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# **Women's Empowerment and Environmental Governance**

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# Shifting Gender Roles in Society and the Workplace: Implications for Environmental Sustainability

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Majid Khan<sup>1</sup>

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## ABSTRACT

United Nations Sustainable Development Goal 5 (SDG-5) focuses primarily on the need to provide women and girls with equal opportunities in all spheres of society, such as education, technology, and work. The research looked at the impact of women's empowerment on Pakistan's environmental sustainability agenda from 1975 to 2022, using a market-based methodology. The findings demonstrate that increasing the number of women in the labour force positively impacts the environment by decreasing carbon emissions. Despite improvements in women's rights and literacy rates, as well as technical and economic progress, the country is producing more carbon dioxide because of its economic and industrial conditions that cannot reduce its adverse effects on the environment. The Granger causality estimates verified that economic development caused female labour market outcomes and female autonomy. In contrast, the bidirectional causality estimates proved that female autonomy caused technical progress and vice versa. The research concludes that even though the technology industry continues to expand astoundingly, women are still disproportionately underrepresented. This is a severe issue because women make up more than half of the population yet still account for less than one-quarter of tech jobs. Women's shifting roles in society and the workplace demand more attention. Several causes, including shifts in economic focus from manufacturing to services and shifting cultural norms about women's moral responsibilities, have all played a part in this development. Women's independence significantly impacts the economy, liberal arts, and environmental footprint. More independent women also tend to have more education and work experience than their less independent counterparts. In turn, it reduces carbon output.

**Keywords:** Women's empowerment; Environmental sustainability; Carbon emissions; Technological advancement; Labour market outcomes; Pakistan.

## 1. INTRODUCTION

The term "women's empowerment" refers to creating an enabling environment for women that enables them to establish fair treatment and gain the confidence and resources they need to lead independent lives and make full contributions to ensuring the necessary changes in our societies. It needs concerted effort and commitment from the government, business, and civic sectors (Al Hakim et al. 2022, Hafsa Batool & Rehman 2022). Women's empowerment has improved women's economic, political, and social standing (Abou-Shouk et al. 2021). In a male-dominated society, women's empowerment creates an environment where they may go about their daily lives without worrying about being mistreated or retaliated against or subjected to discrimination or harassment (Ademola et al. 2021). Included in SDG5's list of goals for empowering women is the elimination of all forms of discrimination against and violence against women; the promotion of women's equal participation in political and socioeconomic decision-making; and the implementation of reforms to ensure that women are afforded equal rights to economic, financial, and property ownership.



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Hashemi and Schuler (1993) list the many ways in which women are empowered as follows: (a) self-awareness and future vision, including protection from husband's ill-treatment; (b) mobility and appearance; (c) financial security and learning new skills; (d) purchasing rights and power of decision making within the family; (e) participation in financial programmes and interaction ability in public; and (f) joining credit programmes. Better air quality, fertile land, and water availability are all factors that Hanif et al. (2022), Khalil et al. 2022, Ramzan et al. (2022) cites as essential to ensuring environmental sustainability. It is a way for humanity to get what it needs without jeopardising the environment's ability to provide those necessities or to maintain its biodiversity. In 2015, the U.N. General Assembly included it as a sustainable development target, elevating its significance (SDGs). As a result, the SDGs of agenda-2030 has assumed a pivotal role for all U.N. members in the next fifteen years, beginning in 2015. The idea of environmental sustainability is an expansion of the definition of sustainable development, which states that current generations while pursuing their own goals, must also safeguard the needs of future generations so that they are not jeopardised. Environmental sustainability, therefore, is analogous to meeting the resource demands of the current and future generations without jeopardising the ecosystem that provides these services (Ibrahim et al. 2022, Abbasi et al. 2021, Huang et al. 2022). The health of current and future populations depends on the state of the planet. Other people's choices may indeed affect how much worth you have in the future. More than that, the present human generation's facilitation helps build sympathies for future generations to care for the environment comprehensively. Its depletion causes mortality due to dwindling natural resources (Qureshi et al. 2015, Anser et al. 2021, Khan et al. 2022). Women make most of the household's purchasing decisions and have a disproportionate say in what is consumed (Tennyson et al. 2022). To be more specific, women tend to be more careful about the effects of pollution and harmful chemicals on the health of their families (Rumph et al. 2022). In addition, women speak out against environmental destruction of all kinds. Since women's reproductive biology is intrinsically tied to the natural world, it is clear from a survey of relevant literature and presentations at different conferences that there is a long-standing connection between women and the natural world (Broomfield et al. 2021). Similarly, nations with gender non-discrimination are more inclined to protect the environment (Schulz et al. 2022). Additionally, important champions of the environment and ecofeminists are fairly anxious about preserving their children's health from being harmed by environmental difficulties. As a result, the Pakistani government and NGOs have begun working to achieve the Millennium Development Goals of ending discrimination based on gender and empowering women. Local nongovernmental organisations (NGOs) provide vital community services. As a result, the local community has been successfully swayed toward these inexpensive technologies. Environmental non-profits use lobbying and other forms of pressure to get governments to pass and enforce environmental laws. By implementing a slew of policies and programs—including the 10 Billion Tree Tsunami, the Recharge Pakistan, the Clean and Green Pakistan, and the Protected Areas Initiatives—Pakistan has achieved "on track status" concerning Sustainable Development Goal 13 (Climate Change) (Economic Survey of Pakistan, 2021). Climate change is one of the world's most pressing problems. The effects of climate change are being felt worldwide, and Pakistan is no different. The technological transformation helps develop women's empowerment, reduces the gender gap in the socioeconomic system, and gives them the decision-making power to realise the environmental sustainability agenda as the Pakistan government fights climate change through sustainable interconnected policies and strategic recommendations. Like women's participation in the labour force and the financial system may help them cope with the rising price of carbon emissions insurance, women's participation in the labour force can also help them make more environmentally responsible choices in the home and community. Combatting climate change also aids in formulating green policies, such as the efficient use of technology, the exploitation of renewable energy mixes, and the allocation of carbon credits (Lau et al. 2021, Nyahunda et al. 2021, Vazquez et al. 2021).

While there is a wealth of literature on the subject in other economic contexts, there is very little academic research on the issue in Pakistan, making it difficult to advance the cause of women's economic empowerment and ecological sustainability. Specifically for Pakistan, Imran et al. (2021) looked at how learning about environmental issues impacted female students. Twelve women were interviewed systematically by the researchers. Ecological literacy, feminist theory, and the advancement of women were all examined in this research. Environmentally conscious women tend to be more cautious about their impact on the planet. D'Souza & Taghian (2017) looked at how women's spending habits affect sustainability and came to the following conclusion: demand for energy and FDI both cause carbon emissions; however, money supply ultimately leads to a reduction in carbon emissions. Research shows that women's trust in others affects their purchase decisions. In addition, they discovered that women's roles contribute to environmental sustainability. Women who have confidence in public and private institutions are also reported to be more eco-savvy, which helps to guarantee environmental quality. Ibrahim & Asad (2020) examined the importance of educating women and how this might help them achieve economic independence in Pakistan, particularly with strategies to reduce workplace bias against women. It was also shown that there is a negative association between discrimination in the workplace and educational attainment. Choudhry et al. (2019) seek to look at many facets of women's empowerment. The researchers gathered data from 1996 to 2009 about Pakistan. The research concluded that awareness of women's rights and economic independence contribute to women's growth. Mujeed et al. (2021) concluded that investment in R&D, green energy use, and patent filings are required to equip women with current sustainable technology and enhance environmental quality. Researchers discovered that the combination of renewable energy and technological innovation promoted women's independence and, in turn, sustainable development. The effects of gender inequality and environmental deterioration on human well-being in Pakistan were studied Ali et al., (2021). The data they gathered spans the years 1980-2019. Economic development, gender equality, and human well-being are positively related, while a negative and substantial association between gender inequality and human well-being. Thus, to enhance human well-being, the government must reduce gender disparity and boost economic growth[50]. Essential elements contributing to women's empowerment in Pakistan were investigated by Muhammad et al., (2021). Data for 2017–2018 was used from the Pakistan Demographic Health Survey for this study (PDHS). The empirical analysis was performed using a Multiple Regression model, using data from a sample of 1035 married women

