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Investigating The Relationships Between Gender Inequality, International Trade and Innovation: Evidence from Türkiye

Abstract

This study examines the complex relationships between gender inequality, international trade, and innovation in Türkiye. Gender inequality, international trade, and innovation data, compiled for the Turkish economy between 1991 and 2022, were analyzed using the Nonlinear Autoregressive Distributed Lag (NARDL) model. According to the results of the study, a 1% increase in the Gender Development Index (GDI) leads to a 1.4% decrease in trade, while a 1% decrease causes a 1.2% decrease. This indicates that trade responds asymmetrically to changes in gender equality, reflecting differential adjustment effects. Furthermore, innovation, as measured by patent activity, is asymmetrically affected by gender inequality. A 1% increase in the Gender Inequality Index (GII) significantly increases the number of patents by 38%, while a decrease has no significant effect. These findings highlight the importance of addressing gender inequalities to promote inclusive innovation and equitable trade growth. The findings explain the existence of strong and asymmetric relationships between gender inequality, international trade, and innovation. Importantly, these results should not be interpreted as policy recommendations against improving gender equality, but rather as reflecting transitional economic dynamics. When the results are evaluated in terms of the UN Sustainable Development Goals (SDGs), trade contributes to progress in gender equality and supports the achievement of the goals of Gender Equality, Decent Work and Economic Growth, and Reduced Inequalities. At the same time, the findings indicate that an increase in GII leads to a significant increase in the number of patents is related to the SDGs' of Gender Equality, Industry, Innovation and Infrastructure, and Reduced Inequalities.

Keywords: Gender Inequality, International Trade, Innovation, NARDL

JEL Classification: C32, F13, J16, O33

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1. Introduction

Gender equality denotes the equitable rights of both sexes, male and female, regarding opportunity and involvement in society (Şener, 2022). Gender inequality, on the other hand, refers to discrimination and restrictions that prevent or eliminate the recognition and exercise of women's human rights and fundamental freedoms in political, economic, social, cultural, and civil spheres based on their gender, or that aim to do so (Demirgöz Bal, 2014).

This discrimination can be observed in many areas. For example, the restructuring sector has historically been dominated by men. Even today, it is common for a woman in restructuring to be the only woman in a room full of men. This lack of representation of women in sectoral restructuring means that women are generally expected to conform to the behavior typically exhibited by men and may encounter prejudice and resistance if they behave as they are (Williams et al., 2024). When viewed by sector, it is evident that female employment in the construction industry remains at very low levels (Eugenidis et al., 2022). It has been determined that women working in this sector are generally employed in simpler jobs. For example, in the United Kingdom, the majority of women working in the construction sector are employed in office and secretarial roles, and nearly half of these are employed part-time (Davey et al., 2010). When evaluated in terms of company size, gender equality decreases as the company shrinks and increases as it grows. In other words, there is a positive relationship between company size and gender equality. For example, companies with 1 to 5 employees experience nearly twice as many gender equality problems on average compared to larger companies (Segarra & Teruel, 2017). Gender discrimination, which varies by sector and company size, increases particularly during times of crisis. In France, the Laval government's ban on married women working in public services “to combat unemployment” during the economic depression of the 1930s is a case in point (Ordioni, 2019).

There are studies in the literature that examine gender equality from different perspectives, such as the impact on a country's level of economic development (Bertay et al., 2020), employment and wages (Tzannatos, 2016), education and economic growth (Klasen & Lamanna, 2009), and development (Gürbüz, 2019). When the situation of gender equality in Türkiye is evaluated, it shows that despite the continuous improvements in socioeconomic indicators at both national and international levels, the position of women in public life is still not at an optimal level (Kavas, 2018). Gender inequality is widespread in Türkiye's labor market, healthcare system, decision-making structures, and education system (Fındık, 2025). According to the Gender Equality Monitoring Report of Türkiye 2023-2024, the female labor force participation rate in Türkiye (35.8%) in 2023 was half that of men (71.2%). In 2023, the number of unemployed women was 1.498 million, and the unemployment rate was 12.6%. The primary reason women remain outside the labor force is unpaid household and care work, which affects 42.9% of women. As of 2021, almost all housework is considered a woman's responsibility (Toksöz et al., 2025). This disparity in women's employment compared to men in Türkiye, and the perception of women, is evident in many areas of daily life and business life. For example, women's labor force participation in Türkiye remains low (36 percent), political representation is limited (17.3 percent in parliament), and women own only 13.2 percent of agricultural land. Furthermore, persistent gender stereotypes persist both domestically and professionally, reinforced by cultural norms and unequal access to digital technologies (Fındık, 2025).

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Whilst cultural differences, that vary from country to country, play a significant role in this inequality between women and men, it is important to monitor and improve gender discrimination due to its relationship with the country's other economic and social attitudes. Over the years, a series of studies have been conducted on discrimination against women in Türkiye, using various measures as indicators. These studies have generally examined variables such as wage inequality, education and literacy, employment and employment rates, occupational gender wage gaps between low- and high-skilled occupations, economic equality, health equality, and representation in parliament (Kabeer and Natali, 2013). However, no studies in the literature have been found that examine the relationship between the innovation performance of countries that improve the quality of life in Türkiye and the gender inequality stemming from women's exclusion from these processes. Unfortunately, innovation and technology rarely benefit women and men equally. However, digital participation and innovation play an important role in the economic empowerment of women and offer them new opportunities in the fields of science, technology, engineering, and mathematics (World Trade Congress, 2025). A gender gap in this area constrains efforts to promote gender equality and empower women, preventing women from being both developers and consumers of technology that meets their needs.

The relationship between international trade and gender inequality is complex and multidimensional, varying across countries depending on factors such as the level of development, sectoral structure, and social norms. While international trade can reduce inequality by creating new opportunities for increasing women's employment, it can also trigger existing inequalities and structural problems.

However, no studies in the Turkish literature examine the relationship between international trade, which increases national income, and gender inequality. Reducing gender inequality practices that hinder women's employment opportunities and ability to find work, can increase foreign direct investment and international trade by increasing the participation of skilled female workers in the workforce (Ryu & Nam, 2024). This contributes positively to both the national economy and social life.

International trade and export-based growth strategies have increased the demand for female labor, particularly in developing countries (Calvo-Calvo et al., 2025). Companies with global production networks prefer to employ women at relatively lower wages to reduce labor costs, which are the most important source of costs, to gain a competitive advantage (Carvalho, 2021). In countries such as Brazil, Vietnam, and Bangladesh, trade liberalization due to globalization has significantly increased female labor employment in the formal economy, particularly in labor-intensive manufacturing sectors such as textiles and ready-to-wear clothing (Calvo-Calvo et al., 2025; Carvalho, 2021; Connolly, 2022; Jacobsen & Lee, 2025). This increase in female employment is referred to as the feminization of labor (Carvalho, 2021).

One of the underlying reasons for the increase in female employment, as mentioned earlier, is the widening wage gap. The impact of increased competition resulting from globalization on wage inequality occurs in two ways. According to neoclassical economic theory, increased international competition raises the cost of discrimination for firms, which can lead to a reduction in wage differences between women and men (Bezuidenhout et al., 2019; Coniglio & Hoxhaj, 2022). For example, in Japan, exporting firms and multinational companies maintain lower gender wage gaps and pay women more fairly than local firms (Greaney & Tanaka, 2021). In terms of employment rates, as in Brazil, competition from Chinese products increases women’s employment share, thereby reducing female unemployment (Connolly, 2022). On the other hand, shrinking profit margins due to increased international competition cause companies to exploit women's weak bargaining power to reduce costs and employ women at lower wages

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(Menon & Rodgers, 2009). Furthermore, companies engaged in international trade demand flexibility (such as working hours and travel) from their employees to reach customers in different time zones around the world. Women are perceived as less flexible due to the roles society assigns them, which can increase the wage gap in favor of men (Bezuidenhout et al., 2019). In the US, a significant wage gap has been identified, showing that women earn 31.5% less than men as a result of layoffs due to international trade (Ghosh et al., 2022).

The increase in international trade has limited female employment to production stages that are mostly low-skilled, low-paid, labor-intensive, or, in other words, require unskilled labor (Carvalho, 2021). Although international trade increases female employment in lower- and middle-level jobs, there is evidence that it creates a race to the bottom for women in senior management positions (Heckl et al., 2025). Furthermore, when a value chain in sectors such as agriculture and fisheries becomes profitable and commercial, male labor dominance increases in that area, while women are pushed into less profitable parts of the value chain (Pyburn et al., 2023).

Foreign direct investment and international trade facilitate the transfer of goods, capital, and gender norms across borders (Greaney & Tanaka, 2021; Heckl et al., 2025). Multinational companies from countries with high gender equality (especially those making greenfield investments from scratch) contribute to reducing gender inequality by applying their own more egalitarian human resource and wage policies in the countries where they operate (Greaney & Tanaka, 2021; Bezuidenhout et al., 2019).

Orthodox (mainstream) trade policies generally adopt a market-oriented approach that ignores women's unpaid care work, domestic responsibilities, and structural inequalities (Carvalho, 2021; Hannah et al., 2022). Such liberalization can sometimes destroy women's traditional livelihoods. For example, women in Haiti, who play a key role in local agricultural production, have been forced out of production as a result of the spread of free trade and cheap food import policies (such as rice imports); instead, they are pushed into the less profitable position of distributors and consumers of imported products, losing both their income and their autonomy (Vansteenkiste, 2022).

Just as international trade affects gender inequality, the latter has a direct impact on international trade. Gender inequality can negatively affect international trade and, indirectly, the economic growth. Gender inequality in education and employment leads to the misallocation of talent, a shrinking labor pool, reduced productivity, and stifled innovation (Nam et al., 2026; Ryu & Nam, 2024). The failure to utilize women's potential reduces a country's attractiveness for direct foreign investment (Ryu & Nam, 2024). Studies conducted in transition economies in Europe show that while trade liberalization contributes positively to economic growth, gender inequality significantly suppresses and weakens this positive effect (Nam et al., 2026). However, although it may seem paradoxical, gender inequality can numerically increase international trade, export capacity, and global competitiveness in the short and medium terms, especially in developing countries and labor-intensive sectors. While gender inequality may appear positive for export strategies based on low-cost channels in the short term, deepening inequality undermines the quality of international trade and sustainable growth in the long term.

Despite global progress and legal efforts in many countries, gender-based inequalities persist, particularly in contexts such as Türkiye, where complex cultural and institutional dynamics prevail. Although significant progress has been made in raising women's educational attainment, gender inequalities persist in other areas. While global research emphasizes the importance of women's creativity and role in

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international trade for increasing countries' prosperity levels, Turkey has not sufficiently utilized its socio-economic system to challenge and reshape dominant gender norms.

