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Sustainable Financial Development: Does It Matter for Greenhouse Gas Emissions?

Yuang He 1, Xiaodan Gao 2,* and Yinhui Wang 2

1 College of Liberal Arts, Sejong University, Seoul 05006, Korea; 1293647581@sejong.ac.kr
2 College of Commerce, Jeonbuk National University, Jeonju 54896, Korea; wyh1103@jbnu.ac.kr
* Correspondence: gaoxiaodan92@naver.com

Abstract: As the detrimental effect of greenhouse gas emissions becomes increasingly significant, it has been a worldwide concern. As a result, the purpose of this paper is to examine the effect of sustainable financial development on greenhouse gas emissions via heterogeneous technological progress, using 162 countries as a sample. Empirical assessment is conducted using panel data from 2000 to 2019 and the mediation effect model as well as the country and year fixed-effect model. The findings are shown as follows: (1) Greenhouse gas emissions are increased as a result of sustainable financial development. (2) Environmental technology progress and technology choice progress have a dilution effect. Together, they have the ability to lower the amount of greenhouse gas emissions caused by sustainable financial development. However, these two dilution effects do not completely cut down on the amount of greenhouse gas emissions that come from global sustainable financial development, even though they do help. (3) The direct and indirect effects of sustainable financial development on greenhouse gas emissions are heterogeneous among countries with different income levels. Through technological progress, sustainable financial development in middle-income countries significantly cuts greenhouse gas emissions. Sustainable financial development, on the other hand, increases greenhouse gas emissions in both high- and low-income countries, although there are distinctions between them. (4) Environmental technology progress in high-income countries has a dilution effect. Meanwhile, technological choice and progress in low-income countries have a mediating effect on greenhouse gas emissions. To conclude, the evidence provided in this paper may provide some potential solutions to the issue of greenhouse gas emissions, and also enrich the existing literature.

Keywords: sustainable financial development; greenhouse gas emissions; mediating effect; dilution effect; country and year fixed-effect model

1. Introduction

Global warming has become an important obstacle to the sustainable development of the human economy and society. We need to attach a lot of great importance to the control of greenhouse gas emissions. As the International Energy Agency reported, global greenhouse gas emissions will increase by 57% by 2030. Based on the Global Climate Summit, it is reported that how to reduce greenhouse gas emissions has become a common challenge for mankind in the near future. Recently, many scholars have begun to discuss how to reduce greenhouse gas emissions in terms of financial development. With a sample of 129 countries, Al-Mulali et al. [1] found that financial development has a negative effect on carbon dioxide emissions (as a proxy for greenhouse gas emissions). Meanwhile, this result was supported by Dogan and Seker [2], Abbasi and Riaz [3], Shahbaz et al. [4], and Shahbaz et al. [5]. On the contrary, Isik et al. [6] found that financial development had a positive effect on greenhouse gas emissions in the case of Greece from 1970 to 2014. Moreover, their findings were consistent with Javid and Sharif [7], Shahzad et al. [8], and Haseeb et al. [9]. In addition, using the cointegration test with structural breaks, Charfeddine and Khediri [10]...
found that the relationship between financial development and carbon dioxide emission was not significant. Their findings were supported by Zambrano-Monserrate et al. [11], Mahmood [12], and Abokyi et al. [13]. To summarize these three kinds of findings on this proposition, it can be easily found that scholars have not coincided in opinion with respect to the effect of sustainable financial development on greenhouse gas emissions.

Based on the uncertain relationship between financial development and greenhouse gas emissions, this paper attempts to explore how sustainable financial development affects greenhouse gas emissions, to find out how sustainable financial development curbs greenhouse gas emissions more effectively via what kind of technological progress channel, and to investigate how the inhibiting effect of sustainable financial development works well so as to promote sustainable economic development. Then, based on the panel data of 162 countries over the period of 2000 to 2019, the country and year fixed-effects model is used to find out what kind of technological progress can help curb greenhouse gas emissions more effectively. Via the empirical analysis, it can be found that, at present, sustainable financial development increases greenhouse gas emissions. Environmental technological progress and technological choice progress can dilute the promotion effect of sustainable financial development on greenhouse gas emissions. However, this dilution effect does not completely dilute the promotion effect of sustainable financial development on greenhouse gas emissions in the world as a whole. Meanwhile, the effect of sustainable financial development on greenhouse gas emissions and the indirect effect of technological progress are heterogeneous.

This paper contributes to the literature in four ways. First, this paper uses three different financial development indicators (domestic credit to the private sector by banks, financial markets, and financial institutions) to measure sustainable financial development [14]. This treatment can more accurately explore the effect of financial development on greenhouse gas emissions when compared with Ziaei [15], who only used one financial development indicator to study this proposition. Second, this paper reveals that sustainable financial development has two effects: the technology upgrading effect and the total expansion effect. Through technological innovation and other channels, sustainable financial development can indirectly reduce greenhouse gas emissions. Third, most of the existing studies, such as Bekhet et al. [16], had only taken technological innovation as the control variable. However, the heterogeneity of technological progress was rarely included in the analysis framework of sustainable financial development and greenhouse gas emissions to explore its mechanisms. Therefore, this paper uses the mediation effect model to perform empirical analysis and focuses on the role of sustainable financial development in technological progress. In this way, it can be seen what kind of technological progress can help sustainable financial development curb greenhouse gas emissions more effectively. Fourth, there are characteristics and differences among different income countries in the world. Therefore, in addition to the overall analysis of sustainable financial development, technological progress, and greenhouse gas emissions among different income countries, this paper also analyzes them from three different income countries, namely high-income countries, middle-income countries, and low-income countries, to enrich the relevant current literature.

The remaining sections of this paper are organized as follows. Section 2 presents the literature review on the effect of sustainable financial development on greenhouse gas emissions. Section 3 describes variables and explains models. Section 4 analyzes the discussion and findings. Section 5 provides conclusions and suggestions.

2. Literature Review

There is a very vast literature available on the effect of financial development on greenhouse gas emissions. In this section, we build on three strands to discuss how financial development affects greenhouse gas emissions in previous studies.