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as the dependent variable. Several factors were shown to positively and substantially influence women's empowerment: women's education, participation, the wealth index, and men's occupations. They also found that women's age and where they lived favoured their confidence and social standing. Debnath et al. (2020) investigated the drivers of women's entrepreneurship in Bangladesh to better understand women's business activity's role in helping the country reach its Sustainable Development Goals. The researchers sampled 203 women business owners from around Bangladesh. They stress the importance of women's economic independence and business ownership in fulfilling the United Nations' Sustainable Development Goals (SDGs). Elahi & Malik (2021) set out to identify the societal and environmental factors inhibiting the growth of women-owned businesses in Pakistan. The study relied on primary data from five central regions of Pakistan, where 200 social entrepreneurs were interviewed about the challenges they face in operating their businesses. According to the results, women's entrepreneurship in Pakistan is hampered by several factors, including societal expectations, a dearth of available funding, a lack of necessary physical facilities, and a general lack of formal recognition and documentation. Because women's independence is directly linked to their ability to enhance environmental quality, it follows that governments should increase women's access to resources like money and recognition to empower women.

The study has the following novel contribution that is unique in the earlier cited literature. First, the study covered three main aspects of women's autonomy, i.e., women's participation in the labour force (market outcomes), women's literacy rate (social outcomes), and women's access to technology (economic outcomes). The earlier literature mainly focused on one or two outcomes while ignoring any outcome that led to policy lacuna for women's independence (Du et al., 2022, Mujeeb et al., 2021, Handayani et al., 2022). Second, the majority of the studies worked on highly developed countries, like China or even worked in African economies. In contrast, very few studies worked on Asian women, particularly in Pakistan, which also faced different hurdles to empowering women in the workplace and household affairs (Liu et al., 2021, Nassani et al., 2019). Finally, the country's economic growth matters for sustainable environmental development. Hence, the women's role in deciding on environmental affairs makes the issue more exciting and highlights feminist action as environmental stewards to lead the corporate toward eco-friendly production. The following constructive discussion shapes the study's aims:

- I. To investigate how advancing the status of women might enhance environmental quality.
- II. To examine how women's labour force involvement affects the rate of carbon intensity decline, and
- III. To analyze how the education level of women, technical development, and economic expansion contribute to lowering carbon emissions.

The research uses cutting-edge statistical methods to draw broad conclusions on gender equality and women's empowerment in Pakistan.

## 2. MATERIAL AND METHODS

The study collected a data from the World Bank (2022) database for a Pakistan's economy for a period of 1975 to 2020. Carbon emissions served as a response variable of the study. While, women's autonomy, female share in labour market, female literacy rate, technological innovation, and economic growth served as explanatory variables. Table 1 shows the list of variables for ready reference.

**Table 1: List of Variables**

Variables	Symbol	Unit	Definition	A Priori Expectations
Carbon dioxide emissions	CO2	Kiloton of carbon equivalent	CO2 emissions raise the earth's temperature and cause global warming.	
Women business and law index score	WA	Its value ranges between 0 (lowest) and 100(highest).	The index evaluates how policies affect women's access to economic resources.	Women's autonomy will likely serve as a steward to improving environmental quality.
Female labor force participation rate	FLFPR	% of female total population	The labour force participation rate represents the percentage of 15-and-older women working.	Greater women's autonomy in corporate affairs is likely to indulge in eco-friendly production.
Female literacy rate	FLR	% of female total population	It is the % of people ages not below 15 who can read, write and comprehend a paragraph.	Educated women remain to take care of their surroundings and corporate

Variables	Symbol	Unit	Definition	A Priori Expectations
				environmental affairs.
GDP per capita	GDPPC	% of GDP	It is the income per person within a country.	Continued economic growth increases carbon emissions.
Residents patent rights	Technology Innovation (TIONV)	% of GDP	Patent applications safeguard the rights of the owner.	Women equipped with technology help to reduce carbon emissions.

One of the goals of SDG is to ensure that women are given equal economic, financial, and land ownership rights. Other goals in this area include eliminating all kinds of discrimination against women and eliminating all forms of violence and harmful behaviours against women. Women have more sway in the marketplace because they are the primary shoppers and decision-makers in the home (Daniel et al. 2021). Women are more likely to worry about the effects of pollution and harmful chemicals on their families' health (Giudice et al. 2021). Additionally, women speak out against environmental destruction of various kinds. Since women's reproductive systems are inextricably intertwined with the natural world, it stands to reason that there is a long-standing historical relationship between nature and women, as shown by several conferences and reviews of relevant literature (Albert & Ogunbanjo 2022, Gebhardt et al. 2021, Obinna 2021). It is also evident that nations without discrimination against either gender are more inclined to protect their natural resources. Climate change is one of Earth's most pressing problems. Climate change is a global phenomenon, and Pakistan is not immune to its effects. Women make up almost half of Pakistan's population, and it is clear that climate change has a significant impact there as well. As a result, it will be fascinating to see how empowering women in Pakistan affects the country's emissions and coping with sustainable policy instruments.

### 2.1. Theoretical Framework

The concept of ecofeminism seeks to shed light on the connection between women and the natural world. Francoise d'Eaubonne, a prominent feminist from France, first proposed the idea in 1974. It does this by adhering to the fundamental premise of equal treatment between the sexes and maintaining a world perspective that respects biological processes (Dipanwita, 2021). Degradation of the environment has hurt women's role in managing the natural resources of their families and communities. Women control access to water, food, and fuel sources. Women produce sixty to eighty percent of the food in developing nations. On the other hand, restrictions regarding inheritance and local traditions sometimes prevent them from owning or leasing property and getting loans (Addaney et al. 2022, Abebe & Flintan 2021). The economy's expansion has been helped by the development of technologies that augment both labour and capital. However, it has also contributed to a worsening in the air quality. Therefore, women should access environmentally friendly technology that may help reduce greenhouse gas emissions. In addition, it is important to point up here that women are seen as being environmentally friendly because of the factors that lead to the natural empowerment of women. The ecofeminist movement promotes the idea that the female labour force should be compelled to have access to technology spillover to reduce greenhouse gas emissions. Women seem to care more about the environment than their male colleagues do (Mujeed et al. 2021).

### 2.2. Econometric Framework

OLS regression correctly estimates parameters and determines the relationship between independent (predictor) and dependent (regressed) variables. It is a model; therefore, if its assumptions are satisfied, it will provide accurate estimates. Influence statistics may identify OLS outliers due to data variability or inaccuracy. Four methods to visualise impact statistics: R-Student, Hat Matrix, DFFITS, COV RATIO. Influential statistics graphically illustrate outliers. Outliers may modify the regression model's coefficient parameters. Influence statistics may uncover data outliers during regression equation estimation. This graph highlights outliers. An analysis of impact statistics shows how eliminating outliers alters estimated parameters. High leverage values are outliers in the dataset. Each estimated variable may be plotted separately. Leverage graphs show dataset position. The leverage plot's x-axis shows leverage points for each value, while the y-axis shows standardised residuals. The leverage plot illustrates which data points are furthest from other observations and have the largest effect on model fitness. Leverage graphs show whether our model accurately describes input variables. Depending on their distance from the regression line, these figures may be in the upper left or lower right corner of a leverage plot. Robust Least Squares Regression

#### 2.2.1. Robust Least Squares (RLS) Regression

When OLS cannot account for outliers, RLS is used. The robust least square estimator reduces outliers. The method is well-suited to severe scenarios. M-estimation, S-estimation, and MM-estimation<sup>83</sup> are outlier-handling robust least squares. Outliers generate model issues. In such instances, we may use robust least square estimators instead of OLS since they are less sensitive to data distortion. Huber (1973) introduced the M-estimation approach for robust LSE. Maximum-likelihood type is M-estimation. This method helps reduce excessive residuals by removing outliers' independent variables. S-estimator was suggested by Rousseeuw and Yohai (1984). This strategy may reduce high leverage points and extreme independent variable values. Yohai (1987) offered the third RLS technique.



