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Impact of Women Entrepreneurship on Green Innovation; Evidence from Asian Region

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Abstract

Female entrepreneurship is vital for economic diversification, it fosters a sustainable economy and promotes green innovation. This study empirically investigates the link between WENP and GIN regionally by employing panel data of 23 Asian economies from 2008 to 2022 from different sources such as WDI, OECD, and WGI. A system-generalized method of moments (Sys-GMM) has been applied and the findings revealed that green innovation is related to women entrepreneurship. Furthermore, GIN is positively correlated with women entrepreneurship, while male entrepreneurship negatively impacts GIN. In addition, the role of education in promoting women entrepreneurship and green innovation (GIN) is significant, suggested that women with more education are likely to use more eco-friendly technologies at a regional level

Keywords: Women entrepreneurship, green innovation (GIN), Asian countries, education

Abbreviations:

WENP: Women Entrepreneurship

GIN: Green Innovation

HC: Human Capital

FDI: Foreign Direct Investment

GST: Gender socialization theory

WGI: Worldwide Governance Indicators

WDI: World Development Indicators

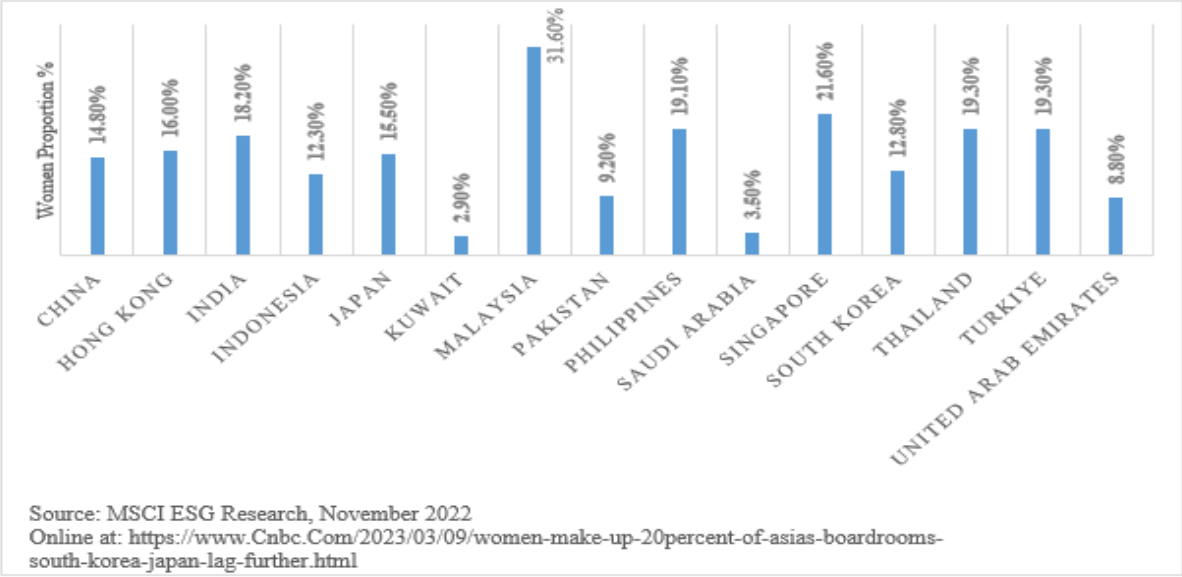
1. Introduction

Sustainable development has always been a priority, and the current economic growth is not sustainable and adversely impact the environment that raises the demand for green innovation (or environmental innovation) to mitigate the deteriorating state of the environment (Wu et al., 2022). The concept of GIN has become more prevalent in recent years, as environmental degradation and climate change poses significant threats to the overall welfare of the world's population. (Yong et al., 2019). Technology and practices that promote sustainable development and enhance the well-being are called green innovations and it is essential for achieving a more favorable trade-off between economic growth and environmental protection (Tambovceva et al., 2019).

Among the all crucial SDGs, "sustainability of the environment (SDG 13)", "employment opportunities and economic growth (SDG 8)", "clean water and sanitation (SDG 6)", as well as, "healthiness and well-being (SDG 3)", are biggest challenges for developing nations that can be resolved through the adoption of environmental friendly technologies (Baumeister, 2018); (Sinha et al., 2018). Sustainable economic development requires a variety of economic and social interventions, such as incorporating women into the economic process and it is broadly accepted that women entrepreneurs play a pivotal role in promoting balanced economic and social development, as well as their heightened awareness, community impact, and commitment to sustainable practices, utilizing local resources for diverse economic activities. (Al-Qahtani et al., 2022). Women entrepreneurship is considered a powerful tool to empower females for the socio-economic benefits that generate sustainable business activities (MeenuMaheshwari & PriyaSodani, 2015).

