultaneity issue. To address this endogeneity problem, we used the same variables as an instrument and employed an alternative IV-based Generalised Method of Moments (GMM) for robustness.

These instrument variables strongly correlate with the endogenous variable, meeting the instrument validity criterion of relevance. We use cross-sectional data for analysis. Therefore, the possibility of endogeneity concerns from these instruments is limited. The results are presented in Tables 5.1 and 5.2. The IV-based GMM estimates are largely consistent with the baseline results, suggesting that our empirical analysis has not suffered from endogeneity problems, as shown in Figure 1. Figure 1 illustrates the pathways through which technological and non-technological innovations influence gender-based employment diversity within enterprises.

Our robust analysis reveals that technological innovation, particularly process innovation, increases overall employment. It is consistent with the compensation mechanism whereby efficiency gains lead to output expansion and subsequent employment creation. At the

aggregate level, product innovation positively affects female employment, especially among permanent production workers, compared with male workers, suggesting potential demand-driven employment gains. However, process innovation appears to have a displacement effect on female labor, particularly among permanent non-production workers, likely due to automation or task reorganization that disproportionately affects these roles.

In addition, non-technological innovation, especially marketing innovation, contributes positively to total employment (through the compensation mechanism), possibly by expanding markets and increasing product demand. In contrast, organizational innovation decreases aggregate female employment, implying a displacement effect potentially driven by structural changes that may reduce the need for female labor. Furthermore, marketing innovation is also associated with reduced employment among permanent non-production female workers, indicating that its positive impact on aggregate employment may not be uniformly distributed across all worker categories.

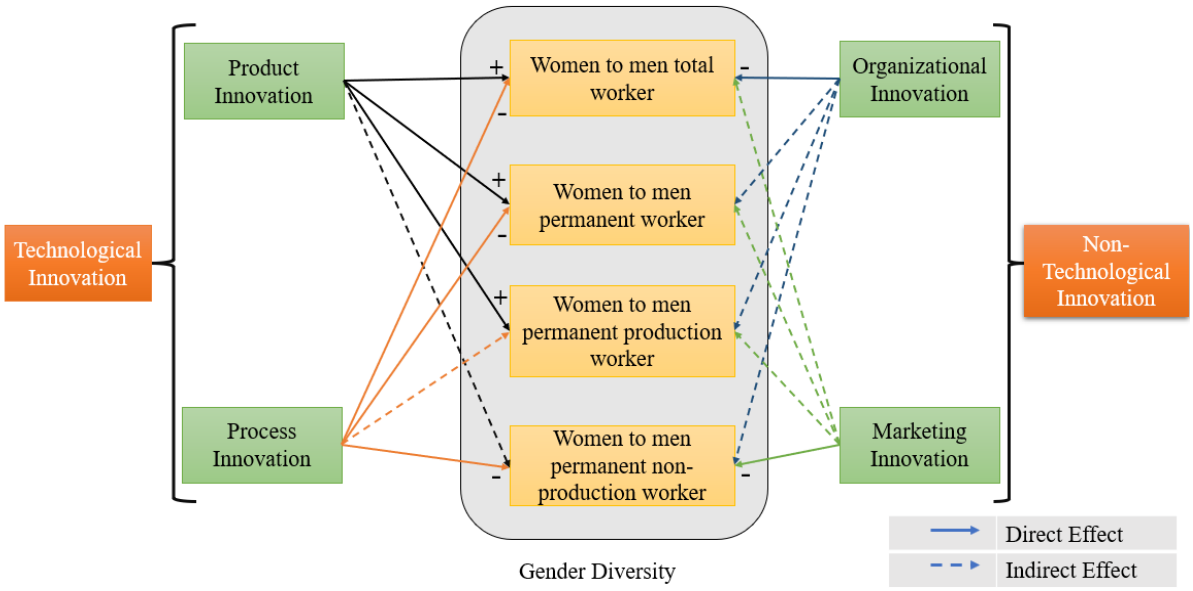


Figure 1: Impact of Technological and Non-Technological Innovation on Gender Diversity in Indian Manufacturing Firms

Table 5.1. The impact of technological innovation on gender-based employment diversity in Indian Manufacturing Enterprises (with IV-based two-satge GMM method)