It handles S-estimator and M-estimator outliers, or dependent and independent outliers. Equation (1) shows RLS variables, i.e.,

$$CO2 = \alpha_0 + \alpha_1 WA + \alpha_1 FLFPR + \alpha_1 FLR + \alpha_1 GDPPC + \alpha_1 TINOV + \varepsilon$$

$$\therefore \frac{\partial(CO2)}{\partial(WA)} < 0, \frac{\partial(CO2)}{\partial(FLFPR)} < 0, \frac{\partial(CO2)}{\partial(FLR)} < 0, \frac{\partial(CO2)}{\partial(GDPPC)} > 0, \frac{\partial(CO2)}{\partial(TINOV)} > 0 \tag{1}$$

Where, CO2 shows carbon emissions, WA shows women’s autonomy, FLFPR shows female labour force participation rate, FLR shows female literacy rate, GDPPC shows GDP per capita, and TINOV shows technology innovation..

2.2.2. VAR Granger Causality

The Granger Causality test identifies causality between two variables. Granger causality analysis measures one variable's ability to predict another. Each variable may be causative in three ways:

- I. To prove unidirectional causality from Y to X, we must show that Y Granger causes X but not Y.
- II. To prove unidirectional causality from X to Y, we must show that X Granger causes Y but not Y.
- III. Bidirectional causality: When X Granger causes Y and vice versa, and
- IV. Deficiency of a Causal Relationship: When neither X nor Y causes the other, or when there is no other way to explain the lack of a correlation, we claim no causality exists between the two variables.

For Granger causality, equation (2)'s VAR framework shows, i.e.

$$\begin{bmatrix} \ln(CO2)_t \\ \ln(WA)_t \\ \ln(FLFPR)_t \\ \ln(FLR)_t \\ \ln(GDPPC)_t \\ \ln(TIONV)_t \end{bmatrix} = \begin{bmatrix} \tau_0 \\ \tau_1 \\ \tau_2 \\ \tau_3 \\ \tau_4 \\ \tau_5 \end{bmatrix} + \sum_{i=1}^p \begin{bmatrix} \sigma_{11t} \sigma_{12t} \sigma_{13t} \sigma_{14t} \sigma_{15t} \\ \sigma_{21t} \sigma_{22t} \sigma_{23t} \sigma_{24t} \sigma_{25t} \\ \sigma_{31t} \sigma_{32t} \sigma_{33t} \sigma_{34t} \sigma_{35t} \\ \sigma_{41t} \sigma_{42t} \sigma_{43t} \sigma_{44t} \sigma_{45t} \\ \sigma_{51t} \sigma_{52t} \sigma_{53t} \sigma_{54t} \sigma_{55t} \\ \sigma_{61t} \sigma_{62t} \sigma_{63t} \sigma_{64t} \sigma_{65t} \end{bmatrix} \times \begin{bmatrix} \ln(CO2)_{t-1} \\ \ln(WA)_{t-1} \\ \ln(FLFPR)_{t-1} \\ \ln(FLR)_{t-1} \\ \ln(GDPPC)_{t-1} \\ \ln(TIONV)_{t-1} \end{bmatrix}$$

$$+ \sum_{j=p+1}^{d \max} \begin{bmatrix} \theta_{11j} \theta_{12j} \theta_{13j} \theta_{14j} \theta_{15j} \\ \theta_{21j} \theta_{22j} \theta_{23j} \theta_{24j} \theta_{25j} \\ \theta_{31j} \theta_{32j} \theta_{33j} \theta_{34j} \theta_{35j} \\ \theta_{41j} \theta_{42j} \theta_{43j} \theta_{44j} \theta_{45j} \\ \theta_{51j} \theta_{52j} \theta_{53j} \theta_{54j} \theta_{55j} \\ \theta_{61j} \theta_{62j} \theta_{63j} \theta_{64j} \theta_{65j} \end{bmatrix} \times \begin{bmatrix} \ln(CO2)_{t-j} \\ \ln(WA)_{t-j} \\ \ln(FLFPR)_{t-j} \\ \ln(FLR)_{t-j} \\ \ln(GDPPC)_{t-j} \\ \ln(TIONV)_{t-j} \end{bmatrix} + \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \varepsilon_3 \\ \varepsilon_4 \\ \varepsilon_5 \\ \varepsilon_6 \end{bmatrix} \tag{2}$$

Equations (3) to (8) shows Granger causality for multivariate system, i.e.,

$$CO2_t = c_1 + \sum_{i=1}^2 \beta_1 CO2_{t-i} + \sum_{i=1}^2 \beta_2 WA_{t-i} + \sum_{i=1}^2 \beta_3 FLFPR_{t-i} + \sum_{i=1}^2 \beta_4 FLR_{t-i} + \sum_{i=1}^2 \beta_5 GDPPC_{t-i} + \sum_{i=1}^2 \beta_6 TINOV_{t-i} + \varepsilon \tag{3}$$

$$WA_t = c_1 + \sum_{i=1}^2 \beta_1 WA_{t-i} + \sum_{i=1}^2 \beta_2 CO2_{t-i} + \sum_{i=1}^2 \beta_3 FLFPR_{t-i} + \sum_{i=1}^2 \beta_4 FLR_{t-i} + \sum_{i=1}^2 \beta_5 GDPPC_{t-i} + \sum_{i=1}^2 \beta_6 TINOV_{t-i} + \varepsilon \tag{4}$$

$$FLFPR_t = c_1 + \sum_{i=1}^2 \beta_1 FLFPR_{t-i} + \sum_{i=1}^2 \beta_2 WA_{t-i} + \sum_{i=1}^2 \beta_3 CO2_{t-i} + \sum_{i=1}^2 \beta_4 FLR_{t-i} + \sum_{i=1}^2 \beta_5 GDPPC_{t-i} + \sum_{i=1}^2 \beta_6 TINOV_{t-i} + \varepsilon \tag{5}$$

$$\begin{aligned}
FLR_t = & c_1 + \sum_{i=1}^2 \beta_1 FLR_{t-i} + \sum_{i=1}^2 \beta_2 WA_{t-i} + \sum_{i=1}^2 \beta_3 FLFPR_{t-i} + \sum_{i=1}^2 \beta_4 CO2_{t-i} + \sum_{i=1}^2 \beta_5 GDPPC_{t-i} \\
& + \sum_{i=1}^2 \beta_6 TINOV_{t-i} + \varepsilon
\end{aligned} \tag{6}$$

$$\begin{aligned}
GDPPC_t = & c_1 + \sum_{i=1}^2 \beta_1 GDPPC_{t-i} + \sum_{i=1}^2 \beta_2 WA_{t-i} + \sum_{i=1}^2 \beta_3 FLFPR_{t-i} + \sum_{i=1}^2 \beta_4 FLR_{t-i} + \sum_{i=1}^2 \beta_5 CO2_{t-i} \\
& + \sum_{i=1}^2 \beta_6 TINOV_{t-i} + \varepsilon
\end{aligned} \tag{7}$$

$$\begin{aligned}
TINOV_t = & c_1 + \sum_{i=1}^2 \beta_1 TINOV_{t-i} + \sum_{i=1}^2 \beta_2 WA_{t-i} + \sum_{i=1}^2 \beta_3 FLFPR_{t-i} + \sum_{i=1}^2 \beta_4 FLR_{t-i} + \sum_{i=1}^2 \beta_5 GDPPC_{t-i} \\
& + \sum_{i=1}^2 \beta_6 CO2_{t-i} + \varepsilon
\end{aligned} \tag{8}$$