This study aims to reveal how innovation and international trade, two tools for increasing Türkiye's prosperity, are affected by gender inequality. It is believed that this will contribute positively to both the national economy and the social structure by reducing, even slightly, gender inequality practices in the country. No studies on this topic have been found in the domestic literature to date. However, there are a limited number of studies in the foreign literature (Saska and Baruah, 2020: Lin and Yin, 2023; Ryu & Nam, 2024) addressing the relationship between gender inequality, innovation, and international trade. The absence of a previous study in Türkiye that attempts to examine the relationship between gender inequality, innovation, and international trade, and that evaluates innovation and international trade from this perspective, indicates a gap in the literature in Türkiye. Furthermore, by raising awareness that gender equality is not only a factor affecting the social structure but is also related to countries' innovation and international trade activities, it will be possible to draw attention to the issue of reducing gender inequality practices. This study is distinguished from other studies in these fields because no other study has been found in Türkiye that approaches innovation, international trade and gender inequality from this perspective. Based on this, the study aims to clarify the relationship between gender inequality, innovation, and international trade in Türkiye, thus filling a gap in the literature and emphasizing the importance of reducing gender inequality for the advancement of innovation and international trade. Consequently, the research question of this study is stated as follows: "Is there a relationship between gender inequality, innovation, and international trade?"

2. Theoretical Framework and Literature

Gender inequality refers to a situation in which women and men are deprived of equal access to the same rights, opportunities, and resources as a result of discrimination stemming from their assigned social roles. Women must recognize these unequal practices and strive to overcome these injustices. Feminist theories help women become empowered by raising their awareness of their fundamental rights. Feminist theories explain how women's empowerment can lead to increased well-being and the development of society as a whole. These theories help women understand their right to access the same resources and opportunities as men by fostering a sense of self-worth (Grosser and Tyler, 2021).

The disparities between women and men differ among societies, exhibiting variations in both intensity and manifestation from one country to another. Gender disparity is most evident in civilizations characterized by patriarchal systems. Patriarchy, characterized by male dominance over females (Sancar, 2011), posits that traits associated with men are superior to those linked to women within the gender hierarchy established around masculinity and femininity (Aydın and Aydın Aslaner, 2015). This prejudice hinders women from exercising their rights in political, economic, social, and cultural domains, or entirely eradicates them. Consequently, women may endure numerous adverse effects stemming from the infringement of their rights in essential domains such as education, income, social standing, health, and employment (Demirgöz Bal, 2014).

Gender inequality has political, social, and economic elements (Jacobsen, 2011). The limited representation of women in political parties, the scarcity of female political leaders, and the few female candidates in elections exemplify gender disparity in politics. From a social perspective, in the harsh conditions created by globalization and neoliberalism and in poverty, uneducated women from lower classes struggle alongside men for better living conditions, while also having to deal with the violence

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perpetrated against them by men who have been brutalized by these conditions. Moreover, educated women from the middle and upper classes frequently possess access to educational and employment possibilities, thereby reaping the rewards of the women's rights movement without fully comprehending the work invested in this endeavor (Belek, 2013). The economic dimension reveals that the percentage of women in formal work is typically lower than that of males, while the unemployment rate among women is higher than that of men, indicating gender disparity. According to gender-specific Turkish Statistical Institute (TurkStat) employment figures for July 2024, the unemployment rate in Türkiye was 7% for males and 12.4% for females. During the same year, seasonally adjusted total employment rates indicated that 65.7% of the employed individuals were men, whereas 31.4% were women (TurkStat, 2025). However, a more equal distribution of the workforce between male and female employees significantly accelerates productivity growth, depending on the size of the business and the type of work (Wu and Cheng, 2016).

These barriers affect countries socioeconomically in many ways. They can even affect global warming, which has become a problem for the entire world and has various effects on countries' economies. For example, the gender gap in the labor market can affect carbon emission efficiency (CEE) by influencing differences between individuals in terms of employment, career choices, and working conditions. On the other hand, it can also affect individuals' ability to acquire resources in the workplace, thereby influencing their ability and willingness to adopt environmentally friendly behaviors that affect CEE (Dai et al., 2024).

Rae Lesser Blumberg's (1984) "General Theory of Gender Stratification" provides a comprehensive framework for understanding the unequal distribution of resources, opportunities, and power between men and women in society. According to the theory, gender stratification in societies results from a complex interaction between gender roles, societal roles, and institutional practices. Societal gender roles and stereotypes shape the behavior, abilities, and expectations of men and women, which in turn shape the abilities and expectations of particular groups. However, these unequal outcomes also reinforce gender roles and stereotypes (Memon and Satpathy, 2020).

Gender inequality practices negatively affect the perception of social justice as well as the economic growth of countries. Therefore, this is not only a sociological problem but also an economical problem. Previous studies showed that the current gender inequality in the world can cause a loss of up to 12 trillion US dollars in global income, i.e., 16% of the global income. Gender inequality, especially in social institutions, negatively affects economic development by reducing the income levels of countries. This effect is felt more severely in low-income countries (Ferrant and Kolev, 2016, 31). Therefore, countries seeking economic development must take significant steps towards gender equality. International trade is a key element in countries' economies, and gender inequality practices can negatively impact this area as well.

International trade, which favorably influences the economic progress of nations and facilitates funding for national development (Gülmez, 2019), is seen as a significant measure of countries' economic performance. International trade also positively affects economic growth by strengthening competition in domestic and foreign markets by positively affecting the technological development of countries (Kovacı, 2019). Countries undergoing transformation in international trade (countries undergoing a structural transition from low-efficiency agricultural sectors to high-efficiency manufacturing and service sectors) account for approximately two-thirds of the global population and an increasing share of global GDP (Dai et al., 2025). Trade policy of nations should prioritize the advancement of human rights, environmental conservation, and gender equality for sustainable development. Gender inequality can hinder a nation's

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economic development, diminish foreign investment interest, and adversely impact international trade. Reducing gender inequality will enhance women's labor force participation rates, thereby expanding the labor pool, which will result in heightened productivity, the creation of new goods and services, the growth of export markets, and a boost in international trade (Nam & Ryu, 2024). Based on this, the first hypothesis of the study was: There is a relationship between gender inequality and international trade.

In order for international trade to be conducted at the desired scale, innovative products must be produced and, naturally, creativity must be valued throughout the country. Developing countries are trying to increase their innovation activities in order to gain a competitive advantage in global markets, increase their welfare levels and achieve a sustainable growth performance. The Fourth Industrial Revolution offers unprecedented opportunities for innovation and facilitates the achievement of the UN Sustainable Development Goals. Advances in artificial intelligence, automation, and biotechnology have the potential to increase resource efficiency and promote sustainable practices across all sectors (Dai, 2025). Innovation serves as a mechanism for nations to attain economic sustainability both domestically and globally, so enhancing the welfare of their populace. Innovation enhances the advancement of international trade by fortifying links among countries (Adıyaman and Hayaloğlu, 2020). A correlation exists between the cultural attributes of a society and its innovation performance. Variations in the degree of innovation have been noted among nations with distinct cultures. Cultural variations influence the input, process, and commercialization of innovations (Alparslan et al. 2018). The widespread acceptance within society that women lack the capacity for creativity may adversely impact the country's innovation performance as a manifestation of gender inequity.

Research indicates that innovation performance is elevated in nations with minimal gender disparity (Jayachandran, 2015). Mitigating gender inequality can enhance the nation's advantages from a skilled and educated workforce by expanding women's employment prospects and consequently elevating innovation performance. The enhancement of human capital development and innovative capabilities is essential for nations striving to thrive in a globalized environment to achieve competitive advantage (Ryu & Nam, 2024). Based on this, the second hypothesis of this study was that there is a relationship between gender inequality and innovation performance.

Gender equality is not only a fundamental right but also an economic imperative. Research shows that it is economically important for countries to fully utilize the skills and labor of their entire populations. The economic justification for gender equality is even more important for developing economies for two reasons: first, the higher level of gender inequality between men and women, and second, the greater potential benefits of reducing the gender gap (Rocha & Piermartini, 2023). For example, if two developing countries have relatively large labor forces, an expansion in labor supply, such as an increase in the female workforce in just one country, will lead to an improvement in the comparative advantage in labor-intensive products (Busse and Spielman, 2005). For a long time, policymakers did not consider trade through gender lens and shaped their policies accordingly. It is now recognized that international trade affects women and men differently due to existing gender inequalities in production and consumption, labor markets, and access to resources and opportunities (UNCTAD 2014). Aristotle's famous saying, "There is nothing so unequal as the equal treatment of unequal" still serves as a good example of why we need to learn more about gender inequalities in trade (Peltola and MacFeely, 2019).

Similarly, the relationship between gender equality and innovation needs to be investigated. Improving innovation processes, conditions, and environments is a way to ensure better future performance, job creation, and poverty reduction. For many years, the idea that innovation is associated with competence,

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not gender, was accepted. However, in the distinctly male-dominated fields of science, technology, and innovation, it is now believed that there is some degree of gender discrimination (Etzkowitz, 2007).

In the literature, studies on gender and issues affecting a country's economy have generally focused on topics such as economic growth (Braunstein, 2011), economic development (Karoui, 2015), economic cost (Ferrant & Koley, 2016), the relationship between gender differences and innovation and its antecedents (Steyn & De Bruin, 2020), green innovation and gender equality (Lin & Yin, 2023), social innovation and gender equality (2020), patents and gender (Lai, 2020), Gender Disparities in Patent Citations (Subramani & Saksena, 2024). The only study in the literature that examines the relationship between three variables, namely gender, innovation, and international trade, is the study conducted by Ryu & Nam (2024), which includes data from 10 ASEAN member countries (Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, Philippines, Singapore, Thailand, and Vietnam). This is surprising because innovation and international trade are two fundamental economic activities that mutually reinforce each other. The lack of an examination of the relationship between gender inequality, a fundamental management issue, and these two variables creates a significant gap in the literature. This study aims to fill this gap. This study is the first to use data from Türkiye, and the scarcity of studies on this topic in the global literature further enhances its importance. The findings of such a study conducted in Türkiye, a developing country, will also shed light on other developing countries. Furthermore, the study is expected to make a significant contribution to the field due to its close connection to the UN Sustainable Development Goals (SDGs) (gender equality, decent work and economic growth, reduced inequalities, industry, innovation, and infrastructure).

