Study on the Impact of Female Labor Force Participation on Carbon Emissions based on the Fixed Effect Model and FGLS Estimation

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Abstract

Based on the panel data of 16 European countries from 2000 to 2016, I provide the empirical study quantifying the impact of female labor force participation on carbon emissions. In the design of my empirical research, I adopt the fixed effect model and use FGLS estimation. The results show that the increase of female labor force participation rate would significantly reduce carbon emissions. 1 unit increase of the ratio of female to male labor participation rates is associated with 0.30 percentage decrease of the CO2 emission per capita.

Keywords-*female labor participation; carbon emissions; enviro-nmental protection*

1. INTRODUCTION

The employment of labor force is closely related to carbon emission (Wu, et al., 2013; Song & Jin, 2013). There are significant gender differences in labor force participation. For example, according to the statistics of the U.S. Department of labor (DOL), the labor participation rate of women in France is 50%, 12 percentage points lower than that of men. The existence of these differences makes female labor force participation have an impact on carbon emissions. On June 3, 1992, the Framework Convention on Climate Change signed at the United Nations Conference on environment and develop-ment first mentioned the important role played by women in environmental management and sustainable development [1].

There is little literature on the relationship between female labor participation and carbon emissions. Wang, et al. (2021) point out that the increase in the proportion of female labor force would significantly reduce the carbon emissions of imports and exports of industrial and service sectors in developed countries [2]. McKinney and Fulkerson (2015) also find that when women suffer, the environment is also affected.

From the industrial structure of labor participation, production activities with higher physical requirements need more male labor force, while female labor force is more concentrated in the tertiary industry and light industry. In modern society, in heavy industries such as iron and steel industry, metallurgy industry, machinery industry and energy industry, the proportion of male labor force in the total labor force is high, while the proportion of female labor force in education, textile industry and food manufacturing industry is large [3]. From the perspective of social concept, women pay more attention to environmental issues than men because they take more responsibility for taking care of children. Therefore, the possible mechanisms for the impact of female labor force participation on carbon emissions are as follows: first, the improvement of female labor force participation rate improves women's social status, and more women participate in decision-making, so as to promote the formulation of environ-mental protection policies. Second, the increase of female labor force participation rate means that more labor force enters the service industry and light industry, which can promote the development of low-carbon emission industries [4]. At the same time, women could also cultivate the next generation's awareness of environmental protection by partici-pating in the education industry.

Using the panel data of 17 European countries, I provide the empirical study estimating the influence of female labor force participation rate on carbon emissions, and propose corresponding development suggestions based on the empirical results [5]. In view of the expected regression results, I propose the following hypothesis:

Carbon emissions are lower when women's participation in the labor force is higher.

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My research expands the relevant literature on the relationship between labor employment and carbon emissions from the perspective of female labor force participation. At the same time, this paper makes sense for the designation of environmental protection policies and promoting women's role in environmental protection and sustainable development.

2. DATA

I use the panel data of 17 European countries (Belgium, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Luxembourg, Norway, Poland, Portugal, Slovenia and Spain) from 2000 to 2016 as samples. The reasons for I selecting the 17 European countries are, firstly, considering the availability of data, there are fewer missing values in the European sample data. Secondly, European countries are more developed with higher level of HDI (Human Development Index), which means the social environment is more stable. Therefore, the conclusion is more convincing. All the data are from "our world in data", a database providing research data to make progress against the world's largest problems.

I choose the logarithm of annual production-based emissions of carbon dioxide (CO2) per capita as the dependent variable and select the ratio of female to male labor force participation rate as the independent variable. There is no reverse causality in my study [6]. Although there is a study showing that environmental pressure could reduce women's decision-making initiative in economically backward regions in Asia and Africa (Rao, et al., 2019), this conclusion is obviously not applicable to the European sample selected in this paper. Since factors such as the level of economic development, urbanization and the proportion of renewable energy in total energy consumption also have an impact on carbon emissions, I take them as control variables to reduce omitted variable bias.