Women's entrepreneurship or women's access to business has become the fastest-growing economic phenomenon in Asia developing countries in the last decade (Debnath et al., 2019). As reported in the MSCI report published in 2022 by Morgan Stanley Capital International, the percentage share of women at CEO level in the world has increased from 22.6% to 24.5% globally. However, in Asia, the representation of female directors lags significantly behind the global average, with women occupying only 20% of executive boardroom positions. The proportion of female directors in Malaysia along with Singapore, Thailand and India, shows tremendous growth as compared to developed economies of Japan and South Korea, further, female director in Pakistan is around 9.2% (See Figure 1).

Figure 1: Percentage of total director seats held by women in 2022 in Asia



Source: MSCI ESG Research, November 2022
Online at: https://www.Cnbc.Com/2023/03/09/women-make-up-20percent-of-asias-boardrooms-south-korea-japan-lag-further.html

Women in top management positions with strong awareness of environmental issues and corporate social responsibility tend to promote green innovation (Nadeem et al., 2020; Muttakin et al., 2015), that further entail a sustainable business environment (Burke et al., 2019). In accordance with "Gender socialization theory (GST)" the educated women along with values and communication skills support the decisions of boards for protecting the environment and preserve the interests of stakeholder groups(Carlson, 1972; Gilligan, 1977; Eagly & Crowley, 1986).

Board gender diversity enhances corporate as well as green innovation, further women entrepreneurs emphasize more on environmental sustainability and pursue innovative initiatives (Lakhal et al., 2024). Several studies have shown that women entrepreneurs are more aware of the potential impact of their business activities on the communities in which they operate. As a result, they become more involved in economic diversification and contribute to global sustainable development (Al-Qahtani et al., 2022; He & Jiang, 2019; Lakhal et al., 2024). A few studies have examined the impact of more women in leadership positions on corporate innovation (Griffin et al., 2021; Bouchmel et al., 2022; Javed et al., 2023), while some others investigated the impact of 'board feminization' on firms' green innovation level (Adams & Ferreira, 2009; Torchia et al., 2011; Farza et al., 2022). In addition to this, certain studies investigated that women play a significant role in business start-ups and innovation, and further contribute to national economies and economic growth (Vehviläinen et al., 2010; Bullough et al., 2022;Gaies et al., 2023). However, the impact of women entrepreneurship on GIN at national level remains underexplored. The objective of this study is to examine the potential impact of WENP on GIN that can be helpful for the economies to make policies to promote green innovation at macro level.

Although gender research on green innovation has grown significantly in the past few years, however, it is still at an early stage of development (Dohse et al., 2019). Moreover, women entrepreneur play its crucial role towards firm's level corporate and green innovation as well as economic growth, few studies have analyzed the impact of HC on women entrepreneur at regional level (Andersson & Karlsson, 2007; Gaies et al., 2023; Kamal, 2018), hence, the present study fills this gap and expands the existing body of knowledge. Additionally, this study makes a significant contribution to the gender and green innovation literature by concentrating on the involvement of female entrepreneurs in driving country level GIN along with the human capital impact, in terms of education, on gender-innovation relationship. It is the first study that examines how women in top executive positions and on board impact GIN at regional level.

The rest of this study is structured as follows: the following segment examines the existing literature and delineate the formulated hypotheses, third section details the methodology and

provides an overview of data. Lastly, the fourth segment discusses the primary findings, and the concluding section summarizes by discussing the results obtained and their policy implications.

2. Literature Review

2.1 Women Entrepreneurship and Green Innovation

Innovation is one of the most effective ways for economies and companies to deal with external challenges and to promote sustainable development (Carrillo-Hermosilla et al., 2010; De Medeiros et al., 2014). With rigorous environmental rules and more focus on protecting the environment, businesses need to take on social responsibilities, engaging in green innovations to mitigate environmental impact and secure competitive advantages (Cui & Wang, 2022; Henriques & Sadorsky, 1999; Banerjee et al., 2003). GIN, as described by Russo, (2003) is a process to alleviate the adverse effect of business activities on the environment to preserve natural capital for present and future generations.

The impact of entrepreneurs on environmental policies and practices is considerable, as they possess the authority to shape and drive sustainable initiatives within organizations (Waldman et al., 2006; Waldman & Siegel, 2008). Moreover, some studies argued that WENP may be more likely to contribute to green innovation, and typically exhibit greater risk aversion compared to men (Faccio et al., 2016; Boohene et al., 2008). This perspective gets additional support from the ‘upper echelons theory’, emphasizing that top managers play a pivotal role in driving environmental innovation (Hambrick & Mason, 1984). This theory posits that the top managers’ decisions are influenced by their personal characteristics including demographics such as ‘gender’, ‘age’ and ‘education’ (Lewis et al., 2014; Johnson et al., 2013), which, in turn, can impact the organization's direction and initiatives, encompassing those related to the environment (Finkelstein et al., 2009; Aragon-Correa, 1998).

