

# Asymmetric and Dynamic Nexus between Gender Inequality and Green Finance

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Addressing gender inequality is not only a matter of social justice but also a fundamental prerequisite for achieving sustainable development. Despite the growing recognition of green finance as a key instrument for promoting environmental sustainability, the interaction between gender inequality and green finance has received limited scholarly attention. This study investigates the short-run, long-run, and threshold dynamics between green finance and gender inequality in OECD countries by employing Granger causality tests and a panel threshold regression (PTR) framework. The empirical findings reveal a unidirectional relationship in which gender inequality influences green finance only in the short run, whereas green finance exerts a significant impact on gender inequality exclusively in the long run. The results of the threshold regression model further indicate that gender inequality negatively affects green finance across both regimes. Conversely, green finance contributes to a reduction in gender inequality under both threshold conditions. These findings underscore the importance of reducing gender disparities and enhancing women's economic participation as essential strategies for expanding green finance and advancing the Sustainable Development Goals. Moreover, the effective implementation and continuous monitoring of green finance policies aimed at mitigating gender inequality should be prioritized by policymakers and governments.

**Keywords:** Green Finance, Gender Inequality, Causality, Threshold Effect.

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## 1. Introduction

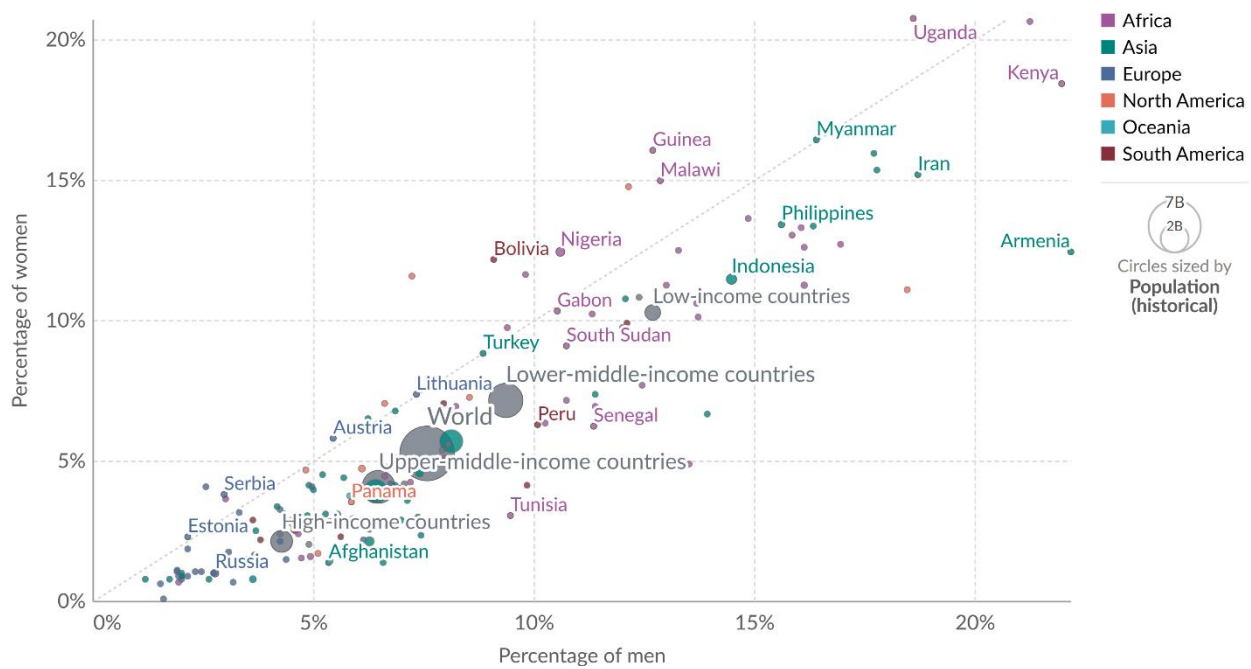
With the expansion of economic globalization, countries strive to utilize domestic and foreign investment as a means of achieving greater economic growth (Aykut et al., 2017). However, the social consequences of such investment are often overlooked, and this neglect can create challenges for social justice,

including gender inequality. Gender inequality refers to the unequal treatment of individuals based on their gender (Sharma, 2020). As shown in Figure 1, there is a significant disparity between men and women in access to financial resources. According to the World Bank's 2024 report, approximately 7.6% of men and 5.3% of women had access to credit capital in 2017 (Jose et al., 2023).

Figure 1

*Borrowing to start or expand a business, men versus women, 2017. Source: <https://ourworldindata.org/economic-inequality-by-gender>*





Gender inequality leads to widespread problems, including economic disparities, violence and harassment, limited educational opportunities, injustice in policymaking, adverse effects on mental health, restrictions on social participation, and the unequal distribution of domestic labor. These problems not only harm individuals but also negatively affect social and economic progress by restricting opportunities for growth and limiting collective potential (Choudhary, 2018; Koengkan et al., 2022).

Therefore, monitoring investment activities to reduce gender inequality is of considerable importance. In this regard, green financing—defined as investment that promotes environmentally sustainable practices—can be considered an effective and viable strategy. Today, as countries transition from non-renewable to renewable energy consumption, the importance of financing green and environmentally friendly projects has also increased (Afzal et al., 2022; Berrou et al., 2019; Lee, 2020; Volz, 2018).