3. Data and Methodology

The data set used in the study covers Türkiye annually from 1991 to 2022. Türkiye was chosen as a sample for this study over other developing countries because it boasts a young, educated, and entrepreneurial population, high competitiveness in manufacturing, a diversified economy with advanced levels of development in specific sectors, a unique geographical location close to both developed and developing countries, and strong export potential, making it a country with high growth potential. International trade, especially for developing countries, serves as a driving force for economic development. There is a relationship between international trade and gender equality. However, this relationship varies depending on countries' levels of gender equality. For example, in Afghanistan, girls are not seen as having a future role in the country's economy (Khan & Tidman, 2023). Bulgaria, while high in equal opportunities in education, has not achieved the same level of success in economics and politics (Xu, 2025). Türkiye ranks 129th out of 146 countries with a GGGI (Global Gender Gap Index) score of 0.638, indicating that Türkiye is slightly more than halfway toward achieving full gender equality. Regionally, Türkiye ranks last among Central Asian countries. While it has nearly achieved equality in Health and Lifestyle and has come close to equality in Educational Achievement, the country still lags far behind in Political Empowerment and faces persistent challenges in Economic Participation and Opportunity (Fındık, 2025).

Gender inequality is measured using (i) the Gender Inequality Index (GII) and/or (ii) the Gender Development Index (GDI) provided by the United Nations Development Program (UNDP). The GII is a composite index that encompasses data on the health state of the female population, the ratio of women to the total population with secondary education, the number of parliamentary seats occupied by women, and the labor force participation rate. The GII ranges from zero to one, where zero signifies complete equality. The GDI is computed independently for female and male populations, utilizing life expectancy at birth, anticipated and average years of education, and per capita GDP, with the index value reflecting

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the extent of the disparity. A value nearing one signifies the attainment of gender equality. In this study, both the GII and the GDI indices were utilized by using the data set, covering from annual UNDP (United Nations Development Programme) reports for Türkiye from 1991 to 2022.

Trade; the natural logarithm of the ratio of total trade to GDP, together with Patent as an indicator of innovation in natural logarithmic form based on the number of patent applications submitted by residents, were incorporated into the models as dependent variables. In the study, Industry, the natural logarithm of the ratio of employment in industry to total employment, and Export, the natural logarithm of the ratio of exports of goods and services to GDP, were used as control variables. The logarithmic transformation was applied to ensure that all coefficients in the regression can be interpreted as elasticities, to minimize the effect of heterogeneity, and to provide analytical consistency and comparability. The variables used in the models and their explanations are summarized in Table 1.

Table 1. Summary Explanations About The Variables

Variable Symbol	**Description**	**Source**
Trade	Total openness (Trade/GDP)	WB (World Bank)
Export	Exports of goods and services (Export/GDP)	WB
Industry	Employment in industry (Industry employment/Total employment)	WB
Patent	Patent applications (Application by resident)	WB
GII	Gender inequality index	UNDP
GDI	Gender development index	UNDP

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The study focuses on explaining the relationship between gender inequality, trade, and innovation using two different panels (i.e., Panel A and Panel B) and a total of five different models such as M1, M2, M3, M4 and M5. Since the study examined the effects of gender inequality on trade and innovation separately, two separate panels were created. Panel A examines the role of gender inequality in Türkiye's trade volume, while Panel B explains the impact of international trade on the relationship between gender inequality and innovation (Figure 1). In Panel A, in order to evaluate the impact of gender inequality on trade, exports and industrial employment must account for a significant share of total employment. This step is followed by the addition of gender inequality indicators to the model and an assessment of their statistical significance. In Panel B, the statistical significance of whether the independent variable of gender inequality affects the innovation dependent variable using the intermediary role of international trade was determined.

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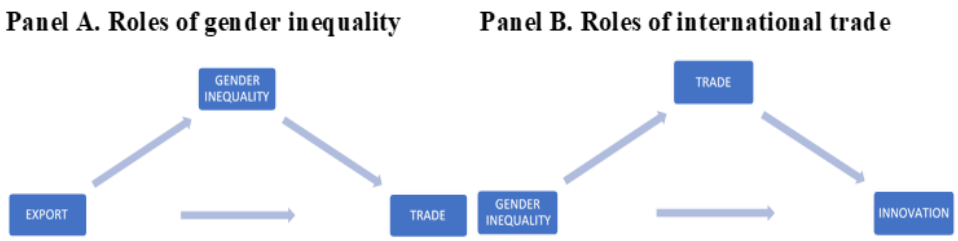


Figure 1. Conceptual models

M1: $Trade_t = \beta_0 + \beta_1 Export_t + \beta_2 Industry_t + \epsilon_t$ (1)

M2: $Trade_t = \beta_0 + \beta_1 Export_t + \beta_2 GII_t + \beta_3 Industry_t + \epsilon_t$ (2)

M3: $Trade_t = \beta_0 + \beta_1 Export_t + \beta_2 GDI_t + \beta_3 Industry_t + \epsilon_t$ (3)

M4: $Patent_t = \beta_0 + \beta_1 GII_t + \beta_2 Export_t + \beta_3 Industry_t + \epsilon_t$ (4)

M5: $Patent_t = \beta_0 + \beta_1 GII_t + \beta_2 Trade_t + \beta_3 Export_t + \beta_4 Industry_t + \epsilon_t$ (5)

Where, *t* denotes time and ϵ denotes the error term.

The most fundamental assumptions of the ARDL method include symmetrical adjustment and linearity. Symmetrical adjustment indicates that the model has a stable rate of change once it reaches equilibrium, while linearity indicates that each unit change in the independent variable always causes a proportional change in the dependent variable. These assumptions regarding the ARDL method are unrealistic and restrictive due to the existence of multidimensional relationships between economic variables (Uğurlu-Yıldırım, 2021). The NARDL method, on the other hand, enables us to make more consistent estimates by showing the asymmetric effects of changes in the independent variable on the dependent variable. The NARDL method is a more comprehensive version of the ARDL method because it captures both negative and positive shocks in the long term (Shin et al., 2014). As decribed above, although autoregressive distributed lag (ARDL) models perform well even with small samples, they have some important shortcomings, the nonlinear autoregressive distributed lag (NARDL) method was used in this study.

The NARDL method was applied by examining the following steps in order. First, as in the ARDL method, ADF unit root tests were performed to determine that none of the variables included in the model were I(2) and that the variables were I(0) or I(1). In the second stage, a bound test was evaluated to determine whether there was cointegration between the variables. In the third stage, long-term asymmetry between the variables was identified using the Wald test. In the fourth stage, the statistical significance of the long-term coefficients was determined. In the final stage, the reliability of the results obtained from the established models was expressed using a normality test (Jarque-Bera), a serial correlation test (LM), and a heteroskedasticity test (Breusch-Pagan-Godfrey), while the structural soundness of the models was proven using CUSUM and CUSUM Square tests.

The NARDL (Shin et al., 2014) equations created to determine the asymmetric effects between variables in the models can be written as follows:

$$\Delta Trade_t = \beta_0 + \sum_{i=1}^{k} \beta_{1i}\, \Delta Trade_{t-1} + \sum_{i=0}^{l} \beta_{2i}\, \Delta Export^{+}_{1t-i} + \sum_{i=0}^{m} \beta_{3i}\, \Delta Export^{-}_{1t-i} + \sum_{i=0}^{n} \beta_{4i}\, \Delta Industry^{+}_{1t-i} + \sum_{i=0}^{o} \beta_{5i}\, \Delta Industry^{-}_{1t-i} + \alpha_1\, Trade_{t-1} + \alpha_2\, Export^{+}_{t-1} + \alpha_3\, Export^{-}_{t-1} + \alpha_4\, Industry^{+}_{t-1} + \alpha_5\, Industry^{-}_{t-1} + \epsilon_t \quad (6)$$

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$$\Delta Trade_t = Þ_0 + \sum_{i=1}^{k} Þ_{1i}\ \Delta Trade_{t-1} + \sum_{i=0}^{l} Þ_{2i}\ \Delta Export^{+}_{1t-i} + \sum_{i=0}^{m} Þ_{3i}\ \Delta Export^{-}_{1t-i} + \sum_{i=0}^{n} Þ_{4i}\ \Delta GII^{+}_{1t-i} + \sum_{i=0}^{o} Þ_{5i}\ \Delta GII^{-}_{1t-i} \sum_{i=0}^{p} Þ_{4i}\ \Delta Industry^{+}_{1t-i} + \sum_{i=0}^{r} Þ_{5i}\ \Delta Industry^{-}_{1t-i} + \alpha_1\ Trade_{t-1} + \alpha_2\ Export^{+}_{t-1} + \alpha_3\ Export^{-}_{t-1} + \alpha_4\ GII^{+}_{t-1} + \alpha_5\ GII^{-}_{t-1} + \alpha_6\ Industry^{+}_{t-1} + \alpha_7\ Industry^{-}_{t-1} + \epsilon_t \quad (7)$$

$$\Delta Trade_t = ŧ_0 + \sum_{i=0}^{k} ŧ_{2i}\ \Delta Trade_{t-1} + \sum_{i=0}^{l} ŧ_{2i}\ \Delta Export^{+}_{1t-i} + \sum_{i=0}^{m} ŧ_{3i}\ \Delta Export^{-}_{1t-i} + \sum_{i=0}^{n} ŧ_{4i}\ \Delta GDI^{+}_{1t-i} + \sum_{i=0}^{o} ŧ_{5i}\ \Delta GDI^{-}_{1t-i} \sum_{i=0}^{p} ŧ_{6i}\ \Delta Industry^{+}_{1t-i} + \sum_{i=0}^{r} ŧ_{2i}\ \Delta Industry^{-}_{1t-i} + \alpha_1\ Trade_{t-1} + \alpha_2\ Export^{+}_{t-1} + \alpha_3\ Export^{-}_{t-1} + \alpha_4\ GDI^{+}_{t-1} + \alpha_5\ GDI^{-}_{t-1} + \alpha_6\ Industry^{+}_{t-1} + \alpha_7\ Industry^{-}_{t-1} + \epsilon_t \quad (8)$$

$$\Delta Patent_t = ƀ_0 + \sum_{i=1}^{k} ƀ_{1i}\ \Delta Patent_{t-1} + \sum_{i=0}^{l} ƀ_{2i}\ \Delta GII^{+}_{1t-i} + \sum_{i=0}^{m} ƀ_{3i}\ \Delta GII^{-}_{1t-i} + \sum_{i=0}^{n} ƀ_{4i}\ \Delta Export^{+}_{1t-i} + \sum_{i=0}^{o} ƀ_{5i}\ \Delta Export^{-}_{1t-i} \sum_{i=0}^{p} ƀ_{6i}\ \Delta Industry^{+}_{1t-i} + \sum_{i=0}^{r} ƀ_{7i}\ \Delta Industry^{-}_{1t-i} + \alpha_1\ Patent_{t-1} + \alpha_2\ GII^{+}_{t-1} + \alpha_3\ GII^{-}_{t-1} + \alpha_4\ Export^{+}_{t-1} + \alpha_5\ Export^{-}_{t-1} + \alpha_6\ Industry^{+}_{t-1} + \alpha_7\ Industry^{-}_{t-1} + \epsilon_t \quad (9)$$

$$\Delta Patent_t = ƙ_0 + \sum_{i=1}^{k} ƙ_{1i}\ \Delta Patent_{t-1} + \sum_{i=0}^{l} ƙ_{2i}\ \Delta GII^{+}_{1t-i} + \sum_{i=0}^{m} ƙ_{3i}\ \Delta GII^{-}_{1t-i} + \sum_{i=0}^{n} ƙ_{4i}\ \Delta Trade^{+}_{1t-i} + \sum_{i=0}^{o} ƙ_{5i}\ \Delta Trade^{-}_{1t-i} + \sum_{i=0}^{p} ƙ_{6i}\ \Delta Export^{+}_{1t-i} + \sum_{i=0}^{r} ƙ_{7i}\ \Delta Export^{-}_{1t-i} + \sum_{i=0}^{s} ƙ_{8i}\ \Delta Industry^{+}_{1t-i} + \sum_{i=0}^{u} ƙ_{9i}\ \Delta Industry^{-}_{1t-i} + \alpha_1\ Patent_{t-1} + \alpha_2\ GII^{+}_{t-1} + \alpha_3\ GII^{-}_{t-1} + \alpha_4\ Trade^{+}_{t-1} + \alpha_5\ Trade^{-}_{t-1} + \alpha_6\ Export^{+}_{t-1} + \alpha_7\ Export^{-}_{t-1} + \alpha_8\ Industry^{+}_{t-1} + \alpha_9\ Industry^{-}_{t-1} + \epsilon_t \quad (10)$$