Additionally, researchers have asserted that as per gender socialization theory (Carlson, 1972; Gilligan, 1977), women entrepreneurs act ethically, develop and maintain better relationships

(Albaum & Peterson, 2006; Jaffee & Hyde, 2000), and are more concerned with environmental issues than their male counterparts (Nadeem et al., 2020). Singh et al., (2012) suggested that women are more likely to be involved in service and community organizations as compared to male executives who have more experience in corporate settings, therefore, female managers are more concerned about environmental issues in their organizations (Diamantopoulos et al., 2003).

Research on WENP evolved over the past few years as a distinct line of inquiry (Cardella et al., 2020; Sajjad et al., 2020; Baptista et al., 2008) regarding the investigation of the underperformance of women-owned businesses in comparison to their male counterparts (Neumeyer et al., 2019; Byrne et al., 2019; Marlow & McAdam, 2012). Women entrepreneurs differ because their motivations are shaped by social factors (McGowan et al., 2012; Cadieux et al., 2002), they face external social barriers and additional challenges in establishing and growing businesses (Abuhussein & Koburtay, 2021; Guzman & Kacperczyk, 2019). Despite this, women directors, according to 'resource dependence theory' more contribute to the valuable resources (Salancik & Pfeffer, 1978; Hillman et al., 2000) and offer unique skills, diverse perspectives, and enhanced decision quality, contributing positively to strategic positioning through their creativity and broader understanding of the marketplace (Post & Byron, 2015; Hillman et al., 2007; Carter et al., 2003). Based on these theoretical perspectives, it is concluded that board gender diversity contributes significantly to firm corporate and green innovation (Lakhal et al., 2024). Besides theoretical approaches, there are some empirical findings regarding the effect of women entrepreneur and green innovation, suggesting that inclusion of more women in executive position leads to the development of firms' green innovation (Lin et al., 2022; Horbach & Jacob, 2018; Zelezny et al., 2000).

However, the above cited literature primarily focuses on individual firm level performance of WENP and GIN, while a few studies examines the link between 'entrepreneurship' and 'innovation' at the country level (Audretsch & Keilbach, 2004; Acs et al., 2009). More recent work in this context is conducted by Gaies et al., (2023) and Sajjad et al., (2020) that investigated the macroeconomic contribution of WENP on global economic development and innovation. As green innovation is one of the key factor that stimulate sustainable development (Ullah et al., 2023), further, Galindo-Martín et al., (2020) investigated the strong relation of

entrepreneurship and GIN, and even though the literature has highlighted the gendered nature of entrepreneurship (Minniti, 2009), the contribution of WENP towards regional green innovation is still underexplored. Based on the literature reviewed above, the following hypothesis are formulated:

H1a: The increase in the proportion of women entrepreneurs will positively affect green innovation at country level.

H1b: The increase in the proportion of men entrepreneurs will positively affect green innovation at country level.

2.2 Women Entrepreneurship, Human capital, and Green Innovation

'Human capital' refers to the combination of knowledge, expertise, and personal qualities embodied within individuals (Flores et al., 2020; Unger et al., 2011), is recognized as fundamental factor to promote GIN and improve environmental quality (Z. Yu & Di Guo, 2023). "Human Capital Theory" (Becker,1964) posits that organizational performance benefits from diversity, as it brings together varied levels of education, skills, experiences, and capabilities. Education and training, identified as crucial components of HC (Becker, 1975). Specifically, a higher level of education is widely acknowledged as a key factor influencing the innovative ideas (Stuetzer et al., 2013; Samuelsson & Davidsson, 2009), further development of HC is an essential element to promote sustainability with eco-innovation ideas (Ahmed et al., 2021; Secundo et al., 2020; Di Fabio & Peiró, 2018).

Human resource, through education enhances environmental impacts by promoting green energy use. In industrial production, skilled human capital with the latest technology increases energy efficiency and the transfer of innovation to firms relies heavily on education (Huang et al., 2022; Jin et al., 2022; Wang, 2010). Individuals with higher education are more likely to develop creative and innovative thinking skills, which can impact innovation in entrepreneurs (Verheul and Van Stel, 2010). Entrepreneur women with greater education are more likely to discover entrepreneurial opportunities, demonstrating creative approaches to introducing new eco-friendly products, services, and processes (Gobena & Kant, 2022; Roomi, 2013).

Recent studies have suggested that female entrepreneurs with higher education are more innovative, suggested that advanced HC encourages both innovation and pro-environmental behavior, which enhances green innovation (Meng et al., 2023; Vadnjal, 2020). In addition, a management board with a mixed gender composition and a significant presence of highly skilled and qualified women are positively associated with innovative environmental practices (Horbach & Jacob, 2018). Thus, the following hypothesis is proposed;

H2: More women entrepreneurs engage in green innovation with the higher level of education.