Green financing can create employment and economic opportunities for women and strengthen their financial independence by supporting inclusive projects in sectors such as renewable energy and sustainable agriculture. Moreover, by improving infrastructure, including access to clean water and renewable energy, green financing can enhance women's quality of life. This form of investment also plays a significant role in reducing

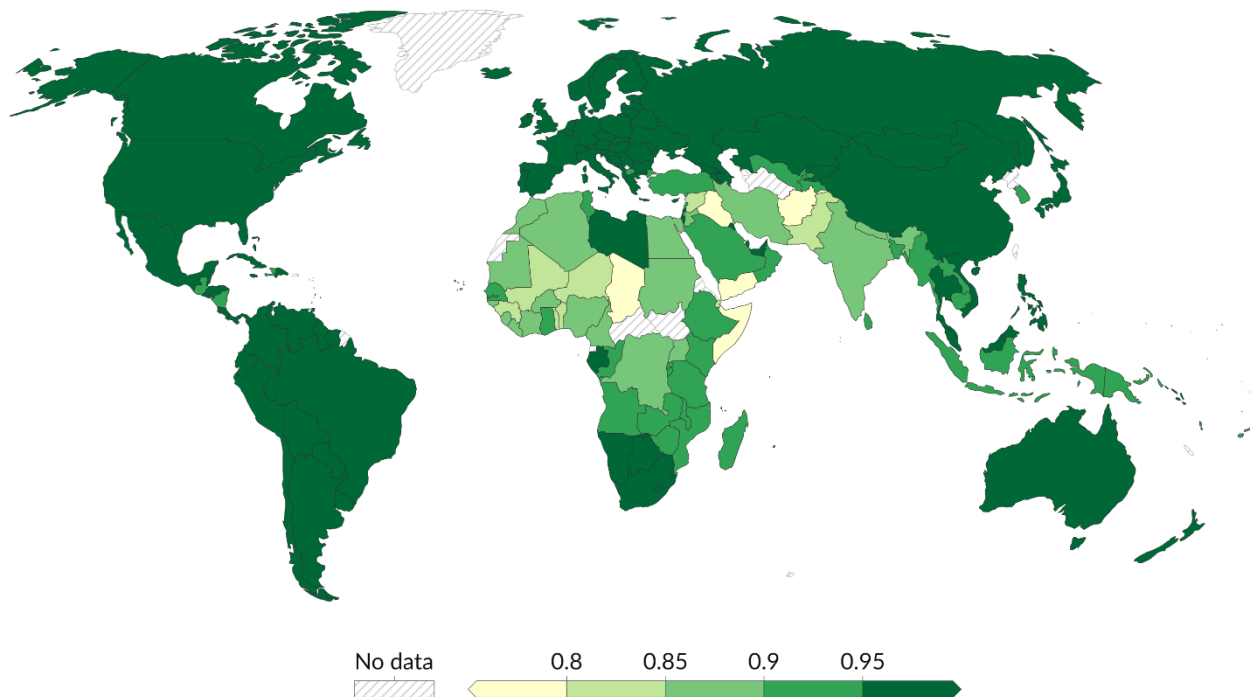
poverty and social inequalities, particularly in less-developed communities where women bear a disproportionate burden, by empowering women in green technologies and strengthening their capacity to address climate change (Dewi et al., 2023; Doku, 2024). Viewed from another perspective, women have limited participation in green finance as investors and decision-makers, in addition to experiencing unequal access to loans and financing related to the green economy (Javeed et al., 2022; Rätty & Carlsson-Kanyama, 2009). Women's limited presence restricts the range of perspectives and solutions available for improving the green economy. Women can provide significant insights and recommendations; however, when they are underrepresented in decision-making positions, their voices and needs are not adequately reflected in the green economy (Łapniewska, 2019; Vinz, 2009).

Reducing gender inequality can strengthen green financing through five key pathways: empowering women in financial decision-making, creating employment opportunities in green sectors, increasing the importance of green investment as a shared value, developing green financial models that account for gender-related effects, and raising awareness and providing women with financial and environmental education (Bosone et al., 2022; Chen, 2024; Paul et al., 2024). Although reducing gender inequality represents a potential means of strengthening green financing,

gender development remains limited in many regions and countries across Asia and Africa (Carlsen, 2020).

**Figure 2**

*Gender Development Index, 2022. Source: <https://ourworldindata.org/human-development-index>*



Although these two issues may initially appear unrelated, there is an important relationship between them that requires in-depth investigation. The first issue concerns unequal access to financial resources between women and men. This inequality substantially reduces women's capacity to participate in economic activities (Asongu et al., 2020; Ryan, 2014). Under conditions of inequality, women cannot adequately access loans and credit facilities associated with the green economy, thereby increasing their deprivation and perpetuating the cycle of poverty (Buechler et al., 2020; Carlsson-Kanyama & Lindén, 2007).

On the one hand, green finance can reduce inequality by increasing employment opportunities for women (Lazoroska et al., 2021; Sundström et al., 2016). From a more pessimistic perspective, however, increased green financing may exacerbate gender inequality. For example, women may depend on non-renewable resources to support their families. Consequently, the expansion of renewable-energy projects may cause them to lose their livelihoods, thereby weakening the potential benefits of green finance (Magnusdottir et al., 2015; Mort, 2019; Yang et al., 2015).

Although an important bidirectional relationship exists between green financing and gender inequality, these two areas have predominantly been examined separately. Many studies have analyzed the role of green financing in environmental sustainability and have demonstrated a positive relationship between them (Falcone et al., 2019; Khan et al., 2022; Mohd et al., 2018; Muganyi et al., 2021; Tran, 2022). Numerous other studies have identified factors contributing to the reduction of gender inequality, emphasizing the roles of education and economic development (Baudino, 2007; Camilletti, 2021; Cuberes et al., 2014; Ding et al., 2014; Khan, 2018).