### 2.2.3. Impulse Response Function (IRF) and Variance Decomposition Analysis (VDA)

The IRF depicts a system where input determines output. The IRF may give positive or negative directions 10 or 20 years from today. Graphs are the usual approach to depicting and assessing impulse responses, and they always show the influence of a one-standard-deviation impulse on a linked variable. The IRF graphs economic variables' responses to an external shock. VDA is a promising forecasting approach. Variance decomposition studies evaluate how much dependent variable variation may be attributable to independent variable changes. After estimating a vector autoregressive (VAR) model, time series analysis employs variance decomposition to predict future uncertainty. This approach simplifies auto-regressive model analysis and comprehension. Variance decomposition is also shown graphically. Equation (9) shows the VDA operator, i.e.

$$\begin{aligned}
& Var(\sigma(CO2, WA) = Var(E[\sigma \perp WA]) + E[Var(\sigma \perp WA)] \\
& \Rightarrow Var(E[\sigma \perp WCO2]) \leq Var(\sigma[CO2, WA]) \\
& Var(\sigma(CO2, RFLFPR) = Var(E[\sigma \perp FLFPR]) + E[Var(\sigma \perp FLFPR)] \\
& \Rightarrow Var(E[\sigma \perp CO2]) \leq Var(\sigma[CO2, FLFPR]) \\
& Var(\sigma(CO2, FLR) = Var(E[\sigma \perp FLR]) + E[Var(\sigma \perp FLR)] \\
& \Rightarrow Var(E[\sigma \perp CO2]) \leq Var(\sigma[CO2, FLR]) \\
& Var(\sigma(CO2, GDPPC) = Var(E[\sigma \perp GDPPC]) + E[Var(\sigma \perp GDPPC)] \\
& \Rightarrow Var(E[\sigma \perp CO2]) \leq Var(\sigma[CO2, GDPPC]) \\
& Var(\sigma(CO2, TINOV) = Var(E[\sigma \perp TINOV]) + E[Var(\sigma \perp TINOV)] \\
& \Rightarrow Var(E[\sigma \perp CO2]) \leq Var(\sigma[CO2, TINOV])
\end{aligned} \tag{9}$$

The study collected a data from the World Bank (2022) database for a Pakistan's economy for a period of 1975 to 2020. Carbon emissions served as a response variable of the study. While, women's autonomy, female share in labour market, female literacy rate, technological innovation, and economic growth served as explanatory variables. Table 1 shows the list of variables for ready reference.

## 3. Results and Discussion

Table 2 shows the descriptive statistics of the variable. According to Table-2's descriptive statistics, the average annual CO2 emissions are 104283.8-kilo tonnes, while the middle annual emissions are 89745-kilo tonnes. The range for CO2 emissions is similarly broad, from a high of 208370 K/T to a low of 60310 K/T. Additionally, the standard deviation is 47083.34. Besides, CO2 emission has typical skewness and Platykurtic curve since the kurtosis value is 2.439285, which is smaller than the standard kurtosis value of 3. Similarly, the mean value of the women in business and the law index is 41.915, and the median value is 38.125. Women's average level of independence is 50%, with a high of 55.625 on the women's business and law index and a minimum of 38. Additionally, the value of its standard deviation is 4.700. In a similar vein, the women's business and law index has a leptokurtic curve ( $3.375 > 3$ ) and a long tail skewness (positive skewness). The mean and median values for FLFPR are 15.81 and 15.51, respectively. Similarly, the lowest number is 7.04, with a maximum value of 24.22, indicating that just 24% of the entire population comprises the labour force. The standard deviation is 5.57 as well. Besides, (FLFPR) exhibits long tail skewness (positive skewness) and has a platykurtic curve ( $1.77 < 3$ ). Moreover, the mean value of (FLR) is 26.57, and its median value is 21.90. Additionally, FLR may go as high as 46.94 and as low as

14.77. This data demonstrates that women in Pakistan comprise 31% of the country's literate population. The female literacy rate has a platykurtic distribution and normal skewness.

**Table 2: Descriptive Statistics**

Methods	CO2	WA	FLFPR	FLR	GDPPC	TINOV
Mean	104283.8	41.91576	15.81261	26.57872	1032.255	84.80435
Median	89745.00	38.12500	15.51500	21.90770	1011.018	40.50000
Maximum	208370.0	55.62500	24.22000	46.49004	1502.891	313.0000
Minimum	60310.00	38.12500	7.040000	14.77155	599.6920	16.00000
Std. Dev.	47083.34	4.700034	5.578111	12.86320	255.8030	80.47018
Skewness	0.791089	1.046238	-0.072570	0.355056	0.059438	1.600316
Kurtosis	2.439285	3.375331	1.771451	1.403666	2.073915	4.723725

Note: CO2 shows carbon emissions, WA shows women's autonomy, FLFPR shows female labor force participation rate, FLR shows female literacy rate, GDPPC shows GDP per capita, and TINOV shows technology innovation.

The average GDP per person is \$1032.255, with the median being \$1011.01. GDP percent range from a high of US\$1502 to a low of US\$600. This equates to an annual income of \$1051 per person. Besides, the standard deviation of GDP PC is 255.80, and it exhibits average skewness and platykurtic curve. Notwithstanding, the mean value of technology patent applications is 84.80, and the median is 40.50. Likewise, the highest value of patent applications is 313, and the lowest is 16. A high kurtosis value implies that the (highest value) of PAP is abnormally dispersed, suggesting the presence of outliers. It also exhibits long-tail skewness and a leptokurtic distribution, with a standard deviation of 80.47. Table 3 shows the correlation matrix.