3. Methodology

3.1 Data

This study empirically examine influence of WENP on GIN at regional level. For investigating the above hypothesis, the data has been compiled from OECD, WGI and WDI. The dataset containing the panel of 23 Asian countries, including Armenia, China, Cyprus, Georgia, Hong Kong, India, Indonesia, Iran, Japan, Jordan, Kazakhstan, Kuwait, Lebanon, Malaysia, Pakistan, Philippines, Saudi Arabia, Singapore, South Korea, Sri Lanka, Thailand, Turkiye, Uzbekistan over the period of 2008 to 2022. The selection of panel data for the countries is determined by the data's availability, especially in case of green innovation given by OECD.

3.2 GIN: Dependent variable

Green innovation refers to the advancements in technologies for developing environmentally friendly products and processes, balancing economics and the environment (Chen et al., 2018; Li et al., 2018). The proxy of GIN is measured as the total number of patent applications related to environmental technology in each country, based on OECD statistics (Shahzad et al., 2020; Cai et al., 2020; Hu et al., 2021).

3.3 WENP: the independent variable

Women entrepreneurship is measured by the WDI variable "Self-employed, female (% of female employment)" which is the "simplest form of entrepreneurship" (Gaies et al., 2023; Blanchflower, 2000; Laferrère & McEntee, 1995). It includes a measure of female employee's

percentage working independently or in collaboration with others or in cooperatives, who have self-employment jobs (Female self-employment).

3.4 HC: the mediation variable

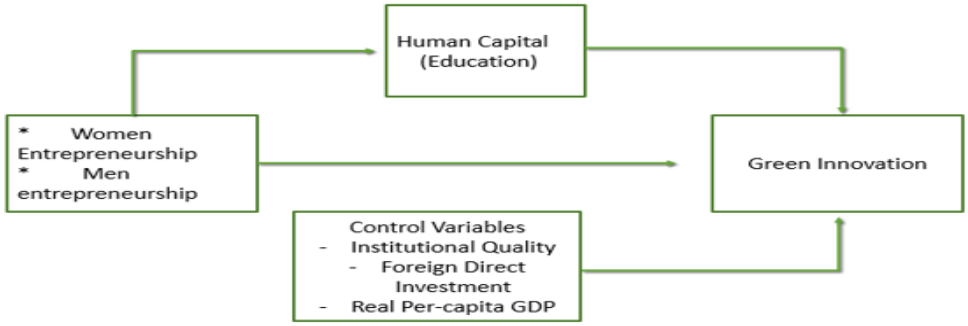
Human capital refers to the combination of knowledge, expertise, and personal qualities embodied within individuals (Flores et al., 2020) and tertiary education is used as a proxy for measuring HC in developing economies (Lin et al., 2021; Zhang et al., 2021; Thomassen, 2021).

3.5 Control variables

The econometric model incorporates Institutional quality (IQ), measuring the effectiveness of a nations' institutions including its government and legal framework, Foreign direct investment (FDI), as a measure of economic openness that has a potential to influence international technology transfer and economic growth (RGDPPc), exhibiting the level of Income, as control variables based on the existing studies (Yuan et al., 2022; Christoforidis & Katrakilidis, 2021; Song & Han, 2022; Bokpin, 2017; Tudor & Sova, 2021; Wen et al., 2022). An average composite institutional quality index is calculated by using six indicators (see Appendix I) from the WGI database for each country. Higher institutional quality (IQ) including intellectual property protection such as patent rights, not only increases the proportion of environment-related patent holders in a market but also creates barriers against imitators, consequently leading to the improvement of GIN (Sun et al., 2019; Gao et al., 2018). FDI is expressed as a proportion of GDP inflows, collected from WDI database (World Bank, 2022). FDI can drive the global exchange of technology, particularly from developed to developing economies, influencing a nation's environmental quality through technology spillover (M. Song et al., 2015; Matsubara, 2005). All the data is converted into natural logarithm (excluding FDI and IQ), to smooth their values overtime, reducing heterogeneity among variables, and allowing us to predict the relationships between them correctly.

3.6 Conceptual Framework

Figure 2: Conceptual Framework



Source: Authors' own work

3.7 Empirical model and estimators

The current study is explicitly designed to explain the contributions of WENP towards green innovation at regional level, particularly consider 'self-employed' female entrepreneurs in Asian countries. All incorporated variables are exemplified in Table 1 below.