The first strand of existing literature on the topic provides empirical evidence on the relationship between financial development and greenhouse gas emissions. They hold
the view that the effect of financial development on greenhouse gas emissions is positive. Specifically, Bekhet et al. [16] used the Gulf Cooperation Council countries from 1980 to 2011 as a sample to study the causal relationship between financial development and carbon dioxide emissions. They estimated a one-way causal relationship between financial development and carbon dioxide emissions using an autoregressive distributed lag model. Moreover, they also found that an improvement in financial development increased carbon dioxide emissions. Taking renewable energy consumption and economic growth into consideration, Charfeddine and Kahia [17] investigated the effect of financial development on carbon dioxide emissions in the cases of 24 countries in the Middle East and North Africa Region from 1980 to 2015. Using the panel vector autoregressive model to perform the empirical analysis, they found that the effect of financial development on carbon dioxide emissions was significantly positive. Incorporating factors such as urbanization and income, Pata [18] used the autoregressive distributed lag bounds testing approach, Gregory-Hansen and Hatemi-J cointegration tests for Turkey during the period of 1974–2014 to examine the effect of financial development on carbon dioxide emissions. The coefficient obtained from the autoregressive distributed lag model, fully modified least squares and canonical cointegrating regression estimators showed that financial development positively affected carbon dioxide emissions. Using the autoregressive distributed lag bounds test for the cointegration procedure and employing the annual time series data from 1971 to 2011, Hafeez et al. [19] found that a 1% increase in financial development would increase carbon dioxide emissions by 0.165% in the case of Pakistan. Moreover, the Granger causality results indicated a unidirectional causality from financial development to carbon dioxide emissions. To sum up, these findings obtained from different samples, methods, and time spans were supported by Le and Ozturk [20], Omri et al. [21], Khan et al. [22], Kahia et al. [23], Ganda [24], and Bayar and Maxim [25]. As a result, the following hypothesis is proposed:

Hypothesis 1 (H1). Financial development positively affects greenhouse gas emissions.

The second strand deals with financial development and greenhouse gas emissions. A group of scholars believes that financial development can reduce greenhouse gas emissions. Zaidi et al. [26] used the Asia-Pacific Economic Cooperation countries as a sample to explore the dynamic linkages between financial development and carbon dioxide emissions over the period of 1990 to 2016. Employing the Westerlund cointegration technique and continuously updated bias-corrected and continuously updated fully modified methods to perform the empirical analysis, their findings suggested that financial development significantly reduced carbon dioxide emissions. Majeed et al. [27] investigated the asymmetric effect of financial development on carbon dioxide emissions by employing a nonlinear autoregressive distributed lag model over the period of 1972–2018. They found that financial development had a negative effect on carbon dioxide emissions. Incorporating income, trade openness, and urbanization, Saidi and Mbarek [28] empirically examined the effect of financial development on carbon dioxide emissions for the panel of emerging economies using time series data over the period of 1990–2013. They found that financial development has a long-run negative effect on carbon dioxide emissions. Based on panel data from 97 countries over the period of 2000–2014, Lv and Li [29] used the spatial econometric model to reexamine the effect of financial development on carbon dioxide emissions. Their results suggested that financial development reduced carbon dioxide emissions. Shahbaz et al. [30] applied the bounds testing approach to cointegration between financial development and carbon dioxide emissions in the case of the Malaysian economy. Their empirical results indicated that financial development reduced carbon dioxide emissions. To summarize, these findings obtained from different samples, methods, and time spans were supported by Yao and Tang [31], Omri et al. [32], Raheem et al. [33], Neog and Yadava [34], Adams and Klobodu [35], Zafar et al. [36], and Khezri et al. [37]. Therefore, the following hypothesis is proposed:
Hypothesis 2 (H2). Financial development negatively affects greenhouse gas emissions.

The third strand deals with the analysis that financial development has no effect on greenhouse gas emissions. Incorporating energy consumption in the framework of the Environment Kuznets Curve hypothesis in India during the period of 1971–2014, Sahu and Kumar [38] used the autoregressive distributed model to study the effect of financial development on carbon dioxide emissions. They found that financial development had no significant effect on carbon dioxide emissions. Dogan and Turkekul [39] investigated the relationship between carbon dioxide emissions and financial development in the USA for the period 1960–2010, incorporating energy consumption, real output, square of real output, trade openness, and urbanization. The results of the bounds testing for cointegration suggested that financial development had no effect on carbon dioxide emissions in the long run. In addition, the results from the Granger causality test showed that there was no causality between carbon dioxide emissions and financial development. Maji et al. [40] also examined the effect of financial development on carbon dioxide emissions with a sample of Malaysia. They found that the elasticity of financial development was not significant in explaining the carbon dioxide emissions from the agricultural sector. To conclude, these findings, obtained from different samples, methods, and time spans, were supported by Lahiani [41] and Nguyen et al. [42]. Consequently, the following hypothesis is proposed:

Hypothesis 3 (H3). Financial development has no effect on greenhouse gas emissions.

To distinguish from the previous literature analyzed above, following Khan et al. [43], Gu et al. [44], Wang et al. [45], and Wang et al. [46], technological progress, which is regarded as the initiative to reduce greenhouse gas emissions, is introduced in this paper. Sustainable financial development can promote technological progress, so sustainable financial development plays a crucial and indirect role in reducing greenhouse gas emissions. To analyze the path of sustainable financial development affecting greenhouse gas emissions, this paper attempts to find out whether sustainable financial development will reduce greenhouse gas emissions in the following four different ways of technological progress: generalized technological progress, environmental technological progress, technological choice progress, and foreign direct investment technological spillover. The details will be shown in Section 4.

3. Variable and Model

3.1. Variable Description

This section provides the descriptions of fifteen variables. These variables are divided into four types. They are dependent variables, independent variables, mediator variables, and control variables. All of them will be described in detail in the following content.