Where, "Δ" is the primary difference; ϵ_t is the error term; "k, l, m, n, o, p, r, s, u" are the appropriate lag numbers; β_0, $Þ_0$, $ŧ_0$, $ƀ_0$, $ƙ_0$ are the model constants; β, Þ, ŧ, ƀ, ƙ are the coefficients of short-term effects; and α_1, α_2, α_3, α_4, α_5, α_6, α_7, α_8, α_9 are the coefficients of long-term effects.

The existence of cointegration between variables in models with F-bounds has been tested. The hypotheses created for this test are as follows:

H_0: $\alpha_1 = \alpha_2 = \alpha_3 = \alpha_4 = \alpha_5 = \alpha_6 = \alpha_7 = \alpha_8 = \alpha_9 = 0$ ''There is no-cointegration''

H_1: $\alpha_1 \neq \alpha_2 \neq \alpha_3 \neq \alpha_4 \neq \alpha_5 \neq \alpha_6 \neq \alpha_7 \neq \alpha_8 \neq \alpha_9 \neq 0$ ''There is cointegration''

The calculated F statistic is compared with the lower and upper critical values derived by Pesaran et al. (2001) for large samples and by Narayan (2005) for small samples. Due to the small sample size, Narayan (2005) is used in this study. If the calculated F statistic is greater than the upper critical value in the table, H_0 is rejected, and it is concluded that there is cointegration among the variables in the model. If the calculated F statistic value is less than the lower critical value in the table, H_0 cannot be rejected. If the calculated F statistic value falls between the lower and upper critical values in the table, no conclusion can be drawn regarding the presence of cointegration between the variables.

The Wald test is used to detect short-term and long-term asymmetric relationships (Shin et al., 2014). The hypotheses formulated for the Wald test are as follows:

Model 1 H_0: $\frac{\alpha_2}{-\alpha_1} = \frac{\alpha_3}{-\alpha_1}$; $\frac{\alpha_4}{-\alpha_1} = \frac{\alpha_5}{-\alpha_1}$ (long run); $\beta^+ = \beta^-$ (short run)

H_1: $\frac{\alpha_2}{-\alpha_1} \neq \frac{\alpha_3}{-\alpha_1}$; $\frac{\alpha_4}{-\alpha_1} \neq \frac{\alpha_5}{-\alpha_1}$ (long run); $\beta^+ \neq \beta^-$ (short run)

Model 2 H_0: $\frac{\alpha_2}{-\alpha_1} = \frac{\alpha_3}{-\alpha_1}$; $\frac{\alpha_4}{-\alpha_1} = \frac{\alpha_5}{-\alpha_1}$; $\frac{\alpha_6}{-\alpha_1} = \frac{\alpha_7}{-\alpha_1}$ (long run); $\beta^+ = \beta^-$ (short run)

H_1: $\frac{\alpha_2}{-\alpha_1} \neq \frac{\alpha_3}{-\alpha_1}$; $\frac{\alpha_4}{-\alpha_1} \neq \frac{\alpha_5}{-\alpha_1}$; $\frac{\alpha_6}{-\alpha_1} \neq \frac{\alpha_7}{-\alpha_1}$ (long run); $\beta^+ \neq \beta^-$ (short run)

Model 3 H_0: $\frac{\alpha_2}{-\alpha_1} = \frac{\alpha_3}{-\alpha_1}$; $\frac{\alpha_4}{-\alpha_1} = \frac{\alpha_5}{-\alpha_1}$; $\frac{\alpha_6}{-\alpha_1} = \frac{\alpha_7}{-\alpha_1}$ (long run); $\beta^+ = \beta^-$ (short run)

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H_1: $\frac{\alpha_2}{-\alpha_1} \neq \frac{\alpha_3}{-\alpha_1}$; $\frac{\alpha_4}{-\alpha_1} \neq \frac{\alpha_5}{-\alpha_1}$; $\frac{\alpha_6}{-\alpha_1} \neq \frac{\alpha_7}{-\alpha_1}$ (long run); $\beta^+ \neq \beta^-$ (short run)

Model 4 H_0: $\frac{\alpha_2}{-\alpha_1} = \frac{\alpha_3}{-\alpha_1}$; $\frac{\alpha_4}{-\alpha_1} = \frac{\alpha_5}{-\alpha_1}$; $\frac{\alpha_6}{-\alpha_1} = \frac{\alpha_7}{-\alpha_1}$ (long run); $\beta^+ = \beta^-$ (short run)

H_1: $\frac{\alpha_2}{-\alpha_1} \neq \frac{\alpha_3}{-\alpha_1}$; $\frac{\alpha_4}{-\alpha_1} \neq \frac{\alpha_5}{-\alpha_1}$; $\frac{\alpha_6}{-\alpha_1} \neq \frac{\alpha_7}{-\alpha_1}$ (long run); $\beta^+ \neq \beta^-$ (short run)

Model 5 H_0: $\frac{\alpha_2}{-\alpha_1} = \frac{\alpha_3}{-\alpha_1}$; $\frac{\alpha_4}{-\alpha_1} = \frac{\alpha_5}{-\alpha_1}$; $\frac{\alpha_6}{-\alpha_1} = \frac{\alpha_7}{-\alpha_1}$; $\frac{\alpha_8}{-\alpha_1} = \frac{\alpha_9}{-\alpha_1}$ (long run); $\beta^+ = \beta^-$ (short run)

H_1: $\frac{\alpha_2}{-\alpha_1} \neq \frac{\alpha_3}{-\alpha_1}$; $\frac{\alpha_4}{-\alpha_1} \neq \frac{\alpha_5}{-\alpha_1}$; $\frac{\alpha_6}{-\alpha_1} \neq \frac{\alpha_7}{-\alpha_1}$; $\frac{\alpha_8}{-\alpha_1} \neq \frac{\alpha_9}{-\alpha_1}$ (long run); $\beta^+ \neq \beta^-$ (short run)

When H_0 is rejected, the existence of long- and/or short-term asymmetric relationships between variables in the model is accepted.

4. Results and Discussion

Descriptive statistical results for the variables included in the models are presented in Table 2. The findings show that the series representing the variables are normally distributed is that the measures of central tendency (mean and median) have close values. On the other hand, since the probability values of the Jarque-Bera statistic are greater than 0.05, all variables can be claimed as normally distributed.

Table 2. Descriptive Statistics for the Variables

	TRADE	EXPORT	INDUSTRY	GII	GDI	PATENT
Mean	1.687712	1.364223	1.392264	0.449594	0.880375	3.079493
Median	1.688369	1.365982	1.409437	0.479500	0.866500	3.143937
Maximum	1.909396	1.586410	1.444912	0.603000	0.941000	3.939369
Minimum	1.483958	1.135889	1.318215	0.259000	0.821000	2.170262
Std. Dev.	0.091404	0.101119	0.040901	0.117451	0.042461	0.666295
Skewness	-0.115215	-0.254141	-0.424921	-0.245634	0.203611	-0.074560
Kurtosis	3.600984	3.767397	3.367903	1.580019	1.435142	1.363670
Jarque-Bera	0.552372	1.129665	0.185639	3.010252	3.486148	3.599751
Prob.	[0.758672]	[0.568455)	[0.185639]	[0.221989]	[0.174982]	[0.165319]
Obs.	32	32	32	32	32	32

The Broock-Dechert-Scheinkman (BDS) test developed by Broock et al. (1996) was used to determine the nonlinearity of the variables in the study. According to the BDS test results, presented in Table 3, it has been proven that all variables included in the models have nonlinear properties. The null hypothesis regarding the independence and normal distribution of all series is rejected even at a 1% significance level. According to these results, the applicability of the nonlinear autoregressive distributed lag (NARDL) estimator has been confirmed.

Table 3. BDS Test Results

Variables	Dimension				
	2	**3**	**4**	**5**	**6**
Trade	0.115	0.164	0.236	0.267	0.286
	(0.00***)	(0.00***)	(0.00***)	(0.00***)	(0.00***)

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Export	0.112	0.176	0.275	0.302	0.332
	(0.00***)	(0.00***)	(0.00***)	(0.00***)	(0.00***)
Industry	0.124	0.210	0.291	0.355	0.380
	(0.00***)	(0.00***)	(0.00***)	(0.00***)	(0.00***)
Gii	0.181	0.296	0.367	0.409	0.429
	(0.00***)	(0.00***)	(0.00***)	(0.00***)	(0.00***)
Gdi	0.166	0.284	0.361	0.410	0.440
	(0.00***)	(0.00***)	(0.00***)	(0.00***)	(0.00***)
Patent	0.194	0.323	0.410	0.469	0.511
	(0.00***)	(0.00***)	(0.00***)	(0.00***)	(0.00***)

Table shows BDS statistics. *, ** and *** denote 10, 5, and 1% significance levels respectively.

For the NARDL method to be applicable, none of the variables included in the models should be stationary at I(2) or exhibit higher differences (all series must satisfy the stationarity condition at the level or first difference). The results of the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) unit root tests are presented in Table 4. Given the low power of the ADF unit root test, the PP unit root test was also applied, and it was found that both unit root tests yielded similar results. All variables included in the models satisfy the stationarity condition at the first difference, i.e., I(1). In this case, the NARDL method can be used for the analysis of the data set, used in this study.