Table 1: Data Description

Variables	Notation	Measurement	Data Source	Reference
Dependent Variable				
Green Innovation	GIN	Environmental-related technologies	OECD	Shahzad et al., (2020)
Independent Variable				
Women Entrepreneurship	WENP	Self-employed, female (% of female employment)	WDI	Gaies et al., (2023)
Mediating Variable				
Education	EDU	School enrollment, tertiary (% gross)	WDI	Lin et al., (2022)
Control Variables				
Institutional Quality	IQ	Six indicators to calculate a composite government quality index for each	WGI	Yuan et al., (2022)

		recipient country		
Foreign Direct Investment	FDI	Percentage of GDP inflows of net foreign direct investment(FDI)	WDI	M. Song et al., (2015)
Real GDP Per Capita	RPGDP	GDP per capita based on midyear population (constant) in dollars	WDI	Tudor & Sova, (2021)

Source: Authors' work

In accordance with the available literature (Gaies et al., 2023; Nadeem et al., 2020; Lin et al., 2022; He & Jiang, 2019) a theoretical model is constructed to evaluate the effectiveness of women entrepreneurship for green innovation.

$$GIN_{it} = f\ (WENP_{it}\ ,\ EDU_{it}\ ,\ IQ_{it}\ ,\ FDI_{it}\ ,\ RPGDP_{it}) \quad (1)$$

The following econometric model for panel data analysis is used to evaluate the impact of women entrepreneurship (WENP) on green innovation (GIN).

$$\ln GIN_{it} = \beta_0 + \beta_1 \ln WENP_{it} + \beta_2\ \ln EDU_{it} + \beta_3\ \ln IQ_{it} + \beta_4\ \ln FDI_{it} + \beta_5\ \ln RPGDP_{it} + \varepsilon_{it} \quad (2)$$

In model (1) and (2) countries and year is denoted by subscript i and t respectively; GIN depicts green innovation of Asian countries, WENP denotes the women entrepreneurship (Female Self-employment), EDU signifies tertiary education for human capital, IQ represents institutional quality, FDI is the foreign investment in each country, RPGDP indicates real per capita GDP in (constant) dollars; β_0 denotes constant term, β_1 - β_5 are the estimated coefficients; ε_{it} is stochastic error term.

Based on the framework suggested by (Baron & Kenny, 1986) and most recently (Shahbaz et al., 2022), the mediation effect between WENP variable and human capital variable (Education) is incorporated in model (3) and (4).

$$\ln EDU_{it} = \rho_0 + \rho_1\ \ln EDU_{it-1} + \rho_2\ \ln WENP_{it} + \rho_3\ IQ + \rho_4\ FDI + \rho_5\ \ln RPGDP_{it} + \varepsilon_{it} \quad (3)$$

$$lnGIN_{it} = \varphi_0 + \varphi_1 lnGIN_{it-1} + \varphi_2 LnWENP + \varphi_3 lnEDU_{it} + \varphi_4 IQ + \varphi_5 FDI + \varphi_6 lnRPGDP_{it} + \varepsilon_{it} \quad (4)$$

Where ρ_0 and φ_0 indicate the constant terms; $\rho_1 - \rho_6$ and $\varphi_1 - \varphi_7$ are the coefficients to be estimated for both models. If the coefficient ρ_2 in (3) and φ_3 (4) are statistically significant, it revealed that education act as mediator between women entrepreneurship and green innovation.

For the estimation, FE and dynamic SGMM models are used. There may be several econometric problems associated with using static models in panel data studies (Khan et al., 2021). It is still possible to use the FE model as a reliable check against the dynamic model. Owing to some issues with the static model, a lag of endogenous variable is added in the model, resulting in persistent time series effect, explaining dynamic nature of data (Espoir & Sunge, 2021; Liu & Bi, 2019). In this case, an estimation technique based on GMM by (Arellano & Bond, 1991) is preferred. This approach has the ability to rectify constant country-specific effects over time, biasness caused by omitted variables, measurement errors, and endogeneity issues. Considering the potential lagged impact of the green innovation, the explained variable is lag-adjusted to one period, eq (2) is written as;

$$lnGIN_{it} = \beta_0 + \beta_1 lnGIN_{it-1} + \beta_2 lnWENP_{it} + \beta_3 lnEDU_{it} + \beta_4 lnIQ_{it} + \beta_5 lnFDI_{it} + \beta_6 lnRPGDP_{it} + \varepsilon_{it} \quad (5)$$

Where $lnGIN_{it-1}$ is the one-period lag of green innovation. Moreover, β_o refers to the constant term, and $\beta_1 - \beta_6$ denotes the coefficients to be estimated. The remaining variables are the same as described in (2). In the econometric model, endogeneity problems are caused by the introduction of a lagged term for the explained variable, therefore the SGMM, a technique developed by (Blundell & Bond, 1998) is applied to mitigate endogeneity. The generalized moment method is categorized into two types: DGMM and SGMM. In both, the validity of the instruments rely on the assumption that the stochastic error terms are genuinely unrelated and lack serial correlation. Despite its efficiency, DGMM has been criticized for its bias and imprecision that cause severe downward bias in small sample standard errors. Another fundamental drawback of DGMM arises from the potential ineffectiveness of using lagged

variable values in first differences, particularly in highly persistent series. For model identification, it is necessary to make additional assumptions regarding the initial condition of the process (Nasreen et al., 2020)