Only a limited number of studies have examined the relationship between green financing and gender inequality in a unidirectional manner (Al Mamun et al., 2024; Arcuri et al., 2024; Dewi et al., 2023; Javeed et al., 2022; Shakil et al., 2024; Taylor, 2024). These studies have investigated either the effect of green financing on gender inequality or the effect of gender inequality on green financing and have generally reported a negative relationship.

Although green financing and gender inequality are each recognized as important issues, studies examining the relationship between them remain limited. This research gap has emerged for several reasons. First, researchers have primarily studied the two subjects separately and have paid insufficient attention to the ways in which gender dynamics and financial strategies may influence each other. Second, financial data are rarely disaggregated by gender, limiting researchers' ability to assess the effects of women's participation in green finance. Therefore, a substantial research gap exists concerning the relationship between green finance and gender inequality. Addressing this gap is important because empowering women and increasing their access to financial resources can accelerate sustainable development. A gender-responsive approach to green finance can create new markets and employment opportunities and ultimately improve countries' economic resilience to environmental shocks.

Existing research has also frequently relied on static and linear models, even though gender inequality is inherently dynamic. Reducing gender inequality requires long-term programs because substantial improvements cannot be achieved within a single year. Ignoring the dynamic nature of gender inequality can result in inaccurate estimates and inefficient predictions (Wallis, 1969). Moreover, linear models assume uniform effects, whereas the relationships under examination may differ across various levels or regimes. Linear models cannot adequately capture such variations, thereby limiting the ability to account for heterogeneity in the relationship between gender inequality and its associated factors.

To address this research gap, the present study employs a Panel Vector Error Correction Model to examine the bidirectional causality between green financing and gender inequality. The study also accounts for the dynamic nature of gender inequality and examines the potentially nonlinear effects of green financing on gender inequality and vice versa. Furthermore, it uses a purposive sample of OECD countries because their advanced economies, extensive financial resources, environmental commitments, potential to foster positive social change, and green innovations can provide valuable models for reducing gender inequality and achieving sustainable development.

The present study addresses the following questions: Has green finance affected gender inequality? Has green finance increased or decreased gender inequality? Conversely, have gender inequality and women's limited participation as decision-makers and investors in green projects affected the financing of these projects? Identifying the causal relationship between gender inequality and green finance can help policymakers working in the fields of women's empowerment and the green economy predict the consequences of future policies.

Accordingly, the first stage of this research investigates the causal relationship between green finance and gender inequality in OECD countries. The second stage examines the threshold effects between these two variables, which constitute an important innovation of the present study. The research seeks to determine whether the relationship between green finance and gender inequality differs across regimes defined by particular threshold values.

Examining the relationship between green financing and gender inequality can provide policymakers with valuable insights into empowering women and increasing their access to financial resources to accelerate sustainable development. Moreover, a gender-responsive approach to green financing can foster the creation of new markets and employment opportunities, ultimately strengthening economies' resilience to environmental shocks.

## 2. Literature Review

One important field of interdisciplinary research is feminist economics, which examines the relationship between gender and economic systems. This field argues that traditional economic theories frequently overlook women's economic participation. Since the emergence of feminist economics in the late twentieth century, numerous studies have challenged mainstream economic assumptions. One of the central concerns of feminist economics is gender inequality (Blais & Dupuis-Déri, 2022).

Gender inequality refers to discrimination or unequal treatment based on gender, whereby one gender is privileged over another. Gender discrimination encompasses numerous forms of prejudice and bias (Jain et al., 2023; Jose et al., 2023). Over time, research has consistently shown that unequal opportunities

negatively affect various aspects of women's lives, including health, education, and employment (Batra et al., 2016; Carlsen, 2020; Jha et al., 2015; Klasen, 2018; Ponthieux et al., 2015). Gender inequality therefore has far-reaching consequences for society (Kleven et al., 2019).

Numerous variables influence gender inequality. Access to education has a major effect on gender equality (Baudino, 2007). Economic development and gender inequality have a bidirectional relationship (Cuberes et al., 2014). Equal opportunities to access natural resources can reduce gender inequality (Ding et al., 2014). Poverty plays an important role in intensifying gender inequality (Khan, 2018), whereas social protection can contribute to its reduction (Camilletti, 2021).

Sustainable and green growth are among the factors that can affect gender inequality. Green growth represents an important response to the challenges of environmental degradation and climate change. It is an economic development strategy intended to promote economic growth while ensuring environmental protection and sustainability. A central issue in establishing green growth concerns the mechanisms through which it is financed, commonly referred to as green financing.

Green finance refers to the financial support of projects related to renewable energy and environmental sustainability (Akomea-Frimpong et al., 2022; Berrou et al., 2019; Ozili, 2022; Sachs et al., 2019). Expansion of the green economy is not possible without adequate financing. Green finance encompasses various instruments, including green bonds and green credit, which support projects intended to protect or improve the environment. Many studies in this field have shown that green finance can contribute to economic growth, climate-change mitigation, and environmental improvement (Afzal et al., 2022; Lv et al., 2021; Meo et al., 2022; Migliorelli et al., 2019; Zhou et al., 2020).

The various definitions of green finance can be summarized as follows: Green finance is an important mechanism for promoting economic growth and supporting sustainable development by providing financial resources for environmentally friendly projects.

Studies have examined numerous dimensions of green financing. Awareness of green-finance opportunities at the grassroots level remains limited (Mohd et al., 2018).