Table 4. Unit Root Test Results

Variables	Level		1st Difference	
	ADF	PP	ADF	PP
	t-stat (p-value)	t-stat p-value	t-stat (p-value)	t-stat (p-value)
Trade	-1.347428 (0.5936)	-1.071821 (0.7141)	-4.789343* (0.0006)	-4.930759* (0.0004)
Export	2.091615 (0.9998)	-1.606229 (0.4675)	-5.221969* (0.0002)	-7.107857* (0.0000)
Industry	-1.578458 (0.4813)	-1.451592 (0.5443)	-6.040545* (0.0000)	-7.073201* (0.0000)
Patent	-0.452405 (0.8875	-0.489936 (0.8802)	-4.496156* (0.0012)	-4.765347* (0.0006)
GII	0.673870 (0.9895)	0.914709 (0.9944)	-5.083916* (0.0003)	-5.116568* (0.0002)
GDI	-0.150892 (0.9348)	-0.150892 (0.9348)	-7.102776* (0.0000)	-7.118169* (0.0000)

Null hypothesis: Series have unit root (non-stationary); * Significant at α = 0,01. Trade, Export, Industry and Patent variables in natural logarithm.

The study utilized annual data, and suitable lag durations were established employing the Akaike Information Criterion (AIC) and Bayesian Information Criterion. The suitable lag durations for all models are shown at Table 5.

Table 5. Optimal Lag Durations

Model	AIC	BIC	Specification
Model 1	-5.7159	-5.2444	NARDL (1,0,1,2,1)
Model 2	-5.7750	-5.0678	NARDL (3,0,1,1,1,1,1,)
Model 3	-6.7590	-5.9102	NARDL (3,0,2,2,1,1,2)

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Model 4	-3.6412	-3.1227	NARDL (1,2,1,0,0,0,0)
Model 5	-3.5561	-3.0056	NARDL (1,0,1,1,0,0,0,0,0)

After determining the stationarity levels of the series, the existence of cointegration relationships between the variables in the models is determined using the F-bound test. The results of the F-bound test are shown in Table 6. According to the test results, Model 1 is significant at the 1% level, Model 2 is significant at the 1% level, Model 3 is significant at the 1% level, Model 4 is significant at the 1% level, and Model 5 is significant at the 5% level. Additionally, the short-term error correction term coefficient of all models is negative and statistically significant. Under these two findings, the existence of a nonlinear cointegration relationship among the variables in all models has been proven.

Table 6. F-Bounds Test Results

Model 1: NARDL (1, 0, 1, 2, 1)			**F critical values**		**F critical values**	
f(Trade | Export $^+$, Export $^-$, Industry $^+$, Industry $^-$)			n=1000		n=35	
F statistic	Result	%	I(0)	I(1)	I(0)	I(1)
30.67***	Co-integration	%10	2.45	3.52	2.69	3.89
		%5	2.86	4.01	3.27	4.63
		%1	3.74	5.06	4.59	6.36
Model 2: NARDL (3, 0, 1, 1, 1, 1, 1)			**F critical values**		**F critical values**	
f(Trade | Export $^+$, Export $^-$, Industry $^+$, Industry $^-$, GII $^+$, GII $^-$)			n=1000		n=35	
F statistic	Result	%	I(0)	I(1)	I(0)	I(1)
24.56***	Co-integration	%10	2.12	3.23	2.38	3.67
		%5	2.45	3.61	2.86	4.32
		%1	3.15	4.43	4.01	5.79
Model 3: NARDL (3, 0, 2, 2, 1, 1, 2)			**F critical values**		**F critical values**	
f(Trade | Export $^+$, Export $^-$, Industry $^+$, Industry $^-$, GDI $^+$, GDI $^-$)			n=1000		n=35	
F statistic	Result	%	I(0)	I(1)	I(0)	I(1)
35.91***	Co-integration	%10	2.12	3.23	2.38	3.67
		%5	2.45	3.61	2.86	4.32
		%1	3.15	4.43	4.01	5.79
Model 4: NARDL (1, 2, 1, 0, 0, 0, 0)			**F critical values**		**F critical values**	
f(Patent | GII $^+$, GII $^-$, Export $^+$, Export $^-$, Industry $^+$, Industry $^-$)			n=10000		n=35	
F statistic	Result	%	I(0)	I(1)	I(0)	I(1)
6.08***	Co-integration	%10	2.12	3.23	2.38	3.67
		%5	2.45	3.61	2.86	4.32
		%1	3.15	4.43	4.01	5.79
Model 5: NARDL (1, 0, 1, 1, 0, 0, 0, 0, 0)			**F critical values**		**F critical values**	
f(Patent | GII $^+$, GII $^-$, Trade $^+$, Trade $^-$, Export $^+$, Export $^-$, Industry $^+$, Industry $^-$)			n=1000		n=35	
F statistic	Result	%	I(0)	I(1)	I(0)	I(1)
4.65**	Co-integration	%10	1.95	3.06	2.18	3.42
		%5	2.22	3.39	2.57	3.93
		%1	2.79	4.10	3.54	5.16

*, ** and *** denote 10, 5, and 1% significance levels respectively.

Table 7 presents both long-term and short-term asymmetry tests applied to the models included in the study. According to the Wald test results for Model 1, both long-term and short-term exports and industrial employment have asymmetric effects on trade. In Model 2, the Wald test reveals that the gender inequality index has symmetric effects on trade in both the long and short term. The Wald test results for Model 3

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show that the gender development index (GDI) has asymmetric effects on trade in both the long and short term. It is noteworthy that the gender development index and the gender inequality index have different effects. However, the difference here stems from the fact that the two indices are calculated using different methods. As explained above, in the GII, gender inequality decreases as the index value approaches zero, while in the GDI, gender inequality decreases as the index value approaches one. Therefore, it is normal for the two indices to have different effects. The GDI is an index that captures gender gaps in life expectancy, education, and income. Life expectancy in the GDI indicates how adult literacy, school enrollment, and per capita income in a country differ by gender. According to 2024 data from the Turkish Statistical Institute (TurkStat), the literacy rate in Türkiye is 96.2% for women and 99.3% for men (TurkStat, 2025). These rates indicate that there is no gender gap in literacy in the country. An examination of the country's enrollment rate by gender reveals no gender gap in secondary education (88.7% for women and 87.3% for men), while the ratio in higher education is higher in favor of women (49% for women and 36.7% for men). Among all workers in the country (wage, salary, casual, employer, and self-employed), the average annual income in 2024 will be 251,050 for men and 183,153 for women (TurkStat, 2024a). This gender inequality may have caused the GDI to have asymmetrical effects on trade in both the long and short term. The Gender Inequality Index (GII) attempts to identify gender inequalities across countries using three dimensions: reproductive health, empowerment, and the labor market. According to TurkStat data, men accounted for 66.9% of the total workforce in Türkiye in 2024, while the female workforce remained at 32.5% (TurkStat, 2024b). This large disparity in male-female participation rates in Türkiye may have caused the GII index to have a symmetrical, rather than asymmetric, impact on trade.

Nonetheless, it is important to note that both indices influence worldwide trade. Gender disparity can adversely impact the effective utilization of human capital within the nation, resulting in economic repercussions. To ensure the efficient use of human capital, a country must ensure educational equality and offer equal opportunities to both genders. In this regard, Türkiye has established and implemented policies in the field of education. In addition to formal education targeting women, the intensity and diversity of various non-formal education activities aimed at acquiring knowledge, skills, and vocational skills while also supporting individual and social development are noteworthy. In addition to various activities carried out by the Ministry of National Education's Directorate General for Lifelong Learning to help women acquire literacy, knowledge, skills, and a profession, women's education is also supported through projects such as Family Support Centers (ADEM) and Multi-Purpose Community Centers (ÇATOM) initiated by the Ministry of Family and Social Services (Dalagan, 2024). Thus, thanks to the training they receive, women will have the opportunity to contribute to the national economy by being employed in various jobs. The slogan of the World Bank's Gender Action Plan, "Gender equality is a smart economy," effectively summarizes this perspective (Braunstein, 2011).

Innovation is a key success factor for businesses and countries to increase their competitiveness and growth and create new employment opportunities. For this reason, this study also examines the impact of gender inequality on innovation. According to the results of the Model 4 Wald test conducted for this purpose, it was determined that the gender inequality index has an asymmetric effect on innovation in the long term, while exports have a symmetric effect on industry employment. The interesting finding in this model is that, in the short term, only gender inequality has asymmetric effects on innovation. This finding is consistent with the findings of the study conducted by Ryu & Nam (2024). Ryu & Nam (2024) found that gender inequality negatively affects international trade and innovation, but international trade increases innovation. The results of the study conducted by Lin and Yin (2023) to determine the effects of gender equality on green innovation also supported these findings, demonstrating that improving

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gender equality improves green innovation performance. Based on this, it can be argued that there is a relationship between gender inequality and innovation in Türkiye, and that reducing gender inequality practices will increase innovation activities. The Women's Empowerment Principles (WEPs) initiative is increasingly being adopted in Türkiye, and awareness of gender equality is rising within the private sector. Many large-scale companies have signed the United Nations Women's Empowerment Principles, declaring their commitments in this area at the international level. For example, Türkiye Sigorta became a WEPs signatory in 2024 and publicly announced that it will take concrete steps to improve gender equality within its company (Kızıltan Işık, 2025). It is expected that such practices in the business world will lead to a reduction in gender-biased practices in Türkiye, which may in turn be reflected in innovation.

Finally, the Wald test results of Model 5, shown in Table 7, indicate that only the gender inequality index has asymmetric effects on patents in both the long and short term. However, recent literature highlights that patenting rates differ between genders. The majority of inventors mentioned in patents is men. If a woman is mentioned as an inventor, this usually indicates a woman within a larger group of male inventors. For example, in United Kingdom (UK), 78.6% of patents belong to men, while the rate of women is only 2.2% (Lai, 2020). In Türkiye, patent rates are published by the patent institute and while distribution is generally given by years and provinces, there is no distribution by gender. This actually shows that as a country, women are not given importance when it comes to obtaining patents. However, according to the results of the study, as gender inequality decreases, the number of patents increases. Considering that innovation is an important element in the long-term growth and development of a country's economy (Raghupathi and Raghupathi, 2017), the number of patents that countries have, as a result of innovation is also important. This result shows that in the future, more support should be given to female researchers in applying for patents in Türkiye.