System GMMs (Arellano & Bover, 1995; Blundell & Bond, 1998) alleviate weak instrument problems based on such assumptions and control potential bias from omitted variables, tackling issues related to endogeneity and unobserved country heterogeneity. In this study two-step system GMM (Blundell et al., 2001) is preferred for analysis to attain reliable and efficient results. GMM estimators' consistency is determined three diagnostic tests assessing the model's specification (Arellano & Bover, 1995); Blundell & Bond, 1998). At first, an over-identification restriction test of Sargen examines the sample analog of moment conditions used in estimation to test the validity of instruments overall. If Sargen test fails to reject the null hypothesis it implies that the instruments are valid and the model is accurately specified. Next is the difference-in-Hansen test of too many instruments that identify instrument proliferation when it fails to reject the null hypothesis. The last one is an autocorrelation test in disturbances, which highlights that the absence of second-order autocorrelation should not be rejected when applying the autocorrelation test. Lastly, the variance inflation factors (VIF) recommended by (Baltagi, 2021) indicates the absence of multicollinearity (see table 2), given that the mean VIF values are close to 1.

4. Results and Discussion

The analysis of this study entails regression of women entrepreneurship in conjunction with some control variables (IQ, FDI, RGDPPc) as well as a mediating variable (HC) against green innovation. This regression analysis is conducted using various estimators, including POLS, fixed-effect model, difference GMM, and 2-step GMM. Table 2 illustrates that independent variables are not correlated with each other as the all VIF values are close to 1. Further, the p-value of Hausman test is less than significance level indicates that fixed effect model is more appropriate.

Table 2: VIF test

Variables	VIF	1/VIF

Dependent Variable		
Green Innovation		
Independent Variable		
Women Entrepreneurship (Self-Employment)	1.32	0.756309
Education	1.55	0.643099
Institutional Quality	1.70	0.589734
Foreign Direct Investment	1.13	0.881650
RGDP Per-capita	1.13	0.882375
Mean VIF	1.37	
Hausman Test	0.00	

Source: Authors' work

Pearson correlation coefficients for the variables used in Table 3 show that the correlations between all independent variables, and the coefficient values deviate from 1. It further elaborates that all of the independent variables are significant at 5% level of significance, except FDI, confirming that models are moderately specified. Moreover, the variables of women entrepreneurship, education, and institutional quality are positively associated with green innovation, whereas foreign direct investment and RGDP per capita are negatively correlated with it.

Table 4 presents results of regression analysis, predicting the level of green innovation for 23 Asian countries using fixed-effects, random-effects, difference GMM (DGMM) and system GMM (SGMM) models. By taking into consideration the first hypothesis the results implies that women entrepreneurship has positive impact on green innovation and estimated coefficient is statistically significant at 5% and 10% in all models except Fixed effect (see table 4; column1-4) , validating the acceptance of alternative hypothesis. It further explains that involvement of women in entrepreneurship positively contributes to the development of sustainable and environmentally-friendly innovations in the Asian region. Research conducted by Javed et al., (2023) on 997 Chinese non-financial companies, and He & Jiang, (2019) on 1585 China's manufacturing firms support this finding and strengthen the case for growing women

entrepreneurship at regional level. The second part of first hypothesis elucidated the impact of male entrepreneurship on the green innovation activities and the results reveal the negative impact of male entrepreneurship (self-employed male) on green innovation. The estimated coefficient is statistically significant in all models validates the acceptance of the hypothesis, indicating that male entrepreneurs negatively affect green innovation and the generation of environment-related patents. This conclusion is in line with the research conducted by Braun, (2010) and (Javed et al., 2023). Furthermore, education is the positive determinant of green innovation, suggesting that development in the human capital leads to the increased environment-friendly business activities (Ni et al., 2023).

In case of control variables, institutional quality exhibits mixed results; negative yet insignificant impact on green innovation in case FE and DGMM (see table 4; column 2 -3), whereas positive and significant impact in case of POLS and SGMM (see table 4; column 1 and 4). It is clear from these findings that the quality of institutions plays a crucial role in encouraging environmentally sustainable innovations, and confirm the findings of Sun et al., (2019) on 71 developed and developing countries and (Qi et al., 2021) on listed companies in China's A-share market. Next, FDI also shows mixed results in these models such as showing negative effect on green innovation for POLS and SGMM (table 4; column 1 and 4), while has a little positive influence green innovation in case of FE and DGMM (table 4; column 2–3). Moreover, the coefficient is significant only in case of POLS (table 4; column 1), reveals that FDI does not significantly contribute to fostering environmentally sustainable business activities in Asian developing countries and confirms the finding of (Brohi & Suzuki, 2023), another research conducted by W. Song & Han, (2022) also found the positive and negative impact of FDI on green innovation practices. Lastly, real per-capita GDP is used to measure the effect of economic growth on green innovation. The result reveals the negative and significant impact of economic growth on green innovation in all models except DGMM (table 4; column 1-4). As a result of rapid economic growth, resources are diverted from environmentally sustainable practices, hindering green innovation and prioritizing immediate financial gains at regional level (H. Yu et al., 2023; Shen et al., 2021).