Green finance is crucial for environmentally sustainable innovation, although manufacturers may face financial constraints resulting from regulatory uncertainty (Falcone et al., 2019). China's green-finance policies have been associated with significant reductions in industrial emissions (Muganyi et al., 2021). Green finance has also reduced environmental footprints and appears to generate beneficial environmental outcomes (Khan et al., 2022). Furthermore, Granger-causality analysis has demonstrated unidirectional causal relationships from renewable-energy consumption to carbon dioxide emissions and from green investment to carbon dioxide emissions (Tran, 2022).

The relationship between green financing and gender inequality can be considered bidirectional.

First, gender inequality can profoundly affect green finance. Women, who are often disproportionately affected by existing gender inequalities, are more dependent on community assets and more vulnerable than men to the degradation of natural resources. Integrating gender considerations into green policies and environmental-protection initiatives can contribute to improving gender equality (Achampong & Officer, 2020; Hassanein, 2023; Saha et al., 2022).

Gender differences exist at multiple levels in roles and attitudes toward technology and renewable energy. Women are generally more likely to express concern about the environment and sustainability (Comeau et al., 2015), which may be associated with their motivation to protect their children and communities (Allen et al., 2019). Despite being perceived as environmentally concerned, women do not necessarily oppose investments in household renewable-energy systems (Schall, 2020). Women are generally interested in socially responsible investment; however, they may be reluctant to invest in renewable energy for their own households because of concerns that such investment will reduce the resources available for other priorities (Schall, 2020; Standal et al., 2020). Women's participation in renewable-energy cooperatives and renewable-energy projects remains considerably lower than men's participation in terms of investment, board membership, and active involvement (Łapniewska, 2019).

The factors contributing to women's limited participation in renewable-energy cooperatives include: (1) women's underrepresentation in the energy sector;



(2) women's greater risk aversion; (3) the establishment and recruitment practices of renewable-energy cooperatives; (4) the limited knowledge or willingness of these cooperatives to involve women; (5) women's time constraints; (6) the gender wealth gap; and (7) the formal structures of renewable-energy cooperatives.

The explanation most commonly offered for women's limited participation in renewable-energy cooperatives is their underrepresentation in the energy sector (Fraune, 2015; Łapniewska, 2019; Lazoroska et al., 2021). Women working in the energy sector rarely hold decision-making positions. Even when they occupy such positions, they often exercise relatively limited influence and are more likely to work in low-skilled or non-technical positions (Wilhite, 2017).

Women's risk aversion is frequently cited as the second most common explanation for their limited participation in renewable-energy cooperatives. A lack of time is also identified as a reason for women's lower participation. The gender wealth gap represents another factor limiting women's investment in renewable-energy cooperatives because women may have fewer financial resources. Women's average per-capita investment in such cooperatives is lower than men's, although the difference may not be statistically significant (Fraune, 2015).

Several studies have examined the effect of gender inequality on green finance. Women's active participation is necessary for improving green-finance mechanisms (Arend et al., 2011). Creating equal opportunities for women can increase green financing (Adegbite et al., 2020). Gender-equality policies can positively affect women's participation in green-finance projects (Atahau et al., 2021). Increasing women's managerial participation can improve the financing of women-owned small and medium-sized enterprises operating in the green economy (Sammy, 2021). Gender diversity can also strengthen green-innovation strategies (Javeed et al., 2022). Women play an important role in managerial choices and can influence green financing decisions (Arcuri et al., 2024). Green financing may therefore increase as women's political and economic empowerment improves (Al Mamun et al., 2024).

Second, green finance can reduce gender inequality by facilitating women's inclusion in related projects. Gender-responsive climate finance appears essential for

promoting sustainable development, reducing poverty, and addressing gender inequality. Accordingly, initiatives such as the Green Climate Fund have incorporated gender perspectives into their financing policies and operations (Shakil et al., 2024; Wong, 2016). Green finance can release women's economic potential, increase green entrepreneurial activities, and reduce gender disparities in access to financial resources. Sustainable development accelerates when more women are able to benefit from green financing (Saha et al., 2022; Wong, 2016).

Several studies have investigated the effect of green finance on gender inequality. Green financing can contribute to increased gender equality (Wong, 2016). However, the potential of green-finance mechanisms to promote eco-innovation can be weakened by persistent gender inequality (Saha et al., 2022). Green financing can also help reduce poverty and gender disparities (Kaddour et al., 2023). Increased financing for green projects can promote gender equality (Shakil et al., 2024), support women's empowerment (Dewi et al., 2023), and facilitate the use of digital green-finance technologies to reduce gender inequality (Taylor, 2024). A review of existing research indicates that several studies have examined the relationship between green financing and gender inequality in only one direction (Chan et al., 2018; Frenova, 2020; Schalatek, 2009; Schalatek et al., 2016; Stephan, 2020; Waheed et al., 2022; Williams, 2015; Wong, 2016). Given that each variable can influence the other, the application of bidirectional causality models is crucial. Moreover, the relationship between green financing and gender inequality may vary across different levels. Therefore, models that explicitly account for regime-specific coefficients are required. This issue is particularly important for policymakers seeking strategies to improve social justice, reduce gender inequality, and enhance environmental quality.

The present study differs from previous research, particularly the study of female political empowerment and green finance (Al Mamun et al., 2024), in two important respects. First, it employs a Panel Vector Error Correction Model. This approach captures the bidirectional causal relationship between green finance and gender inequality while also accounting for threshold effects in both variables. It therefore allows the calculation of threshold values and the estimation of

distinct coefficients that demonstrate the effect of green finance on gender inequality and vice versa. Second, the study employs a purposive sample of OECD countries, which distinguishes it from previous research. To date, no study has examined the bidirectional causality between green finance and gender inequality across OECD countries.

Compared with previous research, the present study offers two principal innovations.