For the control variables, first, HDI, the Human Development Index is a summary measure of average achieve-ment in key dimensions of human development: a long and healthy life, being knowledgeable and have a decent standard of living. It is measured by life expectancy at birth, mean years of schooling and expected years of schooling and GNI per capita. The HDI is the geometric mean of normalized indices for each of the three dimensions. Since it reflects the level of living standard and living standard is closely related to carbon emissions (He, et al., 2012), it has an impact on carbon emissions. Therefore, I take HDI as a control variable. Second, GDP per capita, which can represent the economic development stage of an economy, is one of the control variables in my econometric model. According to the Environmental Kuznets Curve, with the development of economy, carbon emissions may show an inverted U-shaped change (Xu & Song, 2010). In the early stage of economic development, heavy industry is the main source of carbon emissions, and after economic development to a certain extent, it mainly depends on the service industry and high-tech industry, and the carbon emission is reduced. Third, I take fossil fuel consumption as a control variable. Fossil fuel consumption is measured by kwh per capita. Due to the combustion of fossil fuels or biomass energy and the direct emission of CO2, CH4 and N2O into the atmosphere in the process of industrial production, fossil fuel consumption is an important factor directly leading to carbon emissions. Hence, I use fossil fuel consumption as the control variable. Forth, the use of renewable energy could reduce carbon emissions, so I take it as a control variable. Fifth, urbanization rate, which is measured by share of populations living in urban areas is taken as a control variable. The impact of urbanization on carbon emissions includes both positive and negative aspects (Wang & Zhou, 2012; Li & Yu, 2017). On the one hand, urbanization is accompanied by industrialization [7]. The promotion of industrialization and urban construction would cause a lot of carbon emissions. On the other hand, industrial agglomeration in the process of urbanization will reduce energy consumption and thus decrease carbon emissions.

The description of variables is showing in table1.

TABLE 1. SELECTION OF VARIABLES

	Variables	Definition
Dependent variavle	ln*emission*	Logarithm of annual production-based emissions of carbon dioxide (CO2) per capita (t)
Independent variable	*labor*	Ratio of female to male labor force participation rate (%).
Control variables	*hdi*	Human Development Index
	urban	Share of populations living in urban areas
	fuel	Fossil fuel consumption per capita (kwh)

	renew	Percentage of renewable energy
	pergdp	GDP per capita

a. Data from "our world in data"

The summary statistics of data is showing in table2:

TABLE 2. SUMMARY STATISTICS

Variables	Obs	Mean	Std. Dev.	Min	Max
lnemission	289	2.22	0.345	1.493	3.275
labor	289	78.672	6.798	60.302	90.998
renew	289	15.203	21.533	0.089	82.835
pergdp	289	34988.8	14422.1	11903	81923
urban	289	75.202	12.188	50.754	97.919
hdi	289	0.87	0.041	0.769	0.951
fuels	289	38330.6	16860.4	19568.9	113000

a. Data from "our world in data"

From the table, it can be seen that the mean value of the logarithm of carbon emission is relatively high, about 2.22t. The ratio of female to male labor force participation rate, with the mean of 78.672%, shows that female's labor participation is relatively high, which means the gender discrimination of the samples countries is relatively low.

3. MODEL

This paper adopts FE model. Since the number of countries is equal to the number of years, treatment of error term should be considered. In order to control heteroskedasticity, autocorrelation and cross-sectional correlation of the error term, this paper adopts FGLS estimation. For robustness, this paper also uses OLS estimation to test whether the result is robust after changing estimation method. The following formula is the regression model in this paper:

$$\ln emission_{it} = \beta_0 + \beta_1 lobor_{it} + \mathbf{\theta X} + \delta_t + \alpha_i + \varepsilon_{it} (1)$$

In this model, *i* stands for country, *t* refers to year, **X** refers to the matrix of all control variables which are designed to control omitted variable bias, ε_{it} is the error term, α_i and δ_t refer to country fixed effects and time fixed effects respectively.

4. RESULTS

To start with, I draw the figure of the relationship between *labor* and *emission*, and it shows a negative relationship.

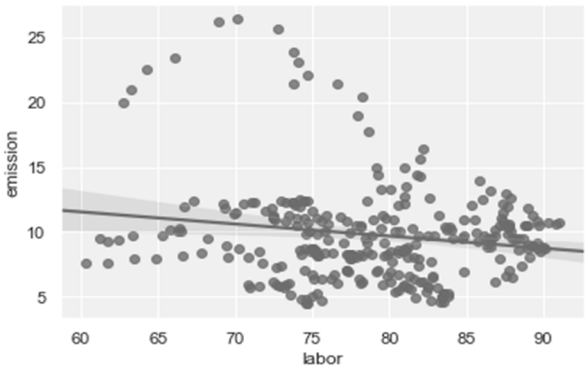

Figure 1. Scatter Graph of *labor* and *emission*

Then, I conduct the regression and gets the following table:

TABLE 3. REGRESSION RESULTS

Variables	FGLS	OLS	FGLS	OLS
labor	-0.0099***	-0.0150***	-0.0030***	-0.0037**
	(0.001)	(0.002)	(0.000)	(0.002)
renew			-0.0036***	-0.0024*
			(0.001)	(0.014)
pergdp			0.0000***	0.0000***
			(0.000)	(0.000)
urb			-0.0102***	-0.0141***
			(0.001)	(0.004)
hdi			-0.1762***	-0.9217
			(0.036)	(0.608)
fuels			0.0000***	0.0000***
			(0.000)	(0.000)