**Table 3: Correlation Matrix**

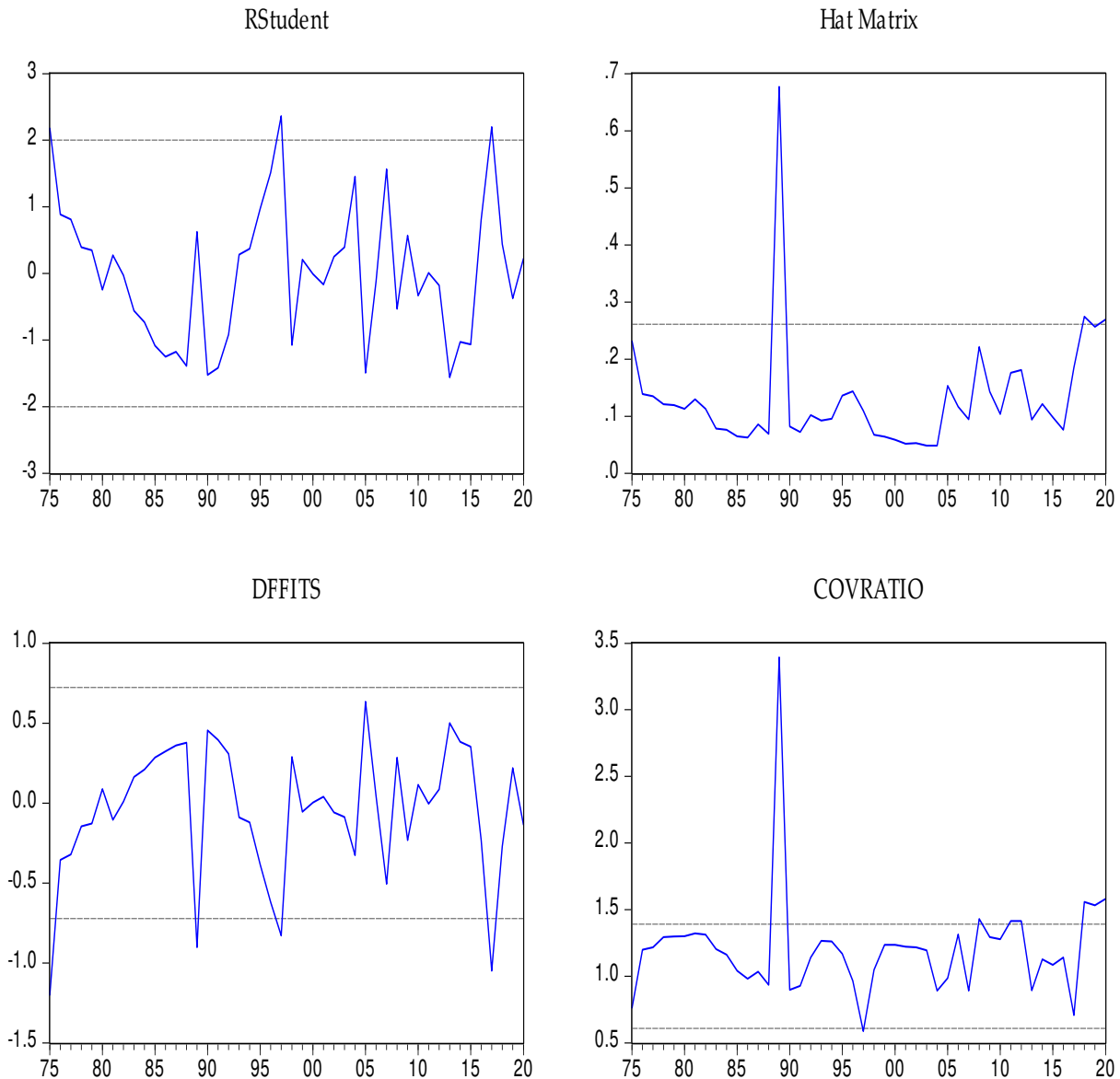
Variables	CO2	WA	FLFPR	FLR	GDPPC	TINOV
CO2	1					
	-----					
WA	0.580501	1				
	(0.0000)	-----				
FLFPR	0.856282	0.328119	1			
	(0.0000)	(0.0260)	-----			
FLR	0.953135	0.475062	0.871727	1		
	(0.0000)	(0.0008)	(0.0000)	-----		
GDPPC	0.938196	0.372020	0.926585	0.904489	1	
	(0.0000)	(0.0109)	(0.0000)	(0.0000)	-----	
TINOV	0.923857	0.722242	0.724782	0.841863	0.812595	1
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	-----

Note: CO2 shows carbon emissions, WA shows women's autonomy, FLFPR shows female labor force participation rate, FLR shows female literacy rate, GDPPC shows GDP per capita, and TINOV shows technology innovation.

According to the findings, the women's business and law index have a strong and positive correlation with CO2 emissions, and the coefficient value for this correlation is 0.58. This research implies that women's independence is linked to higher carbon emissions, showing how the lack of access to technology and the power to make policy decisions may have severe environmental consequences. Thus, it is essential to educate females about environmental concerns. In addition, they should be given a voice in environmental decision-making to encourage women to embrace environmentally responsible behaviours. There is a positive connection between FLFPR and CO2 emissions, and the coefficient value for this correlation is 0.85, suggesting a correlation between women's growing engagement in the workforce and higher levels of carbon emissions. The logical inference is that the environmental impact of the labour market's response to women is negatively impacted, leading to more carbon emissions being released into the atmosphere. Consequently, providing women with access to environmental education may help decrease carbon emissions by inspiring more ecologically responsible behaviour among female citizens. The fact that GDP per capita and carbon emissions are positively connected, with a value of 0.98, demonstrates that a country's economic growth comes at the expense of environmental deterioration. Patent applications have been shown to correlate positively with CO2 emission, with a coefficient value of  $r = 0.92$ . This indicates that economic expansion began with the accumulation of technical spillovers, producing carbon emissions. In addition, it exposes the fact that the manufacturing technique that is currently being employed is not ecologically friendly. As a result, Pakistan has to move toward innovation and environmentally friendly technologies to reduce its carbon emissions. The female labour force participation rate, the female literacy rate, and GDP per capita share are all positively correlated with a women's business law and index with a coefficient value of  $r = 0.32$ ,  $r = 0.47$ , and  $r = 0.37$  respectively. This indicates that an increase in the female literacy rate led to an increase in female labour force participation in the labour market, which in turn led to an increase in the productivity of females. In addition, the filing of a patent has a significant and favourable link with women's business legislation and index, demonstrating that using technology and creativity increases women's autonomy. There is a significant association between the filing of patent applications and women's autonomy. In addition, female literacy rate, GDP per capita, and technology innovation are significant variables that



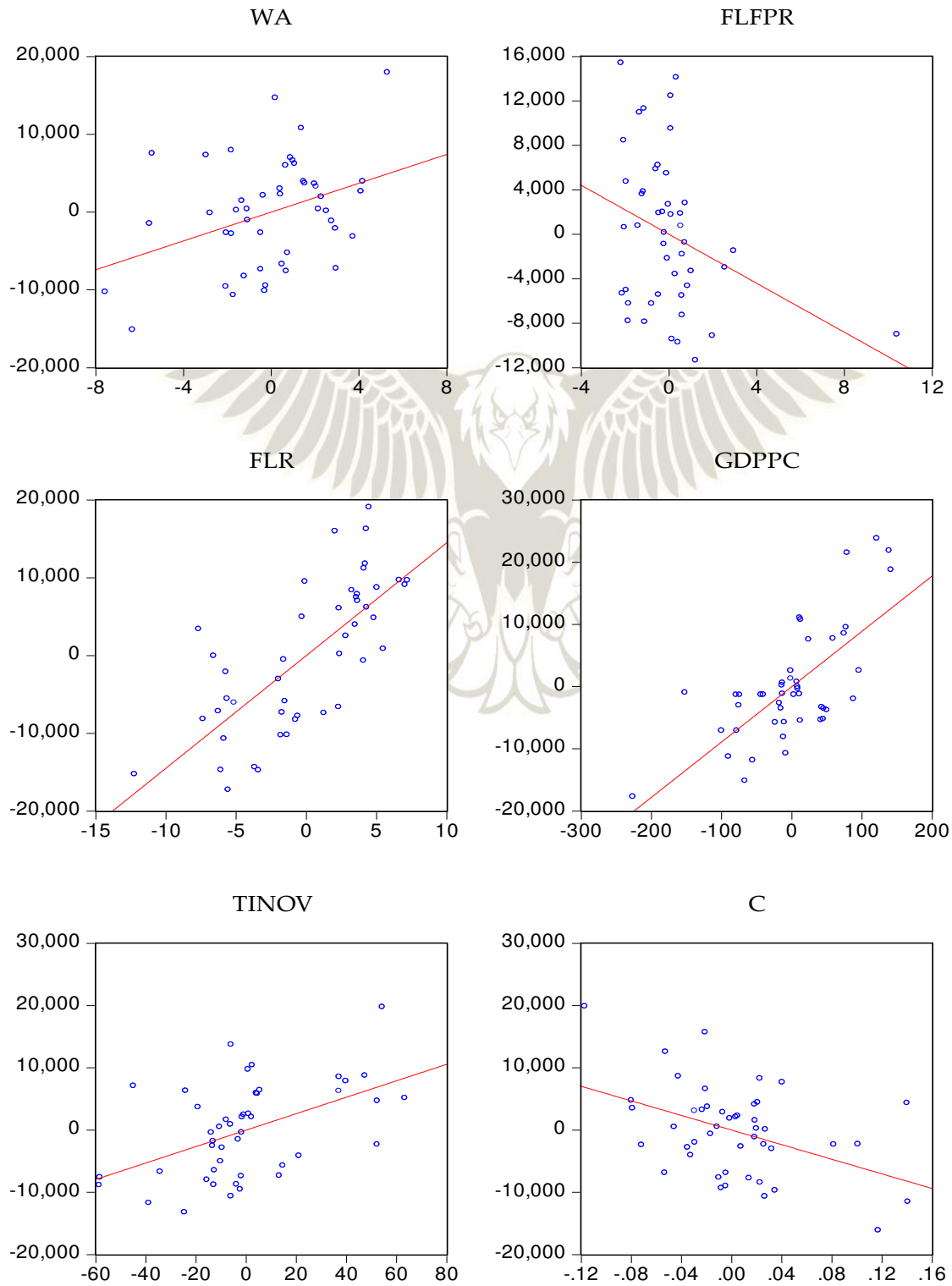
positively correlate with female labor market, and their respective coefficient values are 0.87, 0.92, and 0.72. The findings suggest that an increase in the literacy rate of women leads to an increase in female involvement in the labour force, which leads to an increase in the country's economic growth share in the nation's production via the use of technology. Like GDP per capita and patent applications, the female literacy rate positively correlates with the patent applications. Despite this, patent applications correlate positively with economic growth. It indicates that the technology spillover and innovation increase the output of female labour, which further increases national outputs, leading to an increase in GDP per capita in the economy. Prior to estimate RLS regression, the first step is to get influence statistics of the model. Figure 1 shows the influence statistics for ready reference.