First, previous studies have not examined the bidirectional causal relationship between green finance and gender inequality. One advantage of causality models is their ability to determine whether both variables cause one another or whether the causal relationship operates in only one direction.

Examining the causal relationship between these variables is important because each can affect the other. Both gender inequality and women's limited participation in financing green projects are problematic. An expansion of green projects may create opportunities for greater participation by women and consequently reduce gender inequality.

Second, the present research examines the threshold relationship between the variables.

One of the most important advantages of threshold models is their usefulness for policymaking because the effects of a policy may differ according to prevailing conditions. Threshold models can clearly demonstrate such differences. In the present study, this model helps identify critical points at which the behavior of green financing and gender inequality changes significantly.

By dividing the analysis into different regimes, threshold models provide clearer insights into the ways in which specific variables interact under different conditions. This can contribute to more accurate theoretical and practical interpretations of economic phenomena.

The present research seeks to determine whether green finance, when considered as a threshold variable, has different effects on gender inequality across different regimes. Gender inequality is also considered as a threshold variable to determine whether its effect on green finance varies across regimes.

### 3. Methodology

#### 3.1. Data

The present study investigates the causal relationship between green finance and gender inequality in selected OECD countries over the period from 2001 to 2019. Data for the remaining OECD countries were unavailable.

The principal limitation of the present research concerns data availability. Although the study was conducted in 2024, the most recent available data on green financing were from 2019.

**Green finance:** Data were extracted from the OECD Subnational Government Climate Finance Database.

**Gender inequality:** The Gender Inequality Index is based on three dimensions: reproductive health, empowerment, and economic status. Index scores range from 0 to 1, with higher scores indicating greater inequality.

#### 3.2. Econometric Method

First, the stationarity of the variables is evaluated. According to the theoretical foundations of econometrics, the future cannot influence the past or present, whereas past conditions can influence the present and future. If the variables are non-stationary, the resulting estimates may be misleading.

To select the appropriate stationarity test, cross-sectional dependence must first be examined. The Pesaran cross-sectional dependence test was used to determine whether the cross-sectional units were dependent or independent (Pesaran, 2004).

Panel unit-root tests differ according to whether they account for cross-sectional dependence. In general, two generations of panel unit-root tests can be distinguished. First-generation tests assess stationarity under the assumption of cross-sectional independence (Harris et al., 1999; Im et al., 1997; Levin et al., 1992). In contrast, second-generation tests assess stationarity in the presence of cross-sectional dependence (Choi, 2002; Moon et al., 2004; Pesaran, 2003).

In the second step, the variables included in the research are tested to determine whether a long-run relationship exists between them. The results of the cointegration test determine the type of causality test used in the next stage.

In the third step, if cointegration exists among the variables, the VECM is used to examine the relationships among them; otherwise, the VAR model is employed. Cointegration indicates that at least one long-run relationship exists among the variables, but it does not determine the direction of causality.

When variables are cointegrated, the conventional Granger-causality test within a VAR model is inappropriate because it omits the error-correction term that adjusts short-run disequilibrium. Accordingly, the Vector Error Correction Model should be employed to investigate long-run causal relationships (Engle et al., 1987).

$$\text{GreenFinance}_{it} = \alpha_i + \gamma_t + \beta_1 \text{GenderInequality}_{it} + \varepsilon_{1it} \quad (1)$$

$$\text{GenderInequality}_{it} = \alpha_i + \gamma_t + \beta_2 \text{GreenFinance}_{it} + \varepsilon_{2it} \quad (2)$$

where  $\text{GreenFinance}_{it}$  denotes green finance for country  $i$  at time  $t$ , and  $\text{GenderInequality}_{it}$  denotes gender inequality. The terms  $\alpha_i$  and  $\gamma_t$  represent the time-invariant individual effect and the time effect, respectively. The former captures all relatively stable and unobservable country-specific characteristics, whereas  $\varepsilon_{it}$  represents the error term. Equations (1) and (2) are parsimonious specifications that focus exclusively on the bivariate long-run relationship between gender inequality and green finance. However, the validity of these specifications requires that the variables be stationary or cointegrated (Asteriou et al., 2007; Herzer et al., 2012).

Before estimating Equations (1) and (2), the time-series properties of the variables must be examined using standard panel unit-root tests. If the first differences of

The Wald test is also used to evaluate short-run causal relationships. The direction and form of causality—unidirectional or bidirectional—are determined using the Granger-causality test.

Finally, the threshold relationship between green finance and gender inequality is investigated.

### 3.2.1. Panel Vector Error Correction Model

To examine the relationship between gender inequality and green finance, the empirical framework begins with the following baseline models:

the series are stationary, indicating that the variables are integrated of order one, panel cointegration tests can be conducted to determine whether a long-run equilibrium relationship exists between green finance and gender inequality (Wu et al., 2016). Because the variables are cointegrated, a Panel Vector Error Correction Model is estimated to test whether the relationship between green finance and gender inequality is causal.