3.1.1. Dependent Variable

The dependent variable in this paper is greenhouse gas emissions. Following Vasylieva et al. [47], Ziolo et al. [48], Khan et al. [49], and Magazzino et al. [50], the greenhouse gas emissions (CH$_4$ in CO$_2$ equivalent, CO$_2$, N$_2$O in CO$_2$ equivalent) in kilograms per capita are treated as a proxy for the greenhouse gas emissions.

3.1.2. Independent Variable

Finance is an economic activity in which the main body of the market uses financial instruments to transfer funds from the surplus side to the scarce side. As the core of the modern economy, finance is a complex system. Therefore, the setting and selection of financial development indicators are multi-dimensional. Aluko and Obalade [51], and Zhou et al. [52], used the financial development index (constructed from Global PCA) as a proxy for financial development. Nguyen et al. [53] use private-sector bank credit, stock market capitalization, and liquid liabilities (as a percentage of GDP) as proxies for finan-
cial development. Acheampong et al. [54] used the financial market development, depth, efficiency, and access indexes as proxies for financial development. Avom et al. [55], Magazzino [56], and Magazzino et al. [57] used the ratio of domestic credit to the private sector (% of GDP). In fact, there are also many measures of financial development. Following Ziolo et al. [58], we use domestic credit to the private sector by banks, the financial markets index, and the financial institutions index as proxies for sustainable financial development.

3.1.3. Mediator Variable

To consider the indirect effects of heterogeneous technological progress, following Zhao et al. [59] and Chen et al. [60], we use four indicators to measure technological progress. They are generalized technological progress (it is measured by the number of patents actually authorized). The higher the value is, the higher the technical level will be), environmental technological progress (it is measured by the total energy consumption per unit of GDP). The smaller the value is, the higher the technical level will be), technological choice progress (it is measured by the capital-labor ratio). The larger the value it has, the more capital, rather than labor, is chosen for technological progress in the production process. That is to say, the higher the utilization efficiency of material capital, the higher the foreign direct investment technological spillover will be (it is measured by the ratio of actually utilized foreign direct investment to GDP). The reason is that, with the growth of the investment scale of foreign enterprises, enterprises in the host country can imitate and learn from foreign technology to achieve technological progress.

3.1.4. Control Variable

Following Godil et al. [61], Haini [62], Pata and Caglar [63], Chen et al. [64], Zhang et al. [65], Magazzino et al. [66], and Magazzino and Falcone [67], we use seven control variables in this paper. They are industrial structure (because greenhouse gas emissions mainly come from industry, this paper uses the industry share as a percentage of GDP as a proxy for the industrial structure), economic development level (it is measured by GDP per capita), trade openness (it is measured by the ratio of total import and export to GDP), human capital (it is measured by the average years of education of employees), infrastructure level (it is measured by the total mileage of highway and railway per square kilometer), urbanization (it is measured by the ratio of urban population to total population), and institutional quality (it is measured by the economic freedom index). To summarize, these four kinds of variables will be presented in Table 1.

Table 1. Variable description.

| Variable | Abbreviation | Definition | Source |
|----------|--------------|------------|--------|
| Greenhouse gas emission | gge | greenhouse gas emissions in kilograms per capita in log | World Bank Open Data |
| Sustainable financial development independent variable | | | |
| Domestic credit to private sector by banks | fd1 | Proportion of domestic credit to private sector by banks to GDP | World Development Indicators |
| Financial markets | fd2 | Financial Markets Index in log | IMF database |
| Financial institutions | fd3 | Financial Institutions Index in log | IMF database |
| Mediator variable | | | |
| Generalized technological progress | tech1 | Number of patents actually authorized in log | World Bank Open Data |
| Environmental technological progress | tech2 | Total energy consumption per unit of GDP | World Bank Open Data |
| Technological choice progress | tech3 | Capital labor ratio | World Bank Open Data |
| Foreign direct investment technological spillover | tech4 | Ratio of actually utilized foreign direct investment to GDP | World Bank Open Data |
Table 1. Cont.

| Variable                  | Abbreviation | Definition                                             | Source                      |
|---------------------------|--------------|--------------------------------------------------------|                            |
| Industrial structure      | is           | Industry share as percentage of GDP                    | World Bank Open Data        |
| Economy developing level  | edl          | GDP per capita in log                                   | World Bank Open Data        |
| Human capital             | hc           | Average years of education of employees in log         | World Bank Open Data        |
| Trade openness            | to           | Ratio of total import and export to GDP                | World Bank Open Data        |
| Infrastructure level      | il           | Total mileage of highway and railway per square kilometer in log | World Bank Open Data        |
| Urbanization              | ur           | Ratio of urban population to total population          | World Bank Open Data        |
| Institutional quality     | iq           | Economic freedom index in log                          | Freedom House Report; knoema |

3.2. Model

In order to explore the effect of sustainable financial development on greenhouse gas emissions in the world as a whole, as well as in high-income, middle-income, and low-income countries, the following Ziolo et al. [48], Dogan and Turkekul [39], and Esmaeilpour Moghadam and Dehbashi [68], the baseline models are constructed as follows:

\[
gge_{i,t} = a_0 + a_1 fd_{i,t} + a_2 fd_{i,t}^2 + \sum_{j=3}^{n} a_j cv_{i,t} + \mu_i + \delta_t + \epsilon_{i,t} \quad (1)
\]

where \( i \) stands for the country; \( t \) stands for the year; \( gge \) stands for the greenhouse gas emissions; \( fd \) stands for the sustainable financial development; \( fd^2 \) stands for the square of sustainable financial development; \( cv \) stands for the control variable including seven variables; \( \mu_i \) stands for the country fixed-effects; \( \delta_t \) stands for the year fixed-effects; \( \epsilon_{i,t} \) stands for the white noise. On Equation (1), more attention will be paid to the coefficients \( a_1 \) and \( a_2 \). Specifically, if \( a_1 \) is greater than zero and significant in statistics, the effect of financial development on greenhouse gas emissions is positive. On the contrary, if \( a_1 \) is less than zero and significant in statistics, the effect of financial development on greenhouse gas emissions is negative. Otherwise, if \( a_1 \) is equal to zero or not significant in statistics, financial development has no effect on greenhouse gas emissions. Furthermore, if \( a_2 \) is not equal to zero and significant in statistics, this means that there is a nonlinear relationship between financial development and greenhouse gas emissions. Otherwise, no nonlinear relationship between financial development and greenhouse gas emissions.