The outcome of the diagnostic test indicates that all models are properly specified. The null hypothesis fails to reject regarding the second order serial correlation. The models are unaffected by the excessive number of instruments problem, as the number of cross-sectional units greater than the number of instruments. Moreover, the Hansen test is insignificant, implying the rejection of null hypothesis, thus confirming the instrumental validity.

Table 3: Correlation analysis

Variables	Green Innov.	Women Entrep.	Education	Inst. Quality	FDI	Real GDP Per-capita
Green Innovation	1.0000					
Women	0.0558	1.0000				
Entrepreneurship (Self-Employment)	(0.03015)					
Education	0.2867	-0.3745	1.0000			
	(0.0000)	(0.0000)				
Institutional Quality	0.3474	-0.3743	0.5572	1.0000		
	(0.0000)	(0.0000)	(0.0000)			
Foreign Direct	-0.0431	-0.1171	0.1060	0.3219	1.0000	
Investment	(0.4252)	(0.0297)	(0.0492)	(0.0000)		
RGDP Per-c'apita	-0.1112	0.3036	-0.0522	-0.1810	-0.1446	1.0000
	(0.0390)	(0.0000)	(0.3340)	(0.0007)	(0.0071)	

Note: P-values of Pearson correlation coefficients are indicated above brackets

Source: Authors' work

The results of table 5 examines the mediating role of human capital in terms of higher education between women entrepreneurship and green innovation for Asian region. The coefficients have significant and positive effect on green innovation in both DGMM and SGMM (bold values in table 5; column 1, 3 and 2, 4 respectively).

Women entrepreneurs, particularly those with higher education, play a positive role in driving green innovation suggesting that highly educated women exhibit great concerns for environmental issues and actively promote eco-friendly business activities (Meng et al., 2023; Gobena & Kant, 2022). As women entrepreneurship has a positive and significant influence on

education (see bold values, table 5; column 1 and 2), and educations shows a strong positive significant impact on green innovation (see bold values, table 5; column 3 and 4), these results confirm significant mediation impact of human capital (higher education) between WENP and GIN in Asian countries. Thus, education plays a significant role in the performance of women entrepreneurs, and higher educational levels, can play an important role in improving the environmental innovation level (L. Li et al., 2023; Demirbağ et al., 2022). The diagnostic results are appropriate, particularly, instruments are valid if the Hansen test does not reject over-identification restrictions.

Table 4. Baseline Regression Results

Explained variable: $lnGIN_{it}$				
	(1)	(2)	(3)	(4)
Variables	POLS	FE	Difference GMM	2-Step System GMM
$lnGINT_{it-1}$			-0.190***	0.348***
			(0.069)	(0.101)
$lnWENP_{it}$	1.816***	0.266	1.412**	2.028*
	(0 .340)	(0.167)	(0. .594)	(1.154)
$lnMENP_{it}$	-1.866***	-1.114***	-1.696*	-2.825*
	(0 .522)	(0. 338)	(0.952)	(1.591)
ln EDU_{it}	0 .648**	1.160***	2.297***	1.023**
	(0 .257)	(0.175)	(0.606)	(0.434)
IQ_{it}	1.327***0.231)	-0.238	-0.364	0.143*
		(0.296)	(0.522)	(0.293)
FDI_{it}	-0.012***	0. 001	0.006	-0.002
	(0 .004)	(0. 001)	(0.008)	(0.004)
$lnRPGDP_{it}$	-0.135***	-0.593*	-0.805	-0.115*
	(0.049)	(0.348)	(0.637)	(0.070)
Constant	4.287***	10.172**	-	3.678
	(1.502)	(4.374)		(2.676)
Number of Countries	23	23	23	23
Number of Observation/ Number of Instruments	345	345	18	20
AR (1) [Pvalue]			-0.72	-2.56
			[0.469]	[0.010]
AR (2) [Pvalue]			0.18	1.51
			[0.856]	[0.132]
Hansen Test [Pvalue]			9.39	8.43
			[0.586]	[0.751]

Note: Standard errors enclosed in parentheses, values in [ ] are P values. The significance is represented by *** at 1%; **at 5%; *at 10%.
Source: Author's own creation