Table 7. Wald Test Results for the Long-Run and Short-Run Asymmetric Relationship Among Variables

LR / SR	Model 1	F statistic (Probability)	Conclusion
Long-Run	$WALD_{Export}$ (Export $^{+}$ = Export $^{-}$)	16.34 (0.0005)	Asymmetric
	$WALD_{Industry}$ (Industry $^{+}$ = Industry $^{-}$)	20.54 (0.0002)	Asymmetric
Short-Run	$WALD_{Export}$ (Export $^{+}$ = Export $^{-}$)	144.64 (0.0000)	Asymmetric
	$WALD_{Industry}$ (Industry $^{+}$ = Industry $^{-}$)	12.96 (0.0003)	Asymmetric
	Model 2	**F statistic (Probability)**	**Conclusion**
Long-Run	$WALD_{Export}$ (Export $^{+}$ = Export $^{-}$)	4.06 (0.0439)	Asymmetric
	$WALD_{GII}$ (GII $^{+}$ = GII $^{-}$)	2.27 (0.1540)	Non Asymmetric
	$WALD_{Industry}$ (Industry $^{+}$ = Industry $^{-}$)	4.66 (0.0486)	Asymmetric
Short-Run	$WALD_{Export}$ (Export $^{+}$ = Export $^{-}$)	73.65 (0.0000)	Asymmetric
	$WALD_{GII}$ (GII $^{+}$ = GII $^{-}$)	0.49 (0.4820)	Non Asymmetric
	$WALD_{Industry}$ (Industry $^{+}$ = Industry $^{-}$)	7.21 (0.0073)	Asymmetric
	Model 3	**F statistic (Probability)**	**Conclusion**
Long-Run	$WALD_{Export}$ (Export $^{+}$ = Export $^{-}$)	28.31 (0.0000)	Asymmetric
	$WALD_{GDI}$ (GDI $^{+}$ = GDI $^{-}$)	3.99 (0.0456)	Asymmetric
	$WALD_{Industry}$ (Industry $^{+}$ = Industry $^{-}$)	24.26 (0.0000)	Asymmetric
Short-Run	$WALD_{Export}$ (Export $^{+}$ = Export $^{-}$)	191.98 (0.0000)	Asymmetric
	$WALD_{GDI}$ (GDI $^{+}$ = GDI $^{-}$)	11.85 (0.0006)	Asymmetric
	$WALD_{Industry}$ (Industry $^{+}$ = Industry $^{-}$)	5.68 (0.0171)	Asymmetric
	Model 4	**F statistic (Probability)**	**Conclusion**
Long-Run	$WALD_{GII}$ (GII $^{+}$ = GII $^{-}$)	9.20 (0.0068)	Asymmetric
	$WALD_{Export}$ (Export $^{+}$ = Export $^{-}$)	3.92 (0.0477)	Asymmetric

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	$WALD_{Industry}$ (Industry $^{+}$ = Industry $^{-}$)	3.42 (0.0640)	Non Asymmetric
Short-Run	$WALD_{GII}$ (GII $^{+}$ = GII $^{-}$)	12.68 (0.0004)	Asymmetric
	Model 5	**F statistic (Probability)**	**Conclusion**
Long-Run	$WALD_{GII}$ (GII $^{+}$ = GII $^{-}$)	4.67 (0.0436	Asymmetric
	$WALD_{Trade}$ (Trade $^{+}$ = Trade $^{-}$)	0.23 (0.6355)	Non Asymmetric
	$WALD_{Export}$ (Export $^{+}$ = Export $^{-}$)	0.24 (0.6231)	Non Asymmetric
	$WALD_{Industry}$ (Industry $^{+}$ = Industry $^{-}$)	3.64 (0.0714)	Non Asymmetric
Short-Run	$WALD_{GII}$ (GII $^{+}$ = GII $^{-}$)	16.48 (0.0000)	Asymmetric

The numbers in parentheses show probability values. Some of them indicate that the symmetric relationship is rejected at the 5% significance level. Some of them indicate that the symmetric relationship is not rejected at the 5% significance level.

Tables 8 and 9 present the prediction results of the models using the NARDL method for Panels A and B, respectively. Since the dependent variables in both panels are different, the NARDL estimation results are presented in two different tables.

On the other hand, the estimation results also form the basis for calculating the long-term coefficients of the models. For example, the long-term positive effect coefficient ($Export^{+}$) of the export variable for Model 1 is calculated as follows: the coefficient of the $Export^{+}_{t-1}$ variable, which represents the value of export data one period lagged, (0.468886), the coefficient of the dependent variable's lagged value ($Trade_{t-1}$, -0.833946) [- $Export^{+}_{t-1}$ / $Trade_{t-1}$ = -(0.468886 / -0.833946) = 0.562250].

Table 8. Estimation of NARDL Results – Panel A

Variable	Model 1		Model 2		Model 3	
	Coefficient	**p-value**	**Coefficient**	**p-value**	**Coefficient**	**p-value**
Constant	1.311130***	0.0000	0.730697**	0.0128	1.671926***	0.0000
Trade $_{t-1}$	-0.833946***	0.0000	-0.527665***	0.0029	-1.062773***	0.0000
Export $^{+}_{t-1}$	0.468886***	0.0000	0.601135***	0.0001	0.480448***	0.0002
Export $^{-}_{t-1}$	0.977776***	0.0000	1.730689***	0.0004	0.973676***	0.0003
Industry $^{+}_{t-1}$	0.155060	0.5629	-0.830375	0.1436	0.265488	0.1865
Industry $^{-}_{t-1}$	-1.664136***	0.0014	-3.010932***	0.0019	-3.704114***	0.0004
GII $^{+}_{t-1}$			11.23952**	0.0350		
GII $^{-}_{t-1}$			-0.069500	0.7129		
GDI $^{+}_{t-1}$					-1.479451***	0.0006
GDI $^{-}_{t-1}$					1.293823*	0.0883
ΔTrade $_{t-1}$			-0.436302**	0.0399	-0.033471	0.7444
ΔTrade $_{t-2}$			-0.407106**	0.0224	0.154730*	0.0682
ΔExport $^{-}$	1.726189***	0.0000	2.229310***	0.0000	1.693546***	0.0000
ΔExport $^{-}_{t-1}$					0.154730***	0.0074
ΔIndustry $^{+}$	-0.218092	0.4985	-1.675968**	0.0502	0.020742	0.9401
ΔIndustry $^{+}_{t-1}$	0.358735	0.2004				
ΔIndustry $^{-}$	1.250187***	0.0053	1.236814**	0.0337	0.910743**	0.0119
ΔIndustry $^{-}_{t-1}$					1.405410***	0.0061
ΔGII $^{+}$			2.585164	0.4494		
ΔGII $^{-}$			0.248353	0.3737		

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ΔGDI $^{+}$					-0.105462	0.7948
ΔGDI $^{+}_{t-1}$					2.314836***	0.0005
ΔGDI $^{-}$					2.419866**	0.0422

‘‘+’’ and ‘‘-’’ denote negative and positive partial sums, and *, **, and *** denote 10, 5, 1% significance levels, respectively.

Table 9. Estimation of NARDL Results – Panel B

Variable	Model 4		Model 5	
	Coefficient	**p-value**	**Coefficient**	**p-value**
Constant	0.794509**	0.0151	0.513053**	0.0425
Patent $_{t-1}$	-0.448193***	0.0077	-0.312963**	0.0132
GII $^{+}_{t-1}$	16.98007**	0.0228	10.53166*	0.0570
GII $^{-}_{t-1}$	-0.932772	0.3341	-0.035212	0.9617
Export $^{+}_{t-1}$	-0.544759**	0.0232	-0.784239	0.1418
Export $^{-}_{t-1}$	0.320477	0.3810	-0.359923	0.5589
Industry $^{+}_{t-1}$	1.316317	0.1484	1.002260	0.2868
Industry $^{-}_{t-1}$	-2.937252*	0.0579	-3.418134**	0.0349
Trade $^{+}_{t-1}$			0.566454	0.3584
Trade $^{-}_{t-1}$			0.669720	0.1034
ΔGII $^{+}$	6.951956	0.1997	-2.881216***	0.0012
ΔGII $^{+}_{t-1}$	-5.535581**	0.0497		
ΔGII $^{-}$	-2.742450***	0.0012		
ΔTrade $^{+}$			0.155520	0.8098

‘‘+’’ and ‘‘-’’ denote negative and positive partial sums, and *, **, and *** denote 10, 5, 1% significance levels, respectively.

Table 10 lists the long-term coefficients for the models. The coefficients were calculated using the NARDL estimates presented in Tables 8 and 9. For Model 1, the long-term positive and negative coefficients of exports have a positive effect on trade. This result implies that a 1% positive shock in long-term exports would lead to a 0.5% increase in trade, while a 1% negative shock would result in a 1.20% decrease. On the other hand, while the long-term positive coefficient of industrial employment does not significantly affect trade, a 1% negative shock is found to cause an approximate 2% increase in trade. Indeed, Tunçsiper and Horoz (2023) indicate that exports and imports have a significant impact on GDP in Türkiye's economic growth. Therefore, imports and exports are the most important components of international trade. The study's findings indicate that a negative shock to long-term exports will have a greater trade impact than a positive shock of the same magnitude. These results are consistent with Kose and Riezman (2001) who reported that negative trade shocks lead to long-term recessions, and sensitivity analyses indicated that the most significant impact of trade shocks is on investment.

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In addition, gender inequality may also have a negative impact on international trade. Çağatay (2005) also notes that gender inequalities can affect the outcomes of trade policies, particularly in terms of growth and gains from trade. To this end, Model 2 includes the gender inequality variable in the previous model to examine the impact of gender inequality on trade. An examination of the long-run coefficients reveals no significant effect of the gender inequality index on trade, despite the asymmetric effects of exports and industrial employment on trade. This finding suggests that gender inequality has neither a positive nor a negative impact on trade.

Consequently, Model 3 was developed by using the Gender Development Index, an additional metric of gender inequality, to elucidate the correlation between gender inequality and trade. The NARDL results of Model 3 reveal a significant long-term asymmetric association between gender inequality and trade. A sustained 1% rise in the gender development index diminishes trade by roughly 1.4%, and a 1% decline results in an approximate 1.2% reduction in trade. The response of trade to an increase in the gender development index is more significant and pronounced than its response to a reduction in the index value. These results are in agreement with Ryu & Nam (2024) who determined that reducing gender inequality could be a fundamental basis for increasing international trade, supporting this finding.