Following the two-step procedure for cointegrated variables, the long-run models specified in Equations (1) and (2) are first estimated, and their residuals are obtained (Engle et al., 1987). Second, the lagged residuals from Equations (1) and (2) are defined as error-correction terms,  $ECT_{1,i,t-1}$  and  $ECT_{2,i,t-1}$ , to generate the following Panel Vector Error Correction Model:

$$\Delta \text{GreenFinance}_{it} = \mu_{1i} + \sum_{k=1}^p \beta_{11,k} \Delta \text{GreenFinance}_{i,t-k} + \sum_{k=1}^p \beta_{12,k} \Delta \text{GenderInequality}_{i,t-k} + \lambda_1 ECT_{1,i,t-1} + \varepsilon_{1it} \quad (3)$$

$$\Delta \text{GenderInequality}_{it} = \mu_{2i} + \sum_{k=1}^p \beta_{21,k} \Delta \text{GreenFinance}_{i,t-k} + \sum_{k=1}^p \beta_{22,k} \Delta \text{GenderInequality}_{i,t-k} + \lambda_2 ECT_{2,i,t-1} + \varepsilon_{2it} \quad (4)$$

where  $\Delta$  is the first-difference operator, and  $p$  is the optimal lag length determined using standard information criteria, including the Akaike Information Criterion and Bayesian Information Criterion. Granger

causality can be examined in two ways. First, short-run or weak Granger causality is evaluated by jointly testing the significance of the lagged differences of the variables using a Wald test. Second, long-run causality is evaluated



by examining the statistical significance of the error-correction terms.

The null hypothesis of no short-run causality from gender inequality to green finance is:

$$H_0: \beta_{12,k} = 0 \text{ for all } k = 1, \dots, p.$$

Similarly, the null hypothesis of no short-run causality from green finance to gender inequality is:

$$H_0: \beta_{21,k} = 0 \text{ for all } k = 1, \dots, p.$$

$$\text{GenderInequality}_{it} = \mu_i + \beta_1 \text{GreenFinance}_{it} I(\text{GreenFinance}_{it} \leq \gamma) + \beta_2 \text{GreenFinance}_{it} I(\text{GreenFinance}_{it} > \gamma) + \varepsilon_{it} \quad (5)$$

$$\text{GreenFinance}_{it} = \eta_i + \delta_1 \text{GenderInequality}_{it} I(\text{GenderInequality}_{it} \leq \gamma) + \delta_2 \text{GenderInequality}_{it} I(\text{GenderInequality}_{it} > \gamma) + \nu_{it} \quad (6)$$

where  $\gamma$  denotes the threshold value of the relevant threshold variable (Rostamzadeh et al., 2018), and  $I(\cdot)$  is an indicator function that equals 1 when the stated condition is satisfied and 0 otherwise.

Short-run causality is therefore assessed using the statistical significance of the partial  $F$ - or Wald statistic associated with the relevant regressors. Long-run causality is assessed through the statistical significance of  $\lambda_1$  and  $\lambda_2$ .

### 3.2.2. Panel Threshold Regression

The Panel Threshold Regression model was used to estimate the threshold effect of each variable on the other (Hansen, 2000):

## 4. Findings

The Pesaran cross-sectional dependence test was used to determine whether the cross-sectional units were dependent or independent (Pesaran, 2004). The results are presented in Table 1.

**Table 1**

*Results of the cross-sectional dependence test*

| Variable                       | Test statistic | <i>p</i> -value |
|--------------------------------|----------------|-----------------|
| GreenFinance <sub>it</sub>     | 4639.106       | 0.000           |
| GenderInequality <sub>it</sub> | 6087.000       | 0.000           |

As shown in Table 1, the null hypothesis of the Pesaran cross-sectional dependence test was rejected. This finding indicates the presence of cross-sectional dependence among the investigated variables. Accordingly, the second-generation panel unit-root test

was used to examine the stationarity of the variables (Pesaran, 2003). The null hypothesis indicates the presence of a unit root. The results are presented in Table 2.

**Table 2**

*Results of the panel unit-root test*

| Variable                       | Test statistic | <i>p</i> -value |
|--------------------------------|----------------|-----------------|
| GreenFinance <sub>it</sub>     | -2.21          | 0.040           |
| GenderInequality <sub>it</sub> | -2.15          | 0.048           |

As shown in Table 2, both variables were stationary. In the next step, the Kao cointegration test was used to determine whether a VAR or VECM specification was appropriate. The null hypothesis of the test indicates the

absence of cointegration. When cointegration exists, a VAR model is no longer appropriate, and a VECM should be employed. The results are presented in Table 3.

**Table 3***Results of the Kao cointegration test*

| Test | t-statistic | Probability |
|------|-------------|-------------|
| ADF  | 116.1       | 0.030       |

As shown in Table 3, the null hypothesis was rejected. Therefore, because cointegration existed between the variables, the VECM was used to investigate the long-run Granger-causality relationship.

The VECM and its error-correction terms were used to determine the long-run Granger-causality relationships. Identifying the optimal lag length in a VECM is essential to ensure that the model residuals satisfy the classical

assumptions. Various criteria can be used to determine the optimal lag length, including the Akaike, Hannan–Quinn, and Schwarz criteria. In the present study, the optimal lag length was determined to be one.

The results of the long-run causality analysis between green finance and gender inequality are presented in Table 4. The null hypothesis indicates the absence of causality.

**Table 4***Results of the long-run Granger-causality analysis*

| Error-correction term | $\Delta(\text{GreenFinance})$ | $\Delta(\text{GenderInequality})$  |
|-----------------------|-------------------------------|------------------------------------|
| $ECT_{t-1}$           | -0.000441<br>[-1.26922]       | $8.29 \times 10^{-5}$<br>[5.06834] |

According to the results presented in Table 4, a unidirectional long-run causal relationship exists from green finance to gender inequality. This indicates that green finance affects gender inequality in the long run, whereas gender inequality does not have a statistically significant long-run effect on green finance.

The findings of this section are consistent with previous empirical research showing that green finance can

influence gender equality (Kaddour et al., 2023; Saha et al., 2022; Shakil et al., 2024; Wong, 2016).

The long-run results indicate that only green finance affects gender inequality. The next stage examines whether the direction of causality changes in the short run. The null hypothesis indicates the absence of causality. The results are presented in Table 5.