Table 5. Mediation Regression Results

Explained variable : EDU_{it}			Explained variable : GIN_{it}		
Variables	(1) DGMM	(2) 2-step GMM	Variables	(3) DGMM	(4) 2-step GMM
EDU_{it-1}	0.949*** (0 .035)	1.027*** (0.033)	GIN_{it-1}	0.328*** (0.064)	0.539*** (0.045)
$LnWENP_{it}$	**0 .029*** (0.007)**	**0.011* (0.006)**	$WENP_{it}$	0.113 (.069)	0.263*** (0.102)
IQ_{it}	0.074*** (0.014)	-0.026 (0.024)	**EDU_{it}**	**1.216*** (0.152)**	**0.463*** (0.167)**
FDI_{it}	0.0006** (0.000)	0.0008 (0.000)	IQ_{it}	-1.004*** (0.297)	0.431** (0.195)
$lnRPGDP_{it}$	-0.033 (0.048)	-0.004** (0.002)	FDI_{it}	0.004*** (0.000)	-0.003*** (0.001)
			$lnRPGDP_{it}$	0.116 (0.242)	-0.072 (0.057)
Constant	-	-0.047 (0.151)	Constant	-	0.360 (0.869)
Number of Countries	23	23	Number of Countries	23	23
Number of Instruments	20	20	Number of Instruments	19	21
AR (1) [Pvalue]	-2.84 [0.004]	-2.89 [0.004]	**AR (1) [Pvalue]**	-2.69 [0.007]	-2.90 [0.004]
AR (2) [Pvalue]	-0.90 [0.367]	-1.10 [0.271]	**AR (2) [Pvalue]**	1.63 [0.102]	1.60 [0.110]
Hansen Test [Pvalue]	14.41 [0.494]	16.17 [0.303]	**Hansen Test [Pvalue]**	14.80 [0.320]	14.38 [0.421]

Note: Standard errors enclosed in parentheses, values in [ ] are P values. The significance is represented by *** at 1%; ** at 5%; *at 10%.
Source: Author's own creation

5. Summary and Policy Suggestions

Asian developing nations play a crucial role in global economic and environmental dynamics, so it is imperative to examine the unique relationship between WENP and GIN at country level. This study examines the relationship between women entrepreneurship (self-employed females) and green innovation (number of environment-related patent technologies) in the context of 23 Asian countries from 2008 to 2022. Women's active participation in entrepreneurship plays a

crucial role in creating and implementing environmentally sustainable practices and innovations. This paper explores the impact of women participation in promoting green innovation than male entrepreneurs. Further, human capital is analyzed in terms of high education as a mediator between women entrepreneurship and green innovation.

The findings of this paper reveal that women entrepreneurs are more committed towards green innovation that male counterparts, accepting the first alternative hypothesis. In addition, this study supports the next hypothesis related to the importance of education in the context of women entrepreneurs and increased green innovative activities at regional level. The findings suggest that educated women entrepreneurs play a significant role in fostering green innovation. This highlights the potential for promoting women's education and entrepreneurship as a strategy for advancing environmentally friendly initiatives in the context of Asian developing economies.

The findings of this study have several implications such as (1) assessing the impact of WENP on GIN at the country level, the study increases theoretical knowledge regarding women entrepreneurship (WENP) research. (2) The finding suggests that women perform better at executive position for promoting green environment technologies than males, governments should prioritize the inclusion of women in leadership roles to drive sustainable initiatives and enhance environmental innovation by setting a minimum quota for women at top positions in each organizations. (3) The government should provide tailored policies to support women entrepreneurs, recognizing the valuable contributions they make to innovation at the national level and taking into account their unique motivations. (4) Lastly, education plays a vital role in promoting green innovation, thus policymakers should prioritize tertiary education, recognizing its crucial role in enhancing female entrepreneurial performance. This entails a shift from the prevailing emphasis on basic literacy and secondary education to better support well-educated women in becoming entrepreneurs.

This study does not categorize the different types of innovation such as product innovation or process innovation in analyzing the relationship between women entrepreneurship and green innovation. From this standpoint, a potential future research involves exploring the relationship between women entrepreneurship and various types of innovation to gain a more detailed

understanding of their contribution. There is substantial scope for further research to determine the factors that motivate countries to move from pro-environmental attitudes to pro-environmental behavior to make positive impacts on the environment. As this study is based on the sample of Asian economies, it can be further extended to most women populated countries globally, or for any other region.

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Appendix I

Table 1. The specific indicator system of government quality

Indicator	**Measure**
Control of Corruption	The degree of restriction on the practice of people using public power for private profit
Government Effectiveness	People's perceptions regarding policy formulation and implementation quality, credibility of the government, quality of public services, political pressure, etc
Political Stability	The level of government stability.
Regulatory Quality	Peoples' perceptions of the government's approach to introducing policies
Rule of Law	People's perceptions of quality of police and courts, and likelihood of crime and violence, which reflect the degree of trust in the public sector and compliance with laws and regulations.
Voice and Accountability	People's perceptions of the level of political participation of citizens and freedom of expression, association, media etc.