**Figure 1: Influence Statistics**

Source: Author's illustration.

Figure 1 shows that there are four different influences, and they are represented by the signifiers R-student, Hat-Matrix, DFFITS, and COVRATIO, respectively. In the R-students data set, there are two instances of an outlier, whereas, in the Hat-Matrix data set, there is only one. In addition, there are four outliers in the 'DFFITS' influences, and there are two outliers in the 'COVRATIO' impacts. Figure 2 shows the leverage plots for ready reference.



**Figure 2: Leverage Plots**

Source: Author's illustration. Note: CO2 shows carbon emissions, WA shows women's autonomy, FLFPR shows female labor force participation rate, FLR shows female literacy rate, GDPPC shows GDP per capita, and TINOV shows technology innovation.

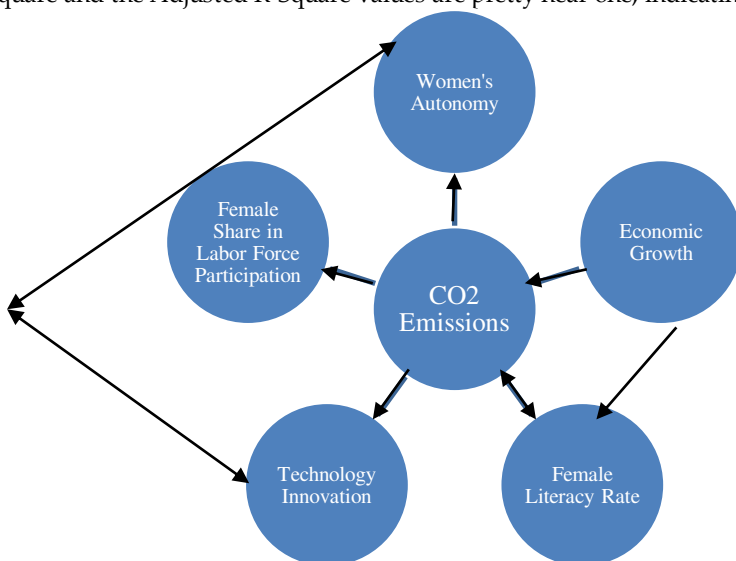
Figure 2 exhibits Leverage plotting findings. There are two outliers in a positive direction and two in a negative direction in the women in business and the law Index. The female labour force participation plot reveals two positive and two negative outliers. In addition, there is one extreme case among the patent applications. On the other hand, the leverage plot of the female literacy rate and GDP per capita is considerably more favourable since most of the data sit on the regression line. As a result, parameter estimations using the RLS-M estimator are doable. Table 4 shows the RLS -M estimator for ready reference.

**Table 4: RLS-M Estimator Results**

Dependent Variable: CO2				
Variables	Coefficient	Std. Error	z-Statistic	Prob.
WA	903.5299	401.5891	2.249886	0.0245
FLFPR	-1045.900	555.5770	-1.882547	0.0598
FLR	1465.871	232.6424	6.300963	0.0000
GDPPC	85.95492	15.30199	5.617238	0.0000
TINOV	135.9138	39.65443	3.427456	0.0006
C	-56488.68	20750.97	-2.722219	0.0065
Robust Statistics				
R-squared	0.854546	Adjusted R-squared	0.836365	
Rw-squared	0.983728	Adjust Rw-squared	0.983728	
Non-robust Statistics				
Mean dependent var	104283.8	S.D. dependent var	47083.34	
S.E. of regression	6864.916	Sum squared resid	1.89E+09	

Note: CO2 shows carbon emissions, WA shows women's autonomy, FLFPR shows female labor force participation rate, FLR shows female literacy rate, GDPPC shows GDP per capita, and TINOV shows technology innovation.

The results of M-estimation, as shown in Table 4, are shown below (Robust least square). Results estimate that an increase of one unit in the women's autonomy index, the female literacy rate, the GDP per capita, and patent applications leads to an increase of 903.52 units, 1465.87 units, 85.45 units, and 135.91 units, respectively, in CO2 emissions. Based on these findings, it seems that women's independence negatively affects environmental standards. Rises in carbon emissions correlate with increases in women's autonomy, as corroborated by Glass et al. (2016), Du et al. (2022), and Mujeed et al. (2021). Similarly, the average percentage of female literacy in Pakistan is 31%, which is much too low to reduce and increase carbon emissions. This discovery contradicts what Asteria et al. (2020) found: higher female literacy levels lead to lower carbon dioxide emissions. In order to raise knowledge about the risks of carbon emissions, it is crucial to boost the literacy rate of women. In addition, the data shows that when GDP per capita rises, so do emissions, indicating that economic growth come at the expense of environmental quality. This conclusion is consistent with the results of other studies showing that rising levels of GDP per capita are associated with higher levels of carbon emissions (Zaman et al. 2016, Rashid Khan et al. 2021, Njoh 2021). The use of technology affects environmental quality, as shown by the fact that the predicted results of patent applications lead to increased carbon emissions. This finding agrees with other research by Ullah et al. (2021), Gao et al. (2022), and Awan & Sroufe (2020), revealing that technology innovation/resident patent rights increase carbon emissions. There is a negative association between the female labour market outcome and CO2 emissions, with a coefficient value of -1045, indicating that for every one unit change in the female participation in labour force, CO2 emissions fell by 1045 units. In addition, it exemplifies that the female labour force actively supports green environmental projects in the marketplace, which is a critical factor in reducing carbon emissions. The R-Square and the Adjusted R-Square values are pretty near one, indicating a solid match between the data and the model.

**Figure 3: Granger Causality Estimates**

Source: Author's illustration.

Figure 3 shows the Granger causality estimates for ready reference. The findings reveal bidirectional causality between the rising percentage of women in the labour force and carbon emissions and between technological advancement and women's independence. This finding suggests that a rise in carbon emissions is responsible for improved labour market results and that the converse is also true. In addition, continuous national progress is linked to technological innovations that pave the way for women to participate fully in the business sector. Carbon emission Granger cause women's autonomy, female labour force participation rate and technology innovation, which confirmed the emissions-led women's autonomy and technology innovation. Finally, economic growth Granger causes women's autonomy, and female share in the labour force substantiates the hypotheses of growth-led women's autonomy in a country. Table 5 shows the impulse response function (IRF) estimates.