GMM Estimation	Product Innovation					Process Innovation				
	TL	FMTW	FMPW	FMPPW	FMPNW	TL	FMTW	FMPW	FMPPW	FMPNW
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
PDI	-1.00 (1.19)	3.11** (1.52)	2.38* (1.26)	1.22* (0.65)	1.49 (1.35)					
PCI						0.23*** (0.06)	-0.15** (0.07)	-0.14** (0.06)	-0.01 (0.02)	-0.23*** (0.05)
EPLF	0.85*** (0.19)	-0.42* (0.25)	-0.29 (0.22)	-0.08 (0.09)	-0.14 (0.17)	0.69*** (0.06)	-0.01 (0.06)	-0.05 (0.03)	0.03 (0.02)	-0.07** (0.03)
ln Age	0.10 (0.08)	-0.01 (0.10)	0.02 (0.08)	-0.02 (0.04)	-0.02 (0.07)	0.13*** (0.03)	0.08** (0.04)	0.08** (0.04)	0.02* (0.01)	0.01 (0.02)
IRQC	0.77*** (0.12)	0.07 (0.18)	-0.03 (0.14)	0.06 (0.07)	0.10 (0.13)	0.68*** (0.05)	-0.18*** (0.05)	-0.17*** (0.05)	-0.05*** (0.02)	0.01 (0.03)
CU	0.95** (0.39)	-0.20 (0.48)	-0.12 (0.38)	-0.07 (0.20)	-0.44 (0.35)	0.81*** (0.13)	-0.07 (0.15)	0.06 (0.06)	0.03 (0.04)	0.01 (0.09)
FAP	0.48*** (0.12)	-0.16 (0.15)	-0.10 (0.13)	-0.01 (0.06)	-0.12 (0.10)	0.49*** (0.05)	0.02 (0.04)	-0.001 (0.03)	-0.01 (0.03)	0.14*** (0.04)
IEW	0.03 (0.15)	-0.01 (0.21)	-0.05 (0.19)	-0.05 (0.08)	-0.07 (0.14)	-0.03 (0.05)	0.21*** (0.05)	0.15*** (0.04)	0.01 (0.02)	0.06* (0.03)
ln TL		-0.03 (0.06)	-0.02 (0.05)	0.10*** (0.03)	-0.02 (0.04)		0.04*** (0.01)	0.03** (0.01)	0.12*** (0.02)	0.06*** (0.01)
Constant	3.03*** (0.61)	-1.58* (0.85)	-1.28* (0.74)	-1.10** (0.44)	-0.23 (0.66)	2.07*** (0.16)	0.003 (0.13)	-0.07 (0.11)	-0.44*** (0.12)	0.06 (0.11)
Observation	615	615	615	612	582	2,475	2,475	2,492	2,464	2,347
R^2	0.1142	-	-	-	-	0.2211	0.0162	0.0169	0.0985	0.0319

Source: Authors' estimation
Notes: Standard errors are in parentheses. ***, **, * are significant at 1%, 5%, and 10% respectively.

Table 5.2. The impact of non-technological innovation on gender-based employment diversity in Indian Manufacturing Enterprises (with IV-based two-stage GMM method)