In addition, to test the indirect effect of sustainable financial development on greenhouse gas emissions by which kind of technological progress, we follow Krichels et al. [69], Pei et al. [70], and Zhen et al. [71], who used stepwise regression to design the mediation effect model. That is, the first step is to test the effect of sustainable financial development on technological progress by taking technological progress as the explained variable and sustainable financial development as the explanatory variable. The second step is to test the effect of technological progress on greenhouse gas emissions with greenhouse gas emissions as the explained variable and technological progress as the explanatory variable. Following this idea, we set the mediation effect model as shown in models (2) and (3):

\[
techn_{i,t} = b_0 + b_1 fd_{i,t} + \sum_{j=2}^{n} b_j cv_{i,t} + \mu_i + \delta_t + \epsilon_{i,t} \quad (2)
\]

\[
gge_{i,t} = c_0 + c_1 techn_{i,t} + \sum_{j=2}^{n} c_j cv_{i,t} + \mu_i + \delta_t + \epsilon_{i,t} \quad (3)
\]

where \( techn_{i,t} \) stands for technological progress. If the sustainable financial development affects greenhouse gas emissions by influencing the technological progress, coefficients \( b_1 \) and \( c_1 \) should be significant in statistics. Moreover, if the sign of \( b_1 \cdot c_1 \) is consistent with that of \( a_1 \), the technological progress has a mediation effect on the effect of sustainable financial development on greenhouse gas emissions, and the value of the mediation effect is \( b_1 \cdot c_1 \).
On the contrary, if the sign of $b_1 \cdot c_1$ is opposite to that of $a_1$, the technological progress will be turned as the dilution effect on the effect of sustainable financial development on greenhouse gas emissions, and the value of the dilution effect is $b_1 \cdot c_1$. That is, the indirect effect of technological progress dilutes the real effect of sustainable financial development on greenhouse gas emissions to a certain extent.

Furthermore, we also attempt to test whether this heterogeneous technological progress is a complete mediation effect. That is, after controlling the indirect effect of technological progress, we need to confirm whether the effect of sustainable financial development on greenhouse gas emissions is still significant. We further construct the following regression model:

$$gge_{i,t} = d_0 + d_1 fd_{i,t} + d_2 tech_{i,t} + \sum_{j=3}^{n} d_j cv_{i,t} + \mu_t + \delta_t + \epsilon_{i,t},$$  \hspace{1cm} (4)

based on model (4), if the sustainable financial development has both direct and indirect effects (it affects greenhouse gas emissions through the technological progress) on greenhouse gas emissions, both $d_1$ and $d_2$ should be significant in statistics. After controlling the direct effect of sustainable financial development on greenhouse gas emissions, the indirect effect of adjustment is $b_1 \cdot d_2$. Additionally, if the effect of sustainable financial development on greenhouse gas emissions is only reflected in the indirect effect of technological progress, $d_1$ will be not significant in statistics, and $d_2$ will be significant in statistics. Then, we can conclude that technological progress is a complete mediator variable.

4. Findings and Discussion

4.1. Sample Description

A total of 162 countries in the world are treated as a sample to examine the effect of financial development on greenhouse gas emissions in terms of a sustainable perspective. From 2000 to 2019, due to the lack of data in some countries, 162 countries will be left to perform the empirical analysis. At the same time, considering the different income levels of countries, we divide 162 countries into three groups: high-income, middle-income, and low-income according to the income standard so as to explore the income heterogeneous effect of sustainable financial development on greenhouse gas emissions.

4.2. Basic Statistical Analysis

To understand the basic characteristics of these variables used in this paper, the basic statistical analyses of the value of mean, maximum, minimum, and standard deviation are conducted. The results of the basic statistical analysis are presented in Table 2.
Table 2 indicates that greenhouse emissions have a mean of 0.829 with a standard deviation of 0.281. Domestic credit to the private sector by banks has a mean of 0.762 with a standard deviation of 0.348. The financial markets index has a mean of 0.526 with a standard deviation of 0.225. The financial institutions index has a mean of 0.653 with a standard deviation of 0.3164. Generalized technological progress has a mean of 2.417 with a standard deviation of 3.692. Environmental technological progress has a mean of 1.278 with a standard deviation of 0.768. Technological choice progress has a mean of 10.485 with a standard deviation of 1.212. Foreign direct investment technological spillover has a mean of 0.502 with a standard deviation of 0.681. The industrial structure has a mean of 0.402 with a standard deviation of 0.079. The economy’s development level has a mean of 1.431 with a standard deviation of 0.798. Human capital has a mean of 0.956 with a standard deviation of 0.091. Trade openness has a mean of 0.384 with a standard deviation of 0.407. The infrastructure level has a mean of 0.872 with a standard deviation of 1.652. Urbanization has a mean of 0.332 with a standard deviation of 0.395. Institutional quality has a mean of 1.112 with a standard deviation of 0.383.

4.3. Examining the Effect of Sustainable Financial Development on Greenhouse Emissions

Ozturk and Acaravci [72] and Farhani and Ozturk [73] pointed out that there was a bidirectional causal relationship between financial development and greenhouse emissions. To deal with the potential reverse causality, following Jian et al. [74], the $t - 1$ period of these determinants of greenhouse gas emissions is used in this paper. Meanwhile, to exclude the influence of some unobservable factors on the empirical results, the county and year fixed-effects model is used to perform the empirical analysis. Furthermore, considering the heterogeneity of groups in different income countries, we make an empirical analysis according to the whole world group, high-income group, middle-income group, and low-income group. The empirical results are presented in Table 3.