**Table 5: IRF Estimates of Carbon Emissions**

Period	CO2	WA	FLFPR	FLR	GDPPC	TINOV
1	4674.140	0	0	0	0	0
2	6017.269	333.2168	827.8265	2325.074	849.3686	60.04620
3	5974.464	415.2675	1487.335	2970.311	1386.709	424.2108
4	5971.075	761.4303	1964.842	3169.576	1760.076	117.7976
5	5705.270	1020.569	2098.605	3462.660	2076.415	-249.1427
6	5250.982	1110.493	2294.227	3655.574	2208.018	-417.0061
7	4815.479	1124.307	2474.670	3795.509	2286.596	-536.9198
8	4487.871	1055.959	2546.783	3936.689	2332.990	-668.4325
9	4249.545	930.9877	2594.404	4092.904	2323.388	-788.2893
10	4068.868	773.8822	2640.725	4257.478	2283.395	-902.6858

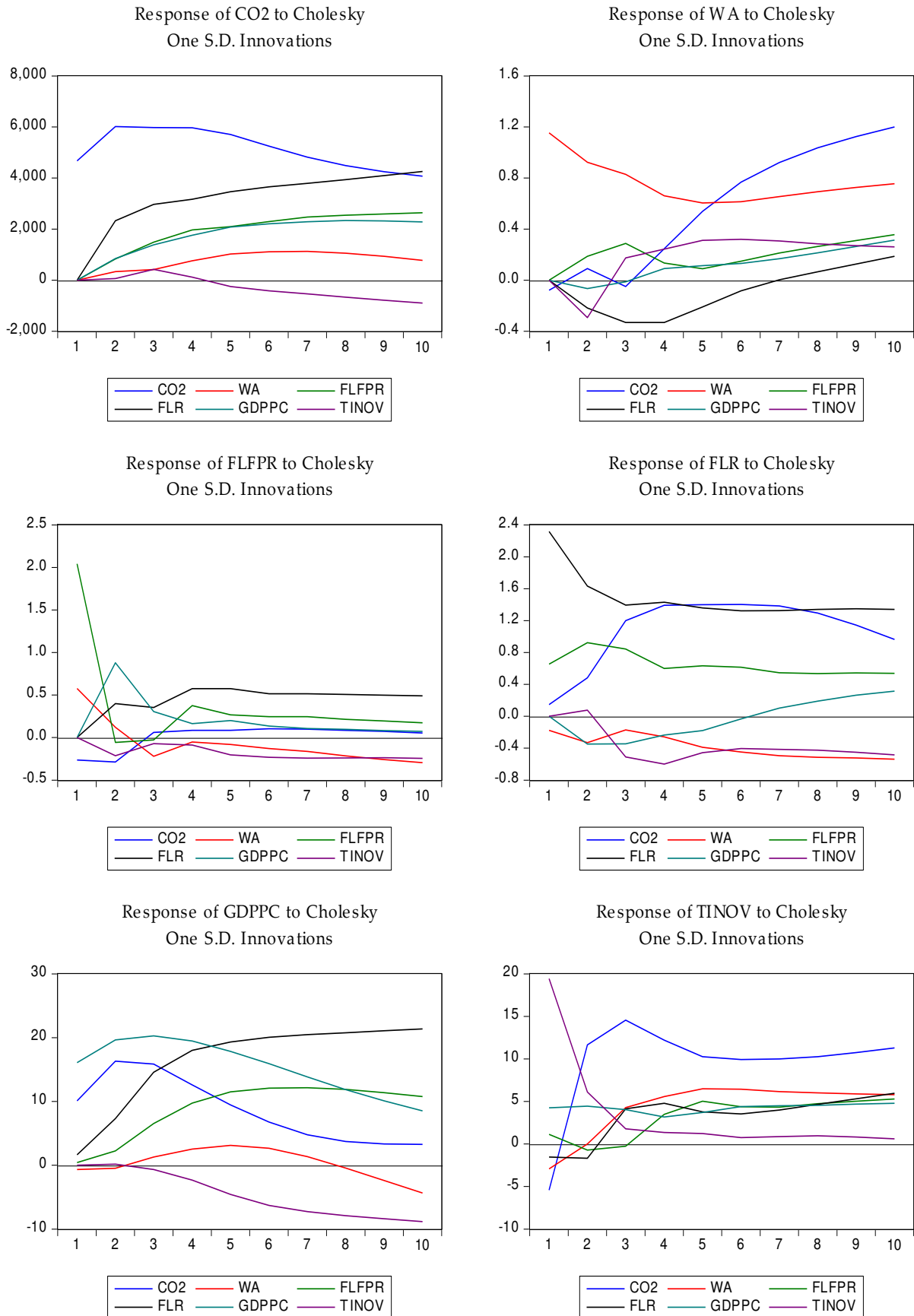
Note: CO2 shows carbon emissions, WA shows women's autonomy, FLFPR shows female labor force participation rate, FLR shows female literacy rate, GDPPC shows GDP per capita, and TINOV shows technology innovation.

According to the findings, factors such as women's autonomy, female labour market outcomes, female literacy rate, and sustained economic development are anticipated to increase carbon emissions over the next ten years. Even though technological innovation has produced contradictory outcomes, it has been demonstrated that technological innovation contributes to reducing carbon emissions as of the fifth period of forecasting. This indicates that the country is progressing toward using cleaner production technologies over time. Figure 4 shows the overall IRF estimates for ready reference. Table 6 presents the variance decomposition analysis (VDA) results, which discovered that the female literacy rate is projected to exert a more significant variance error shock on carbon emissions in the next ten years, as shown by the value of 24.320%. In addition, the consequences of female work and sustained economic expansion would impact carbon emissions, with an estimated variance error of 9.085% and 7.697%, respectively. The innovation in technological capabilities is expected to be the least impacted factor, with an estimated variation of 0.553% across time. Figure 5 shows the overall VDA illustrations for ready reference.

**Table 6: VDA Estimates of Carbon Emissions**

Period	S.E.	CO2	WA	FLFPR	FLR	GDPPC	TINOV
1	4674.140	100	0	0	0	0	0
2	8061.169	89.33969	0.170867	1.054588	8.319119	1.110188	0.005548
3	10676.47	82.24568	0.248696	2.541925	12.48276	2.319906	0.161036
4	12932.09	77.37613	0.516181	4.040962	14.51511	3.433564	0.118057
5	14886.18	73.08409	0.859581	5.037133	16.36516	4.536927	0.117108
6	16555.37	69.14979	1.144925	5.993018	18.10716	5.446980	0.158130
7	18016.10	65.53542	1.356239	6.947342	19.72828	6.210373	0.222345
8	19331.56	62.30935	1.476316	7.769619	21.28167	6.850370	0.312673
9	20545.97	59.43911	1.512274	8.472775	22.80858	7.343257	0.424006
10	21689.16	56.85775	1.484368	9.085532	24.32073	7.697910	0.553703