GMM Estimation	Organizational Innovation					Marketing Innovation				
	TL	FMTW	FMPW	FMPPW	FMPNW	TL	FMTW	FMPW	FMPPW	FMPNW
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
OI	-0.22 (0.35)	-0.75* (0.45)	-0.46 (0.35)	-0.10 (0.17)	0.03 (0.35)					
MI						0.58*** (0.08)	0.12 (0.08)	0.11 (0.07)	-0.01 (0.02)	-0.17** (0.08)
EPLF	0.56*** (0.06)	0.01 (0.07)	-0.03 (0.04)	0.04 (0.03)	-0.12** (0.05)	0.61*** (0.06)	-0.04 (0.06)	-0.08** (0.04)	0.03 (0.03)	-0.06* (0.03)
ln Age	0.16*** (0.04)	0.07 (0.06)	0.08 (0.05)	0.02 (0.02)	0.04 (0.03)	0.12*** (0.03)	0.09** (0.04)	0.08** (0.04)	0.03** (0.01)	0.02 (0.02)
IRQC	0.39*** (0.05)	-0.17** (0.07)	-0.18** (0.07)	-0.05** (0.02)	0.02 (0.04)	0.69*** (0.05)	-0.18*** (0.05)	-0.17*** (0.05)	-0.05*** (0.02)	-0.0002 (0.03)
CU	0.83*** (0.13)	0.03 (0.23)	0.17** (0.09)	0.02 (0.05)	0.12 (0.12)	0.72*** (0.13)	-0.07 (0.15)	0.06 (0.06)	0.03 (0.03)	0.05 (0.09)
FAP	0.40*** (0.05)	0.04 (0.05)	0.02 (0.04)	-0.01 (0.04)	0.15*** (0.05)	0.50*** (0.05)	0.01 (0.04)	-0.01 (0.03)	-0.01 (0.03)	0.12*** (0.04)
IEW	-0.03 (0.05)	0.27*** (0.09)	0.18** (0.08)	0.02 (0.03)	0.08* (0.04)	-0.12** (0.05)	0.18*** (0.04)	0.13*** (0.04)	0.01 (0.02)	0.09** (0.04)
ln TL		-0.0004 (0.03)	-0.01 (0.02)	0.17*** (0.04)	0.01 (0.02)		0.03** (0.01)	0.03** (0.01)	0.12*** (0.02)	0.06*** (0.01)
Constant	2.86*** (0.24)	0.27 (0.32)	0.06 (0.23)	-0.64*** (0.19)	-0.07 (0.29)	2.08*** (0.15)	-0.13 (0.17)	-0.20 (0.15)	-0.45*** (0.12)	-0.07 (0.11)
Observation	1,754	1,754	1,761	1,736	1,663	2,466	2,466	2,483	2,455	2,342
R^2	0.1617	-	-	0.1003	0.0096	0.1946	0.0104	0.0097	0.0981	0.0129

Source: Authors' estimation
Notes: Standard errors are in parentheses. ***, **, * are significant at 1%, 5%, and 10% respectively.

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5. Conclusion

Innovations are crucial in influencing employment patterns and driving overall economic development. Although existing theoretical frameworks offer some insight into the relationship between innovation and gender-based employment diversity, they often lack a holistic perspective and fail to capture the full complexity of this linkage. Most theories tend to focus either on the economic outcomes of innovation or on the structural factors driving gender inequality, without effectively integrating both dimensions. As a result, they provide only a partial understanding and often neglect key mechanisms, such as compensation and displacement effects, that may shape gender-based employment outcomes. In light of this theoretical limitation, the present study takes a primarily empirical approach to explore and better understand how technological and non-technological innovation influences gender-based employment diversity. To examine the effects of technological and non-technological innovation on gender-based employment diversity in India's manufacturing enterprises through compensation and displacement mechanisms, we use enterprise-level data from the World Bank Enterprise Survey and the World Bank Innovation Survey Follow-up for Indian manufacturing enterprises (2014). Our comprehensive analysis indicates that both technological innovations, particularly process innovation, and non-technological innovations, especially marketing innovation, foster overall employment growth through compensation effects. Furthermore, technological innovation, notably product innovation, enhances gender diversity in employment by increasing female participation, particularly in production-oriented occupations. These patterns are largely consistent across enterprises of different sizes, with only marginal variations.

Additionally, despite their potential to significantly enhance business performance and support innovation capabilities, these non-technological forms of innovation have often been overlooked. Consequently, it is important to emphasize the recognition, understanding, and promotion of organizational and marketing innovations as vital elements of an enterprise's comprehensive innovation strategy. Furthermore, these findings suggest that female employment is more positively influenced by product innovation than male employment. Therefore, policymakers should focus on product innovation to increase female employment opportunities and promote gender diversity in employment. Policymakers should also prioritize implementing comprehensive vocational training programs to enhance the skills of female workers, particularly in sectors undergoing technological and non-technological innovations. By equipping women with relevant and up-to-date skills, such programs can improve their employability and readiness to participate in innovation-driven workplaces. This targeted

upskilling may lead to greater inclusion of female workers during the adoption of process innovations and non-technological changes, such as organizational or marketing innovations, where adaptability and specific competencies are crucial. Consequently, increasing women's access to such opportunities can help to promote gender diversity in employment and foster a more inclusive labor market. It also contributes to the attainment of the Sustainable Development Goals (SDGs), particularly SDG 5 (Gender Equality) and SDG 10 (Reduced Inequalities), by supporting inclusive growth, strengthening women's participation in the labour market, promoting gender-balanced employment, and informing the design of innovative policies aimed at equitable and inclusive employment outcomes.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have influenced the work reported in this paper.

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