Table 3 presents the results of the effect of sustainable financial development on greenhouse gas emissions with three different financial development indexes, including domestic credit to the private sector by banks, financial markets, and financial institutions. At the world level, the regression coefficient for the period of financial development on greenhouse gas emissions is positive at a 1% significant level. Namely, a 1% increase in the period of financial development results in a 0.192% increase in greenhouse gas emissions (financial development index 1), a 0.297% increase in greenhouse gas emissions (financial development index 2), and a 0.426% increase in greenhouse gas emissions (financial development index 3). Meanwhile, these outcomes verify Hypothesis 1 (H1) and reject Hypothesis 3 (H3). Moreover, the regression coefficient of the square of financial development is negative at a 1% significant level, which indicates that in the world, the relationship between sustainable financial development and greenhouse gas emissions conforms to the environmental Kuznets curve. This result is consistent with Villanthenkodath and Arakkal [75]. In other words, sustainable financial development cannot reduce greenhouse gas emissions in the world as a whole. On the contrary, sustainable financial development actually increases greenhouse gas emissions. A possible explanation is that the effect of sustainable financial development on greenhouse gas emissions has two effects: the technology upgrading effect and the total expansion effect. The so-called technology upgrading effect means that, through sustainable financial development, technological progress has been upgraded so as to reduce greenhouse gas emissions. In addition, sustainable financial development can also promote the production of more energy-efficient alternative products, which can reduce greenhouse gas emissions. The total expansion effect refers to the fact that long-term financial development encourages production scale expansion, which leads to increased energy consumption. Therefore, greenhouse gas emissions will increase.
Table 3. Results of the effect of sustainable financial development on greenhouse gas emissions.

| Variable | Financial Development Index 1 | Financial Development Index 2 | Financial Development Index 3 |
|----------|-------------------------------|-------------------------------|-------------------------------|
|          | World (1)                     | World (5)                     | World (9)                     |
|          | High (2)                      | High (6)                      | High (10)                     |
|          | Middle (3)                    | Middle (7)                    | Middle (11)                   |
|          | Low (4)                       | Low (8)                       | Low (12)                      |
| \( f_{d1t-1} \) | 0.192 *** (6.278)           | 0.107 *** (9.592)            | 0.069 * (1.715)               |
|          |                              | −2.176 ** (–2.224)           |                               |
| \( f_{d1t-1}^2 \) | −0.007 *** (–5.926)         | −0.008 *** (–5.095)          | −0.007 (–1.262)               |
|          |                               |                               | −0.007 (–1.513)               |
| \( f_{d2t-1} \) | 0.297 *** (7.412)          | 0.238 *** (10.722)           | 0.105 *** (–4.437)            |
|          |                               | −0.105 *** (–4.437)          | 0.091 * (1.926)               |
| \( f_{d2t-1}^2 \) | −0.012 *** (–6.137)         | −0.009 *** (–5.949)          | −0.013 (–1.558)               |
|          |                               |                               | −0.010 (–1.146)               |
| \( f_{d3t-1} \) | 0.426 *** (6.947)           | 0.433 *** (8.549)            | −0.216 ** (–2.531)           |
|          |                               |                               | 0.104 * (1.812)               |
| \( f_{d3t-1}^2 \) | −0.018 *** (–6.529)         | −0.013 *** (–6.114)          | −0.014 (–1.585)               |
|          |                               |                               | −0.016 (–1.062)               |
| cv       | included                     | included                     | included                     |
|          | 0.637 *** (6.211)            | 0.186 *** (4.145)            | 1.164 ** (2.118)              |
|          |                               | 1.099 * (1.598)              | 1.672 *** (7.358)             |
|          |                               | 2.414 *** (5.932)            | 1.253 *** (4.719)             |
| c        | 0.109 * (1.598)              | 1.672 *** (7.358)            | 1.253 *** (4.719)             |
|          |                               | 2.414 *** (5.932)            | 1.253 *** (4.719)             |
|          |                               | 1.054 ** (2.218)             | 0.491 *** (8.144)             |
|          |                               | 0.997 *** (5.423)            | 1.121 *** (2.215)             |
|          |                               | 1.107 * (1.668)              |                               |
| Country  | yes                          | yes                          | yes                          |
|          | yes                          | yes                          | yes                          |
| Year     | Yes                          | Yes                          | Yes                          |
| R²       | 0.674                        | 0.729                        | 0.697                        |
|          | 0.581                        | 0.743                        | 0.655                        |
| F-test   | 97.665                       | 158.722                      | 82.158                       |
|          | 60.934                       | 112.597                      | 186.895                      |
|          | 107.213                      | 92.035                       | 120.714                      |
|          | 190.586                      | 162.491                      | 98.164                       |
| Obs      | 3220                        | 1380                        | 1480                        |
|          | 320                          | 3220                        | 1380                        |
|          | 1480                        | 1480                        | 1480                        |
|          | 320                          | 320                          | 320                          |

Note: cv denotes the control variable. c denotes the constant. Country denotes the country-fixed effects. Year denotes the year-fixed effects. Obs denotes the observation. ( ) denotes the value of t-statistic. * denotes 10% significant level. ** denotes a 5% significant level. *** denotes a 1% significant level.
From the perspective of different income country groups, the regression coefficient of sustainable financial development of middle-income countries is negative at 1% and 5% significant levels, which indicates that the sustainable financial development of middle-income countries reduces greenhouse gas emissions. Stated differently, a 1% increase in financial development (index 1, index 2, and index 3) results in a 2.176%, 0.105%, and 0.216% decrease in greenhouse gas emissions. One possible explanation is that the technology-updating effect of sustainable financial development is greater than the total expansion effect. At the same time, these outcomes verify the Hypothesis 2 (H2) and reject the Hypothesis 3 (H3). The regression coefficients of sustainable financial development in high-income countries and low-income countries are positive, which indicates that sustainable financial development increases the greenhouse gas emissions of these two kinds of countries. Said in detail, for high-income countries, a 1% increase in financial development (index 1, index 2, and index 3) results in a 0.107%, 0.238%, and 0.433% increase in greenhouse gas emissions. For low-income countries, a 1% increase in financial development (index 1, index 2, and index 3) leads to a 0.069%, 0.091%, and 0.104% increase in greenhouse gas emissions. A possible explanation is that the effect of the total expansion of sustainable financial development is greater than that of technological upgrading. These results are also in line with reality. Specifically, in high-income countries, due to the high level of sustainable financial development, their production scales are often large. They consume more energy, which leads to more greenhouse gas emissions. On the contrary, in low-income countries, most of their economic development is supported by energy and chemical industries, and the level of sustainable financial development is low, which is not conducive to reducing greenhouse gas emissions. Simultaneously, these outcomes verify the Hypothesis 1 (H1) and reject the Hypothesis 3 (H3).