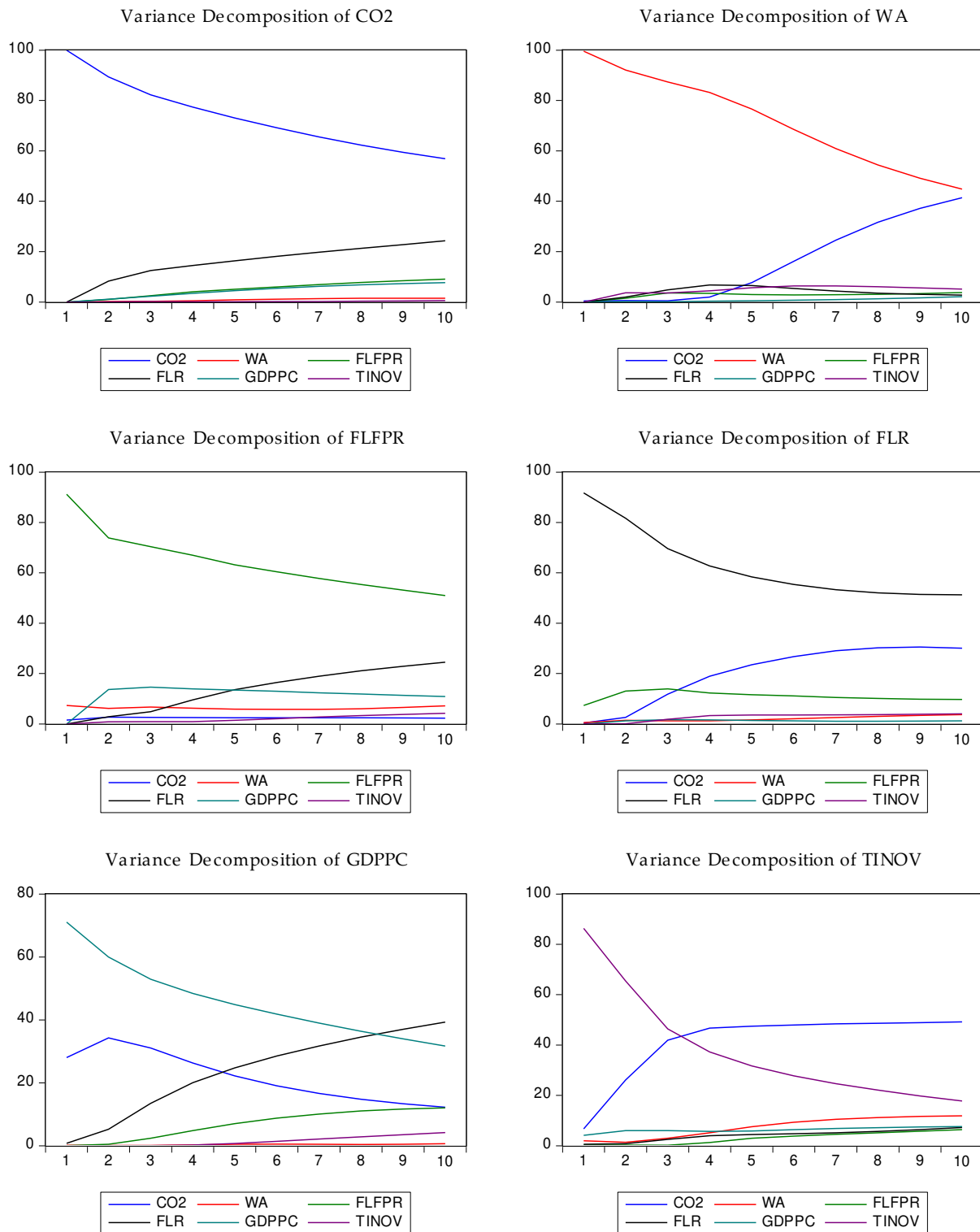
Note: CO2 shows carbon emissions, WA shows women's autonomy, FLFPR shows female labor force participation rate, FLR shows female literacy rate, GDPPC shows GDP per capita, and TINOV shows technology innovation.



**Figure 4: Overall IRF Estimates**

Source: Author's illustration Note: CO2 shows carbon emissions, WA shows women's autonomy, FLFPR shows female labor force participation rate, FLR shows female literacy rate, GDPPC shows GDP per capita, and TINOV shows technology innovation.





**Figure 5: Overall VDA Estimates**

Source: Author's illustration Note: CO2 shows carbon emissions, WA shows women's autonomy, FLFPR shows female labor force participation rate, FLR shows female literacy rate, GDPPC shows GDP per capita, and TINOV shows technology innovation.

#### 4. CONCLUSIONS AND POLICY RECOMMENDATIONS

Climate change is one of the planet's most significant and challenging problems. Pakistan is not an exception since the phenomena of climate change also have a significant impact. This research investigates how enhancing women's economic and political standing in Pakistan affects preserving the natural environment. For this purpose, the study developed a link between carbon emissions, women's autonomy, the female labour force participation rate, the female literacy rate, continued economic growth and technology innovation. The data was collected from 1975 to 2020. The result of using robust least squares demonstrates that increasing women's autonomy worsens the quality of the environment. However, this also reflects that the female workforce is advocating green environmental efforts in the market, which assists in lowering carbon emissions. The relationship between the two factors supports the argument, which is a positive development. The production of environmentally friendly goods in marketplaces traditionally linked with

women's work eventually contributes to improving the quality of the environment by reducing carbon dioxide emissions. The literacy rate of women has been shown to correlate positively with carbon emissions. The per capita income positively correlates with carbon emissions, leading to economic outcomes at the expense of environmental degradation. The diffusion of new technologies and innovations leads to an increase in labour outcomes, increasing national outputs. However, it increases carbon emissions. Economic progress was the impetus for the buildup of technical spillovers, which is the root cause of carbon emissions. It exposes the fact that the manufacturing technique that is currently being employed is not environmentally friendly. The Granger causality estimates show that women's autonomy and the rising proportion of patent applications move in both directions. Further, the female literacy rate and carbon emissions move simultaneously in both directions. Technology is moving in the same direction as the percentage of women participating in the workforce. Based on these results, it can be deduced that women's empowerment is essential for enhancing the quality of the environment.

A significant proportion of women must be employed in the labour force to achieve economic autonomy. It would enable females to feel more empowered to participate in the decision-making process, eventually enhancing the environment's quality. Access to high-quality education for girls and women is a prerequisite for gender equality and the achievement of sustainable development. Women should be educated about the environment and given a voice in environmental decision-making to encourage them to embrace environmentally responsible behaviours. Environmental education should be provided to women to encourage environmentally responsible behaviour on the part of women, thus reducing carbon emissions. In addition, the supply of 4% of GDP share is necessary to be begun in order to begin particular measures to enhance the female literacy rate. The billion tree Tsunami initiative has to be strengthened further, and one way to do so is to provide additional cash to the project. The overall quality of the environment will almost certainly increase as a direct result of this. Carbon emissions and the destruction of the ecosystem are global problems. Therefore, a reaction from the global community should also be requested via different platforms, such as the future conference of parties, to apprehend the threat amicably posed by excessive carbon emissions.

Pakistan should collaborate with the rest of the world to properly combat the already excessive levels of carbon emissions through innovative thinking. The empowerment of women, the establishment of environmental regulations, the imposition of a tax on carbon emissions, and the development of environmentally friendly technology can all contribute to promoting global sustainable development. Future leaders will likely be drawn from the ranks of women, who already possess the leadership skills necessary to tackle problems related to ethical sustainability in procurement and increase their employment participation. Women in green business tend to care better for the world than men do. Women's autonomy is essential to sustainable development, as are equitable opportunities and a supportive society. As a result of a growth strategy that is related to economic inequality, ecocide, biodiversity loss, and the question of healthcare, women's living conditions in cultures dominated by males are growing increasingly precarious. These cultures are also racist, violent, and discriminating. Because of the inextricable link between people and ecosystems, as well as between economic activities and civic systems, the current model of development needs to be rapidly revised to pave the way for a caring society that emphasizes the long-term viability of both people and ecosystems. It is necessary to generate development patterns that are just and equal. The most promising opportunity for a revolutionary and long-lasting recovery in terms of women's rights is found in the service society.

#### **Ethical approval**

Not Applicable.

#### **Informed consent**

The study was conducted with equal participation by all authors.

#### **Conflicts of interests**

The authors declare that there are no conflicts of interests.

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The study has not received any external funding.

#### **Data and materials availability**

The data is freely available at World Development Indicators published by World Bank (2022) at <https://databank.worldbank.org/source/world-development-indicators>.

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