**Table 5***Results of the short-run causality analysis*

| Direction of causality            | Chi-square | Probability |
|-----------------------------------|------------|-------------|
| Gender inequality → Green finance | 8.070748   | 0.000       |
| Green finance → Gender inequality | 0.040021   | 0.840       |

According to the results presented in Table 5, a unidirectional short-run causal relationship exists from gender inequality to green finance. In contrast to the long-run results, green finance does not significantly affect gender inequality in the short run.

The findings of this section are consistent with empirical studies emphasizing the effect of women's participation and gender equality on green financing (Adegbite et al., 2020; Arcuri et al., 2024; Arend et al., 2011; Atahau et al., 2021; Javeed et al., 2022; Sammy, 2021).

Finally, the threshold relationship between green finance and gender inequality was examined using the Panel Threshold Regression model.

First, the threshold effect of green finance on gender inequality was investigated. Green finance was treated as the threshold variable to determine whether its effect on gender inequality differed across regimes. The null hypothesis of a single threshold value was tested. The results showed an  $F$ -statistic of 24.75 and a  $p$ -value of 1.00. Therefore, there was insufficient evidence to reject

the null hypothesis. The estimated threshold value of green finance was 7.76, with a 95% confidence interval

ranging from 7.59 to 7.98. The results are presented in Table 6.

**Table 6**

*Threshold effect of green finance on gender inequality*

| Relationship                                  | First-regime coefficient: Green finance $\leq$ <b>7.76</b> | Second-regime coefficient: Green finance $>$ <b>7.76</b> |
|-----------------------------------------------|------------------------------------------------------------|----------------------------------------------------------|
| Green finance $\rightarrow$ Gender inequality | -0.0645<br>[-18.79]                                        | -0.0682<br>[-18.29]                                      |

As shown in Table 6, the effect of green finance on gender inequality is statistically significant in both regimes. However, its effect is stronger in the second regime. When green finance exceeds the threshold value, its negative effect on gender inequality increases, indicating that higher levels of green financing are associated with greater reductions in gender inequality.

Second, the threshold effect of gender inequality on green finance was investigated. Gender inequality was

treated as the threshold variable to determine whether its effect on green finance differed across regimes. The null hypothesis of a single threshold value was tested. The results showed an  $F$ -statistic of 14.30 and a  $p$ -value of 1.00. Therefore, there was insufficient evidence to reject the null hypothesis. The estimated threshold value of the Gender Inequality Index was 0.1670, with a 95% confidence interval ranging from 0.1590 to 0.1700. The results are presented in Table 7.

**Table 7**

*Threshold effect of gender inequality on green finance*

| Relationship                                  | First-regime coefficient: Gender inequality $\leq$ <b>0.1670</b> | Second-regime coefficient: Gender inequality $>$ <b>0.1670</b> |
|-----------------------------------------------|------------------------------------------------------------------|----------------------------------------------------------------|
| Gender inequality $\rightarrow$ Green finance | -8.10<br>[-23.48]                                                | -10.03<br>[-20.90]                                             |

According to the results presented in Table 7, gender inequality has a statistically significant negative effect on green finance in both regimes. However, this effect is stronger in the second regime. When gender inequality exceeds the threshold value, its negative effect on green finance increases. Thus, higher levels of gender inequality are associated with a sharper decline in green financing.

## 5. Conclusion

Examining the causal relationship between gender inequality and green finance can help identify women's role in promoting sustainable development. The present study investigated the relationship between green finance and gender inequality in OECD countries over the period from 2001 to 2019. For this purpose, long-run and short-run relationships between the two variables were examined using Granger-causality analysis, after which their threshold relationship was investigated using Panel Threshold Regression.

The results demonstrated a unidirectional causal relationship from green finance to gender inequality in the long run and from gender inequality to green finance in the short run. The threshold-effect results also showed that when gender inequality is below its threshold value, it has a negative effect on green finance. When gender inequality exceeds the threshold value, this negative effect becomes stronger. Therefore, as gender inequality increases, its adverse effect on green finance intensifies substantially.

When green finance is considered the threshold variable, it reduces gender inequality both below and above the estimated threshold. However, when green finance exceeds its threshold value, its inequality-reducing effect becomes stronger. Overall, the findings demonstrate a strong and significant relationship between gender inequality and green finance.

Gender inequality affects green finance in the short run. Higher gender inequality is associated with lower levels of green finance, partly because women have fewer opportunities to participate in green-finance projects. Therefore, gender inequality must be reduced to

improve the financing of projects related to sustainable development. This finding is consistent with previous studies emphasizing the importance of women's participation in green financing (Adegbite et al., 2020; Arcuri et al., 2024; Arend et al., 2011; Atahau et al., 2021; Javeed et al., 2022; Sammy, 2021).

Green finance affects gender inequality in the long run. Higher levels of green finance are associated with lower levels of gender inequality. Increasing green finance can create more opportunities for women's participation and thereby contribute to reducing gender inequality.

By supporting women's economic empowerment, increasing financial inclusion, empowering women as investors and decision-makers, and encouraging sustainable consumption and production, green finance can contribute to creating a more equitable and sustainable world. Governments, financial institutions, and individuals must recognize the potential of green finance to address gender inequality and harness this potential to build a better future. This finding is consistent with previous studies demonstrating the contribution of green financing to gender equality and women's empowerment (Kaddour et al., 2023; Saha et al., 2022; Shakil et al., 2024; Wong, 2016).

Accordingly, it is essential to empower women, provide them with equal access to green-finance opportunities, and utilize their knowledge and expertise to accelerate sustainable development.