### 4.4. Examining the Effects of Heterogeneous Technological Progress on Greenhouse Gas Emissions

As the results in Table 3 suggest, sustainable financial development cannot reduce greenhouse gas emissions as a whole in the world. However, as the previous theoretical analyses indicated, sustainable financial development could reduce greenhouse gas emissions through the technology upgrade effect. What is the reason that this theory is inconsistent with reality? Does sustainable financial development affect greenhouse gas emissions through heterogeneous technological progress? To answer these two questions first, this paper examines the effect of heterogeneous technological progress on greenhouse gas emissions. If technological progress can reduce greenhouse gas emissions, this paper will further examine the effect of sustainable financial development on technological progress; that is, whether the higher the level of sustainable financial development, the more effective it is to promote technological progress. If both are significant, sustainable financial development can affect greenhouse gas emissions via this technological progress. The results of the effects of heterogeneous technological progress on greenhouse gas emissions are presented in Table 4.

As the result of Table 4 suggests, generalized technological progress reduces greenhouse gas emissions. This result is consistent with Lemma et al. [76] and Ball [77]. Environmental technological progress refers to the treatment of pollution that has been produced. The regression coefficient of environmental technology progress is significantly negative. This shows that environmental technology progress reduces greenhouse gas emissions, and the role of this kind of technological progress in reducing greenhouse gas emissions is greater than that of other technological progress. Therefore, it can be considered that improving pollution technology and environmental technology levels is an important way to reduce greenhouse gas emissions. This result is consistent with Färe et al. [78], Picazo-Tadeo et al. [79], and Dakpo et al. [80]. Capital is one of the main elements of economic growth, but also the main source of greenhouse gas emissions. Therefore, improving the efficiency of the use of capital is an important way to transform the overall growth mode of the world economy into an intensive one, and improving the utilization rate of capital can effectively reduce greenhouse gas emissions. It can be seen that the regression coefficient
between capital deepening and greenhouse gas emissions is negative, which means that countries in the world can reduce greenhouse gas emissions through technological progress in capital deepening. This shows that the effect of the world economy moving from extensive to intensive mode is obvious. This result is consistent with Dulal et al. [81] and Chaturvedi et al. [82]. Using foreign capital for technology introduction or joint venture innovation plays an important role in reducing greenhouse gas emissions in the world. This result is consistent with Liobikien and Butkus [83], Kastratovíc [84], and Kim [85].

Table 4. Results of the effects of heterogeneous technological progress on greenhouse gas emissions.

| Variable (13) (14) (15) (16) |
|-----------------------------|
| tech1_{-1} 0.168 *** (5.583) |
| tech2_{-1} -0.269 *** (-6.747) |
| tech3_{-1} -0.185 (-1.312) |
| tech4_{-1} -0.108 (-1.049) |
| cv included included included included |
| c 0.954 *** (3.943) 0.868 *** (4.691) 0.912 *** (4.374) 0.977 *** (3.802) |
| Country yes Yes yes yes |
| Year yes Yes yes yes |
| R² 0.542 0.597 0.538 0.615 |
| F-test 196.338 143.857 186.149 182.076 |
| Obs 3220 3220 3220 3220 |

Note: cv denotes the control variable. c denotes the constant. Country denotes the country-fixed effects. Year denotes the year-fixed effects. Obs denotes the observation. ( ) denotes the value of t-statistic. *** denotes a 1% significant level.

4.5. Examining the Effects of Sustainable Financial Development on Heterogeneous Technological Progress

As the results of Table 4 suggest, technological progress can reduce greenhouse gas emissions. In this sub-section, we will examine the effect of sustainable financial development on technological progress. The reason for this is to test whether the higher the level of sustainable financial development, the more effective it is to promote technological progress. Through technological progress, if the estimated coefficient is significant, sustainable financial development can affect greenhouse gas emissions in this way. The results of the effects of sustainable financial development on heterogeneous technological progress are presented in Table 5.

Table 5 shows the results of the effects of sustainable financial development on heterogeneous technological progress. The effects of sustainable financial development on generalized technological progress and technological choice progress are positive. This result is supported by many scholars, such as Zhou et al. [86], Santhakumar et al. [87], Comin and Nanda [88], and Kumar [89]. On the contrary, the effects of sustainable financial development on environmental technological progress and foreign direct investment technological spillover are negative, but the regression coefficient of foreign direct investment technology spillover is not significant. This shows that the sustainable financial development in the sample does not effectively promote the technological spillover progress brought by foreign direct investment. It should be noted that environmental technology progress is negative; that is to say, the larger the scale of sustainable financial development, the lower the level of environmental technology, which is inconsistent with Kayani et al. [90], and Yuxiang and Chen [91]. One possible reason is that the world is currently in the stage of vigorously developing green technology, and the research, development, and use of new technology needs a long period to reflect its effect. In addition, sustainable financial development promotes capital deepening at a 1% significant level, which indicates that the sustainable financial development in the sample promotes the transformation of the economy into an intensive development mode. This result is consistent with Guiso et al. [92].
Table 5. Results of the effects of sustainable financial development on heterogeneous technological progress.