Constant	3.1281***	3.3948***	2.6811***	3.7387***
	(0.058)	(0.373)	(0.098)	(0.640)
Observations	289	289	289	289
R-squared		0.538	0.658	0.927
Number of id	17	17	17	17

a. Data from "our world in data"
b. Standard errors in parentheses
c. *** p<0.01, ** p<0.05, * p<0.1

Table3 shows the regression result of this paper. First, without adding control variables, the regression coefficient of labor is -0.0099 and shows a significant level of 0.01 [8]. Therefore, 1 unit increase of the ratio of female to male labor participation rates is associated with 0.99 percentage decrease of the CO2 emission per capita. Second, after adding control variables, although the absolute value of the coefficient of labor decreases, the sign doesn't change and the result is still significant. Thus, 1 unit increase of the ratio of female to male labor participation rates is associated with 0.30 percentage decrease of the CO2 emission per capita.

The results of FGLS estimation and OLS estimation show consistent results. So, this result can be regarded as high robust.

5. Discussion

Large amounts of measures are proposed to address the greenhouse effect and reduce carbon emission. In this paper, I focus on the impact of the proportion of females in the workforce on carbon emissions.

Actually, the co-movement between female workforce participation and ecological environment has been a hot issue in the recent decades. Since the 1970s, many feminists, especially ecofeminists, have embraced the idea that environmental issues are one of the issues that feminists should address. Many women around the world have become activists in the ecological movements. In Sweden, some women gave their councilor jam made from contaminated berries to protest against use of herbicides in forests. Women in India participated in "Chipko Movement" to protect trees that will be used for fuel. In Kenya, they planted trees and joined the "Green Movement" to turn deserts into oases. Women in Britain protested against the threat of nuclear missiles to life on Earth; German women helped found the Green Party as a forum for pursuing a green future for the country and the planet. In 1987, Ecofeminists have also held a conference to mark the 25th anniversary of Silent Spring, calling on women to join and lead an ecological revolution to protect the planet's ecosystems.

The term "ecofeminism" was proposed in 1974 by a French feminist called Francoise d'Eaubonne, who emphasized the potential of females in addressing the global ecological crisis and called upon female to lead a revolution to save the earth and establish a new relationship between nature, male, and female.

Based on these events, there are two possible reasons to explain why females pay more attention to ecological environment and care more about carbon emission. One is the gender socialization [9]. In the process of socialization, individuals are shaped into the gender temperament that matches their physiological gender. Females show the femininity of caring and pay more attention to environment protection.

Another explanation comes from societal gender structure. It emphasized the impact of difference in social status on attitudes to environment.

Generally, women are to some extent at disadvantage in income and social status. And they play an important role in social division of labor such as caring and upbringing, which leads to more concerns for the negative impact of the carbon emission and. In other words, they spend more time on taking care of their families and worry about their families' health and safety, the living environment for offspring rather than economic development. Therefore, they are friendlier to the environment and more likely to accept the idea of environment protection.

So, as the labor participation rate of female increases, women will play more and more important roles in economics and politics. Then they can exert more influence on policies concerning environment protection and reduction in carbon emission. That means women could turn their concerns about ecological environment into active policy, which could lead to less carbon emission in the reality.

6. Conclusion

From the results of the empirical part, I draw the following conclusions:

First, the higher the participation rate of women in the workforce, the lower the carbon emissions, which supports the initial hypothesis.

Second, from the perspective of control variables, the development and utilization of new energy would significantly reduce carbon emissions, which is coincide with people's intuition. The development and utilization of new energy would reduce the consumption of fossil fuels to a certain extent, which could reduce carbon emissions.

Generally speaking, in the workforce of different apartment, the factor of gender should be paid more

attention and the policy makers ought to introduce the more equality between men and women in the industrial production process. More women should be encouraged to participate in the workforce, which can reduce the emission of carbon and enhance the impact of gender factor on the environmental protection.

7. Weaknesses

In the process of data acquisition and processing, there may exists omitted variable bias. Because the participation rate of women in the labor force may be related to other factors such as education level, the education level of men and women may be inconsistent on the whole, which leads to the different participation rate of women in the labor force in some countries, resulting in the error of result estimation.

Since the countries I study are more developed countries in Europe, the extent of economic development, people's environmental protection concept, degree of gender equality, level of education and cultural background are very similar and in the high level, which makes the selection of countries lack of universality. So, this conclusion may be not so persuasive in other less developed countries or countries with different cultural background. it's the problem of the external validity. In this way, the above regression results may not lead to the general conclusion that the participation rate of women in the labor force can reduce carbon emissions for all countries.

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