Table 10. Long-Run Coefficients Estimation Results

Model 1					
	Coefficient	**p-value**		**Coefficient**	**p-value**
Export $^{+}$	0.562250***	0.0000	**Export** $^{-}$	1.172469***	0.0000
Industry $^{+}$	0.185935	0.5534	**Industry** $^{-}$	-1.995496***	0.0028
Model 2					
	Coefficient	**p-value**		**Coefficient**	**p-value**
Export $^{+}$	1.139236**	0.0112	**Export** $^{-}$	3.279902**	0.0350
Industry $^{+}$	-1.573679	0.2694	**Industry** $^{-}$	-5.706144**	0.0504
GII $^{+}$	21.30049	0.1502	**GII** $^{-}$	-0.131712	0.7234
Model 3					
	Coefficient	**p-value**		**Coefficient**	**p-value**
Export $^{+}$	0.452070***	0.0002	**Export** $^{-}$	0.916165***	0.0014
Industry $^{+}$	0.249807	0.1904	**Industry** $^{-}$	-3.485330***	0.0007
GDI $^{+}$	-1.392067***	0.0004	**GDI** $^{-}$	1.217403*	0.0655
Model 4					
	Coefficient	**p-value**		**Coefficient**	**p-value**
GII $^{+}$	37.88561***	0.0040	**GII** $^{-}$	-2.081182	0.1827
Export $^{+}$	-1.215455**	0.0187	**Export** $^{-}$	0.715043	0.3700
Industry $^{+}$	2.936941	0.1672	**Industry** $^{-}$	-6.553541	0.1384
Model 5					
	Coefficient	**p-value**		**Coefficient**	**p-value**
GII $^{+}$	33.65139**	0.0493	**GII** $^{-}$	-0.112512	0.9611
Trade $^{+}$	1.809967	0.3818	**Trade** $^{-}$	2.139930	0.1441
Export $^{+}$	-2.505847	0.1545	**Export** $^{-}$	-1.150048	0.5722
Industry $^{+}$	3.202481	0.2724	**Industry** $^{-}$	-11.11355*	0.0936

*, **, and *** denote 10, 5, and 1% significance levels, respectively.

In Models 4 and 5, the relationship between innovation and gender inequality was examined. In Model 4, a long-term asymmetric relationship was found between exports, gender inequality index, and the number of patents. According to the analysis results, a 1% increase in the gender inequality index significantly affects the number of patents by approximately 38%. Wang (2025) also states that gender equality is a

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crucial element for innovation, stating that gender inequality is not only a matter of fairness but also crucial for encouraging innovation. He states that the active role of women in innovation enriches cultural products and provides new opportunities for market growth. Therefore, promoting gender equality in creative industries is vital to ensuring their long-term sustainability and relevance.

On the other hand, a negative change in the gender inequality index does not significantly affect the number of patents. Similar results were obtained in Model 5, which also included trade. As in Model 4, the results of Model 5 indicate an asymmetric relationship between gender inequality and innovation. A 1% increase in the gender inequality index leads to an approximately 34% increase in the number of patents.

However, the finding that improvements in gender equality, as measured by GDI, are associated with a decrease in trade should be interpreted strictly within a positive (rather than normative) framework. This relationship does not imply that increasing gender equality is undesirable. Rather, it reflects short-term structural adjustments in the economy. In developing countries such as Türkiye, improvements in gender equality may increase labor costs and reduce cost-based competitiveness in labor-intensive sectors, leading to temporary declines in trade volume. In the long run, however, gender equality enhances human capital, productivity, and innovation, thereby contributing positively to sustainable economic development and improving the quality of trade.

Therefore, the results of this study should be interpreted within a broader economic framework, taking into account both short-term adjustment dynamics and long-term development benefits. Reducing gender inequality is essential not only from a social perspective but also for achieving sustainable and inclusive economic growth.

Diagnostic tests to verify the assumptions of the models defined in Table 11 are provided. The Lagrange Multiplier (LM) test was initially employed to evaluate the presence of autocorrelation issues within the models. The test findings indicate the absence of autocorrelation issues in all models at the 5% significance level. In the second stage, the Breusch-Pagan-Godfrey test was conducted to assess the presence of heteroscedasticity in the models, revealing no heteroscedasticity issues at the 5% significance level. In the third stage, the Ramsey Reset test was employed to assess potential model specification mistakes. No model specification mistakes were identified in any of the models.

Table 11. Diagnostic Tests Results

	Model 1		**Model 2**		**Model 3**		**Model 4**		**Model 5**	
	Coefficient	**p-value**	**Coefficient**	**p-value**	**Coefficient**	**p-value**	**Coefficient**	**p-value**	**Coefficient**	**p-value**
$\mathbf{X^2_{SC}}$	1.365375	0.1386	0.152100	0.6769	0.123609	0.6787	1.151547	0.1613	0.422803	0.4710
$\mathbf{X^2_{NORM}}$	0.422502	0.8096	0.590883	0.7442	1.029268	0.5977	0.238076	0.8877	4.235114	0.1203
$\mathbf{X^2_{HET}}$	1.301390	0.2963	2.028162	0.1038	1.443382	0.3226	0.408989	0.9246	1.000047	0.4824
CUSUM	Stable		Stable		Stable		Stable		Stable	
CUSUM^2	Stable		Stable		Stable		Stable		Stable	

X^2_{SC}: Serial correlation; X^2_{NORM}: Jarque-Bera normality test; X^2_{HET}: heteroscedasticity; CUSUM and CUSUM^2: stable or not.

The CUSUM and CUSUMQ tests were employed to assess the stability of the coefficients of the variables in the developed NARDL models. CUSUM and CUSUMQ statistics indicate whether the coefficients of the variables in the model are stable over time at a 5% significance level. Figure 2 shows the CUSUM and CUSUMQ results for all models in the study. In both graphs, all models remained within critical

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limits at a 5% significance level. These results clearly show that the coefficients of the estimated models are stable over the analysis period.

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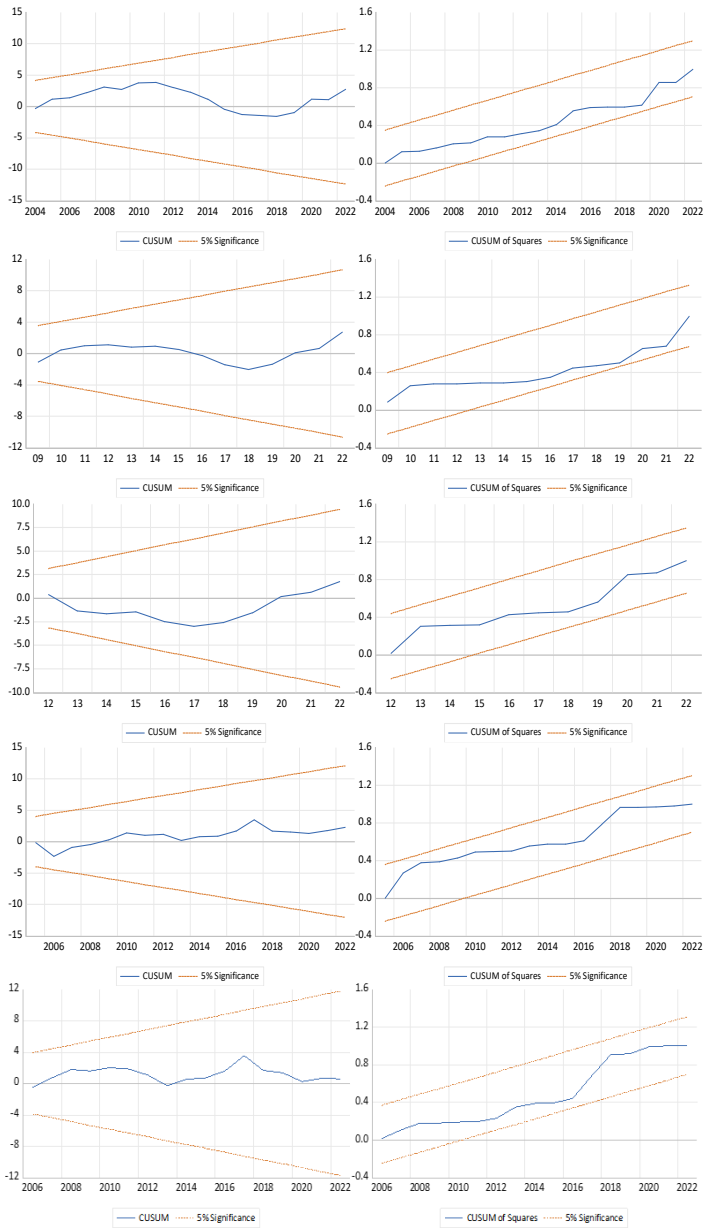


Figure 2.

CUSUM and CUSUMQ results

Finally, the following figures (Figures 3 to 7) show the cumulative dynamic multipliers of NARDL models, which measure the effect of one-unit (+) and (-) shocks of independent variables included in the models over 15 years on the dependent variable. Examining the adjustment path and imbalance duration after a positive/negative shocks provides pattern insights the model. The multipliers were estimated using the optimal NARDL model according to the Akaike Information Criterion.