One of the most important manifestations of gender inequality in green finance concerns women's access to financial resources and their representation in leadership positions within environmental enterprises. Women frequently encounter systematic obstacles to obtaining loans and benefiting from investment because of discrimination, insufficient collateral, and limited financial literacy. Even when women's participation in environmentally related labor markets is substantial, they may receive only a small proportion of the financial support allocated to these sectors.

Women's limited access to investment constrains their ability to adopt green technologies, implement sustainable agricultural practices, and develop renewable-energy solutions. Another dimension of gender inequality is women's underrepresentation in leadership and decision-making roles within financial institutions.

Women's participation is essential to the development of policies related to environmental sustainability. Gender-diverse leadership teams are more likely to consider a wider range of perspectives and solutions, thereby contributing to stronger green-finance initiatives. However, the predominance of male leadership in financial industries can result in insufficient attention to women's specific needs and their potential contributions to sustainable development. This situation not only affects policy outcomes but can also discourage women entrepreneurs from entering green sectors.

Although green finance has primarily focused on combating climate change and promoting sustainable economic activity, it also has important implications for gender inequality. Women often encounter barriers to accessing financial resources because of inequalities rooted in sociocultural norms. Green-finance initiatives that prioritize gender diversity can increase women's access to financing.

Microfinance programs for women entrepreneurs in renewable-energy sectors can enable women to invest in sustainable enterprises and thereby strengthen economic sustainability. The transition to a green economy can also provide diverse employment opportunities for women in sectors such as renewable energy and sustainable agriculture.

By implementing policies that explicitly incorporate gender considerations, governments can ensure that women have adequate and equitable opportunities to participate. Women's participation in green employment can generate broader social benefits, including stronger community resilience and sustainability. Training programs can also strengthen women's managerial and leadership skills in green projects.

The findings of the present research inform policymakers about the consequences of excluding women from green projects. The short-run results indicate that increased gender inequality and women's absence as investors and decision-makers reduce green financing. This is an important and challenging finding. Accelerating sustainable development is not possible without women's participation. Therefore, governments and policymakers should create the conditions necessary for women to participate more actively as decision-makers and investors.

Another important finding concerns the long-run effect of increased green financing on reducing gender

inequality. Accordingly, conditions should be established to ensure that women and men can benefit equally from green-finance resources.

The relationship between gender inequality and green financing is complex, and policies addressing this relationship may be difficult to implement. Nevertheless, initiatives such as the Green Climate Fund have made considerable progress in integrating gender perspectives into their operations. Projects specifically designed to benefit women can help ensure that women and men participate equally in project implementation. Furthermore, promoting women's green entrepreneurship through education, training, and other forms of support can reduce gender disparities in access to financial resources. Investors and governments can increase women's participation by granting loans for green projects based partly on their contribution to reducing gender inequality.

Green finance has substantial potential to address gender inequality by promoting economic empowerment, creating employment opportunities, and strengthening community resilience. To realize these benefits fully, stakeholders should prioritize gender mainstreaming in the planning and implementation of green-finance initiatives. Aligning environmental objectives with gender equality can contribute to a more sustainable and just future.

Achieving the Sustainable Development Goals by 2030 is an ambitious but necessary objective for ensuring a better future. Among these goals, gender equality under SDG 5 and climate action under SDG 13 are particularly important pillars that influence numerous global economic variables. Women are generally affected disproportionately by environmental degradation and climate change. Empowering women can promote more efficient resource management and increase countries' resilience to climate change. Integrating gender perspectives into environmental policies can therefore produce more inclusive and effective strategies that both reduce environmental damage and accelerate community development.

### 1. 5. Policy Implications

Addressing gender inequality in the context of green finance is essential for achieving the Sustainable Development Goals. By implementing the following policy measures, stakeholders can create a more

equitable financial environment that enables women to participate meaningfully in environmental activities.

A holistic approach that incorporates gender considerations into green-finance policies will not only increase equity but also improve the effectiveness and global impact of sustainable-finance initiatives.

Gender inequality and green financing create both critical opportunities and significant challenges for sustainable development. As countries and public and private organizations increasingly prioritize environmental issues, it is necessary to consider the role of gender dynamics in designing financial mechanisms and green investments.

To increase women's participation in green finance, policies should be designed to strengthen the development of green financing while promoting gender equality. This objective can be pursued through the following measures:

1. Design financial products, such as low-interest loans with extended repayment periods, specifically for women entrepreneurs and women engaged in environmental activities.
2. Implement educational programs that improve women's financial literacy and familiarize them with the green economy and sustainable development.
3. Encourage companies engaged in green activities to employ more women and involve them more extensively in their projects.
4. Support research and university projects that examine the relationship between gender policies and the financing of sustainable-development initiatives.
5. Establish partnerships that utilize the resources and expertise of both the public and private sectors to promote gender-responsive green-finance initiatives.
6. Involve women-led organizations in the design and implementation of green-financing policies to ensure that women's perspectives and needs are adequately represented.

Policies intended to strengthen gender equality in green finance should also include robust regulatory frameworks that promote equal access and opportunities. The principal components of these frameworks include the following:



2. Introduce financial incentives, such as tax rebates or grants, for institutions that prioritize lending to women-owned businesses in green sectors.
3. Ensure that property-rights systems and legal frameworks support women's ownership and control of land and other assets.

### Authors' Contributions

Authors contributed equally to this article.

### Declaration

In order to correct and improve the academic writing of our paper, we have used the language model ChatGPT.

### Transparency Statement

Data are available for research purposes upon reasonable request to the corresponding author.

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### Declaration of Interest

The authors report no conflict of interest.

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### Ethical Considerations

In this research, ethical standards including obtaining informed consent, ensuring privacy and confidentiality were observed.

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