| Var    | (17) tech1 | (18) tech2 | (19) tech3 | (20) tech4 | Var    | (21) tech1 | (22) tech2 | (23) tech3 | (24) tech4 | Var    | (25) tech1 | (26) tech2 | (27) tech3 | (28) tech4 |
|--------|------------|------------|------------|------------|--------|------------|------------|------------|------------|--------|------------|------------|------------|------------|
| fd1_t−1| 0.847 ***  | −0.647 *** | 0.373 ***  | −0.462     | fd2_t−1| 1.046 ***  | −1.021 *** | 0.960 ***  | −1.211     | fd3_t−1| 1.645 ***  | −1.434 *** | 1.219 ***  | −1.503     |
|        | (4.138)    | (−2.667)   | (5.356)    | (−1.432)   |        | (5.817)    | (−5.168)   | (4.861)    | (−1.017)   |        | (4.414)    | (−4.593)   | (4.358)    | (−1.013)   |
| cv     | included   | included   | included   | included   | Cv     | included   | included   | included   | included   | cv     | included   | included   | included   | included   |
|        |            |            |            |            |        |            |            |            |            |        |            |            |            |            |
| c      | 1.431 *    | 1.967 **   | 2.454 *    | 1.629 **   | C      | 3.996 ***  | 2.812 ***  | 3.633 **   | 3.801 **   | c      | 1.536 **   | 1.738 ***  | 1.316 ***  | 1.883 ***  |
|        | (1.722)    | (2.068)    | (2.146)    | (2.167)    |        | (6.782)    | (5.979)    | (2.112)    | (2.219)    |        | (2.017)    | (3.987)    | (4.021)    | (3.822)    |
| Coun   | yes        | yes        | yes        | yes        | Coun   | yes        | yes        | yes        | yes        | Coun   | yes        | yes        | yes        | yes        |
| Year   | yes        | yes        | yes        | yes        | Year   | yes        | yes        | yes        | yes        | Year   | yes        | yes        | yes        | yes        |
| R²     | 0.496      | 0.517      | 0.438      | 0.524      | R²     | 0.743      | 0.712      | 0.768      | 0.687      | R²     | 0.385      | 0.407      | 0.398      | 0.464      |
| F-test | 76.223     | 81.045     | 71.162     | 86.904     | F-test | 192.415    | 216.373    | 180.852    | 187.034    | F-test | 102.981    | 132.615    | 98.344     | 99.547     |
| Obs    | 3220       | 3220       | 3220       | 3220       | Obs    | 3220       | 3220       | 3220       | 3220       | Obs    | 3220       | 3220       | 3220       | 3220       |

Note: Var denotes the variable. Coun denotes the country. cv denotes the control variable. c denotes the constant. Country denotes the country-fixed effects. Year denotes the year-fixed effects. Obs denotes the observation. ( ) denotes the value of t-statistic. * denotes 10% significant level. ** denotes a 5% significant level. *** denotes a 1% significant level.
Compared with these kinds of financial development indexes, the financial institutions index plays the most important role in promoting technological progress. To this end, it can be generally concluded that sustainable financial development increases greenhouse gas emissions. The reason is that the mechanism of technological progress through which sustainable financial development reduces greenhouse gas emissions does not work well. As the results of Tables 4 and 5 suggest, among the four paths of technological progress, only two regression coefficients, those of generalized technological progress and environmental technological progress, are significant, while generalized technological progress does not inhibit greenhouse gas emissions. Therefore, it is preliminarily judged that the indirect effects of financial development on greenhouse gas emissions are dilution effects rather than mediation effects. Namely, it reduces the increase in greenhouse gas emissions brought about by sustainable financial development. The comprehensive effects of sustainable financial development on greenhouse gas emissions are 0.192, 0.297, and 0.426. Therefore, after controlling the dilution effect of environmental technology progress, the effects of sustainable financial development on greenhouse gas emissions are 0.018 (0.192 - 0.174), 0.022 (0.297 - 0.275) and 0.040 (0.426 - 0.386). The mediation effect of sustainable financial development on greenhouse gas emissions through generalized technological progress is 0.142 (0.847 × 0.168), 0.176 (1.046 × 0.168), and 0.276 (1.654 × 0.168). After controlling the mediation effect of generalized technological progress, it is preliminarily judged that the effects of financial development on greenhouse gas emissions are 0.334 (0.142 + 0.192), 0.473 (0.176 + 0.297), and 0.693 (0.276 + 0.426).

4.6. Robustness Test on the Effects of Sustainable Financial Development on Greenhouse Gas Emissions

In this sub-section, after controlling the indirect effect of technological progress on greenhouse gas emissions, we further examine the effect of sustainable financial development on greenhouse gas emissions. The results are presented in Table 6.

Table 6 presents the robustness test on the effects of sustainable financial development on greenhouse gas emissions. It can be seen that after controlling the indirect effect of technological progress on greenhouse gas emissions, the regression coefficient of sustainable financial development on greenhouse gas emissions is still significantly positive at 1% and 10% significant levels. For example, compared with the values in Table 3, the values in Table 6 are greater. This further proves that in the effect of sustainable financial development on greenhouse gas emissions, technological progress has an indirect effect. However, after controlling the progress of environmental technology, the regression coefficient of the effect of sustainable financial development on greenhouse gas emissions becomes positive and not significant. Said differently, this shows that although sustainable financial development can inhibit greenhouse gas emissions through environmental technology progress, this inhibition path does not have a significant effect on the sample. After controlling for generalized technological progress, the mediation effects of sustainable financial development on greenhouse gas emissions are 0.145 (0.168 × 0.866), 0.156 (0.168 × 0.929), and 0.155 (0.168 × 0.921). After controlling for the indirect effect of generalized technological progress, the effects of modified financial development on greenhouse gas emissions are 0.866, 0.929, and 0.921.