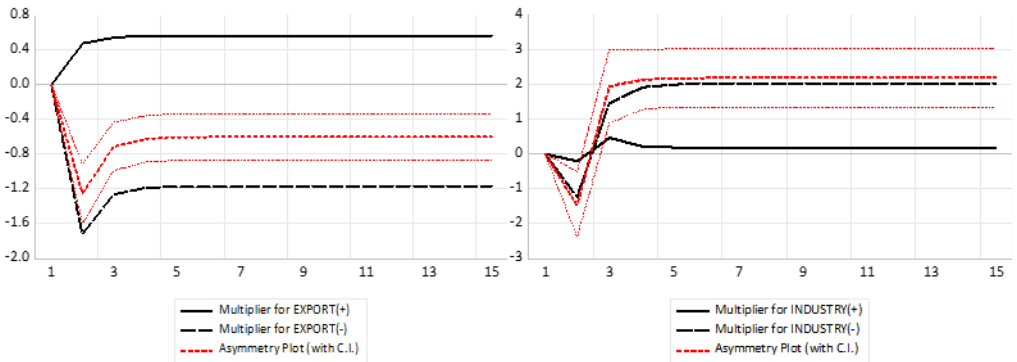


Figure 3. Model 1 dynamic multiplier graphs

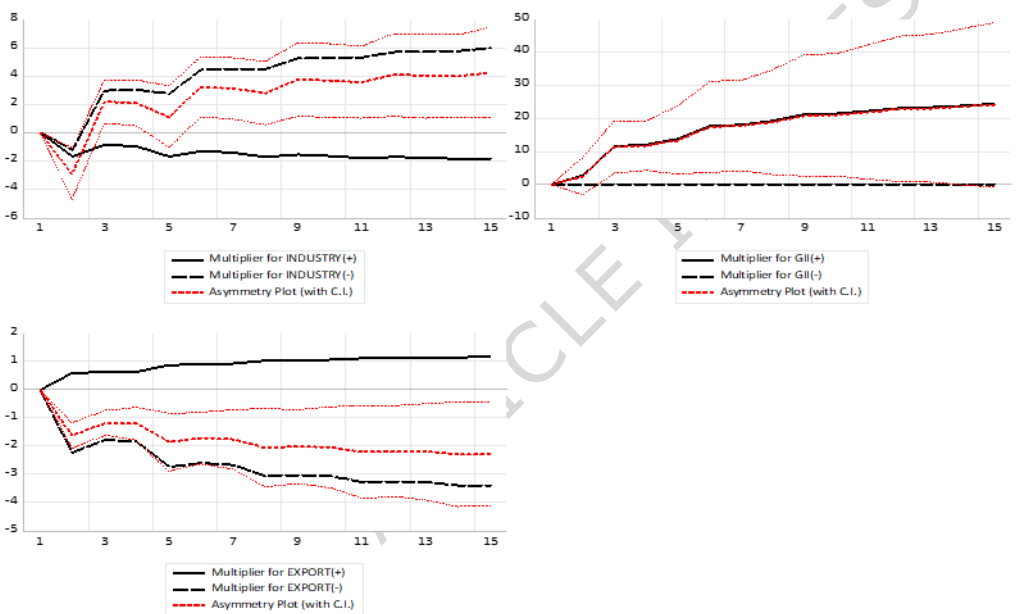


Figure 4. Model 2 dynamic multiplier graphs

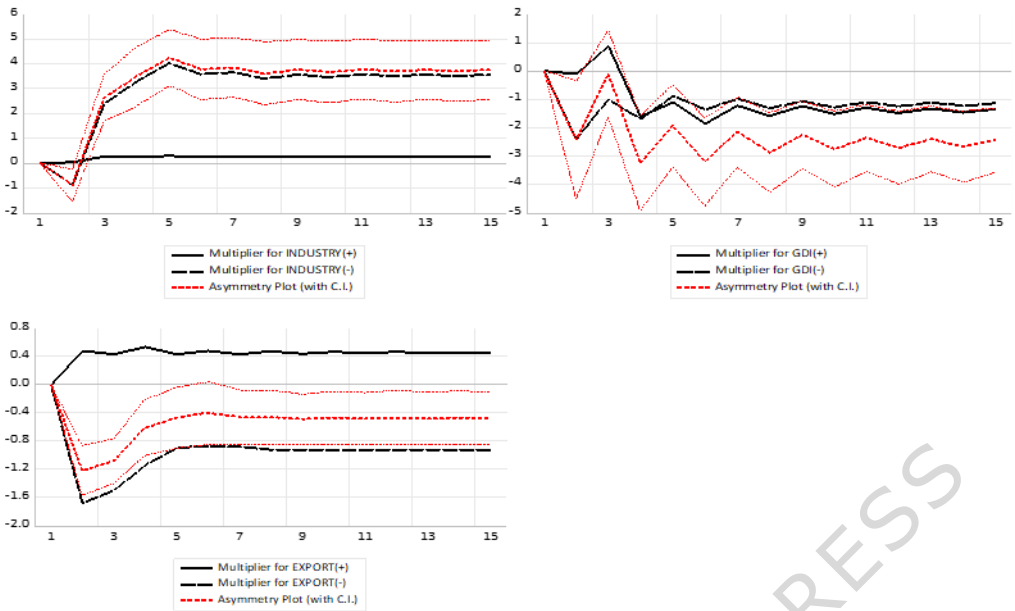


Figure 5. Model 3 dynamic multiplier graphs

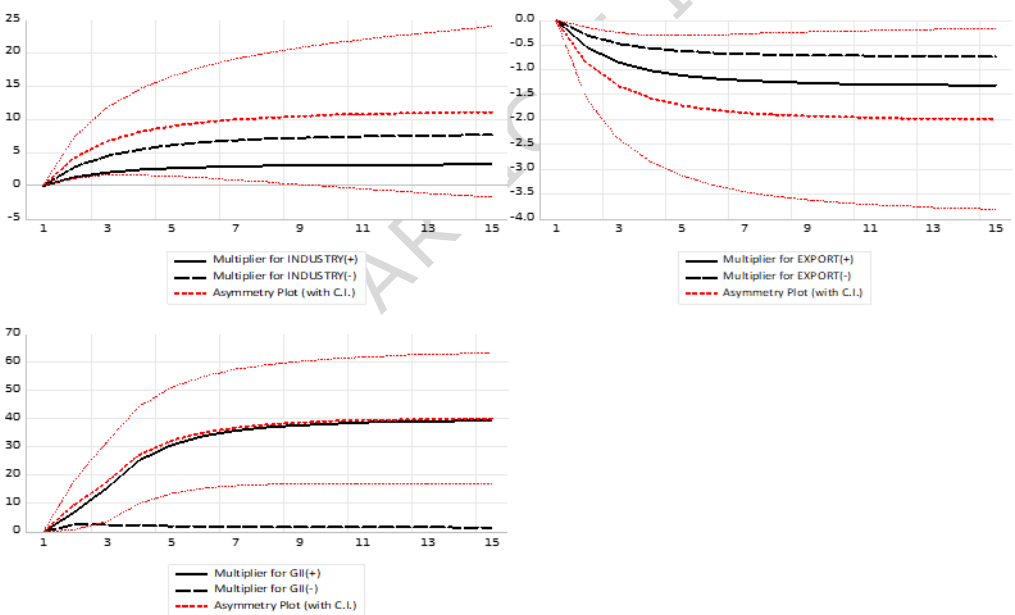


Figure 6. Model 4 dynamic multiplier graphs

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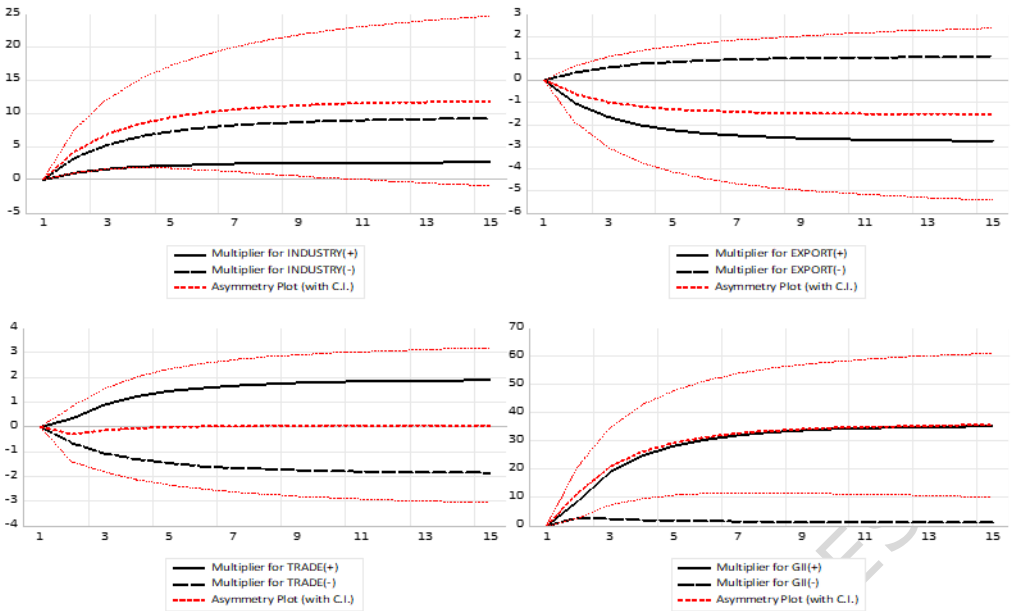


Figure 7. Model 5 dynamic multiplier graphs

Positive changes in the dependent variable are indicated by the thick solid line top, while negative changes are indicated by the thick dashed line bottom. The thick red dotted line in the middle represents the asymmetry line showing the difference between the positive and negative shock multiplier effects on the dependent variable over a 15-years period. The thin red dashed lines upper and lower indicate the 95% significance level that provides significance for asymmetry. If the zero line falls between the intervals, the asymmetry is not statistically significant at the 5% level. According to this theoretical framework, the dynamic multiplier graphs of all models confirm the results obtained in the analyses.

5. Conclusions

This study aimed to elucidate the correlation between gender inequality, international trade and innovation in Türkiye. The findings of the study indicate a difference between the gender inequality index and the gender development index results. Gender inequality exerts symmetrical impacts on international trade in both the short and long term, but the gender development index has asymmetrical effects on international trade over the same timeframes.

When examining long-term coefficients, it was found that exports and industrial employment asymmetrically affect trade, but the gender inequality index has no significant effect on trade. To establish the relationship between gender inequality and trade, another gender inequality indicator, the gender development index, was included in the model to create Model 3. When examining the NARDL results of Model 3, a long-term significant asymmetric relationship between gender inequality and trade is observed. This effect can be explained as follows: A long-term 1% increase in the gender development index reduces trade by approximately 1.4%, while a 1% decrease in the GDI reduces trade by approximately 1.2%. In other words, trade's response to an increase in the gender development index is greater and more pronounced than its response to a decrease in the index value. This suggests that the increase in gender inequality practices in Türkiye has a greater impact on trade than its decrease. This result suggests that in Türkiye, efforts to prevent the increase in gender inequality practices whenever

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possible are far more crucial than efforts to reduce them. To achieve this, the country should implement gender equality policies (e.g., preventing male violence against women, making women's poverty visible and compensating, implementing special mechanisms to increase women's participation in political and public decisions, etc.), including men in the development of gender equality policies, and strengthening the fight against sexist stereotypes and social values (Sancar, 2021).

When examining the relationship between innovation and gender inequality, it has been determined that gender inequality has an asymmetric effect on innovation in the short term. Similarly, a long-term asymmetric relationship has been identified between the export and gender inequality index and the number of patents. According to the results of the study, a 1% increase in the gender inequality index significantly affects the number of patents by approximately 38%. On the other hand, a negative change in the gender inequality index does not significantly affect the number of patents. The Gender Inequality Index is a composite measure reflecting the inequality of achievement between women and men across three dimensions: reproductive health, empowerment, and the labor market. A high Gender Inequality Index (GGI) score indicates significant gender inequalities that can hinder overall development. Such inequalities can lead to lower rates of women's participation in education and the workforce, hindering economic growth. Indeed, the study's results indicate that even a modest increase in this index has a significant impact. To maintain a low value for this index, gender-focused policies aimed at improving women's access to education, healthcare, and employment opportunities in Türkiye should be developed and integrated into development strategies. This can help increase the number of patents and innovation activities by fully utilizing women's potential. Furthermore, increasing women's interest in education in all fields, such as natural sciences, technology, engineering, and mathematics, can help reduce gender discrimination in innovation. Moreover, when the results are evaluated in terms of the UN SDGs, they show that trade contributes more strongly to progress in gender equality contributes to the goals of Gender Equality, Decent Work and Economic Growth, and Reduced Inequalities. At the same time, the findings demonstrate that an increase in GII leads to a significant increase in the number of patents is related to the SDGs' measures of Gender Equality, Industry, Innovation and Infrastructure, and Reduced Inequalities.

Therefore, policymakers should interpret the short-term negative association between gender equality and trade as a transitional adjustment rather than a long-term trade-off, and continue to promote gender equality as a key driver of sustainable economic development.

In the future, studies can be conducted to examine the relationship between gender inequality and international trade and innovation on a sectoral basis, to reveal which sectors have more gender inequality practices and how this affects international trade and innovation, particularly in those sectors.

The biggest limitation of the study is that the study data is restricted to data related to Türkiye only.

Data Availability

The data that support the findings of this study are available from corresponding author upon reasonable request.

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