4.7. Examining the Heterogeneous Effects of Sustainable Financial Development on Greenhouse Gas Emissions in Terms of Three Sub-Samples

There are differences in the development characteristics of different countries in the world. To investigate the heterogeneity of income differences among sustainable financial development, heterogeneous technological progress, and greenhouse gas emissions, following Khan et al. [93], the full sample is divided into three sub-samples: high-income countries, middle-income countries, and low-income countries in this paper. The results are shown in Tables 7–9.
Table 6. Results of robustness test on the effects of sustainable financial development on greenhouse gas emissions.

| Variable | Financial Development Index 1 | Financial Development Index 2 | Financial Development Index 3 |
|----------|-------------------------------|-------------------------------|-------------------------------|
|          | (29)                          | (30)                          | (31)                          | (32)                          | (33)                          | (34)                          | (35)                          | (36)                          | (37)                          | (38)                          | (39)                          | (40)                          |
| $fd_{1t-1}$ | 0.866 * (1.927)               | 0.670 (1.261)                 | 1.191 *** (6.129)             | 0.592 *** (7.257)             |                              |                              |                              |                              |                              |                              |                              |
| $fd_{2t-1}$ |                              | 0.929 * (1.867)               | 0.889 (1.489)                 | 0.785 *** (3.611)             | 0.713 *** (3.136)             | 0.921 * (1.976)               | 0.567 (1.406)                 | 1.061 *** (4.871)             | 0.612 *** (4.246)             |                              |                              |
| $fd_{3t-1}$ | 0.098 *** (3.561)             | 0.016 *** (5.763)             | 0.013 *** (2.805)             |                              |                              |                              |                              |                              |                              |                              |                              |
| $tech_{1t-1}$ | 0.133 *** (6.827)             | 0.109 ** (2.292)              | 0.171 *** (8.652)             |                              |                              |                              |                              |                              |                              |                              |                              |
| $tech_{2t-1}$ | −0.186 (−1.527)              | −0.148 (−1.084)               | 0.171 *** (8.652)             |                              |                              |                              |                              |                              |                              |                              |                              |
| $tech_{3t-1}$ | −0.178 (−1.487)              | −0.154 (−1.377)               | −0.181 (−1.174)               | −0.114 (−1.358)               |                              |                              |                              |                              |                              |                              |                              |
| $tech_{4t-1}$ | included                     | included                     | included                     | included                     | included                     | included                     | included                     | included                     | included                     | included                     | included                     | included                     |
| $cv$      | 1.635 *** (3.499)             | 1.823 *** (5.805)             | 1.354 (4.055)                 | 1.858 *** (4.912)             | 2.628 * (1.718)               | 2.841 *** (3.508)             | 1.262 (1.687)                 | 2.483 ** (6.675)              | 1.702 * (4.828)               | 1.706 * (6.512)               | 2.635 *** (4.553)            |
| $c$       | 0.493 (0.466)                 | 0.447 (0.482)                 | 0.622 (0.694)                 | 0.655 (0.631)                 | 0.377 (0.428)                 | 0.419 (0.511)                 | 0.377 (0.428)                 | 0.419 (0.511)                 | 0.377 (0.428)                 | 0.419 (0.511)                 | 0.377 (0.428)                 |
| Country   | yes                          | yes                          | yes                          | Yes                          | yes                          | yes                          | yes                          | yes                          | yes                          | yes                          | yes                          |
| Year      | yes                          | yes                          | yes                          | Yes                          | yes                          | yes                          | yes                          | yes                          | yes                          | yes                          | yes                          |
| $R^2$     | 0.493                        | 0.466                        | 0.447                        | 0.482                        | 0.622                        | 0.655                        | 0.631                        | 0.377                        | 0.428                        | 0.419                        | 0.511                        |
| F-test    | 85.325                       | 81.103                       | 71.747                       | 98.014                       | 119.184                      | 115.191                      | 147.194                      | 121.722                      | 76.823                       | 63.213                       | 89.744                       | 79.275                       |
| Obs       | 3220                         | 3220                         | 3220                         | 3220                         | 3220                         | 3220                         | 3220                         | 3220                         | 3220                         | 3220                         | 3220                         | 3220                         |

Note: cv denotes the control variable. c denotes the constant. Country denotes the country-fixed effects. Year denotes the year-fixed effects. Obs denotes the observation. ( ) denotes the value of t-statistic. * denotes 10% significant level. ** denotes a 5% significant level. *** denotes a 1% significant level.
Table 7. Results of effects of sustainable financial development on greenhouse gas emissions (high-income countries).

| Variable       | Financial Development Index 1 | Financial Development Index 2 | Financial Development Index 3 |
|----------------|-------------------------------|-------------------------------|-------------------------------|
|                | (41)                         | (42)                         | (43)                         |
|                | (44)                         | (45)                         | (46)                         |
|                | (47)                         | (48)                         | (49)                         |
|                | (50)                         | (51)                         | (52)                         |
| fd1_{t-1}      | 0.105 **                     | 0.107 ***                    | 0.112 ***                    |
|                | (2.424)                      | (3.214)                      | (3.265)                      |
|                |                               | 0.125 ***                    | 0.127 ***                    |
|                |                               | (3.202)                      | (2.672)                      |
|                |                               | 0.122 ***                    | 0.095 ***                    |
|                |                               | (3.954)                      | (3.337)                      |
| fd2_{t-1}      |                               |                               | 0.091 *                      |
|                |                               |                               | (1.855)                      |
| fd3_{t-1}      | 0.182                        | 0.203                        | 0.049                        |
|                | (1.024)                      | (1.166)                      | (1.401)                      |
| tech1_{t-1}    | 0.024 ***                    |                               |                               |
|                | (3.994)                      |                               |                               |
| tech2_{t-1}    | −0.178                       | −0.062                       | −0.168                       |
|                | (−1.233)                     | (−1.473)                     | (−1.384)                     |
| tech3_{t-1}    | 0.148                        | 0.183                        | 0.096                        |
|                | (1.521)                      | (1.416)                      | (1.154)                      |
| cv             | included                     | included                     | included                     |
|                | (3.152)                      | (2.952)                      | (2.325)                      |
|                | (2.486)                      |                               |                               |
|                |                               | 0.286 *                      | 0.886 *                      |
|                |                               | (1.821)                      | (1.704)                      |
|                |                               | 0.436 **                     | 0.687 *                      |
|                |                               | (2.545)                      | (1.952)                      |
|                |                               | 0.765 **                     | 0.617 **                     |
|                |                               | (2.325)                      | (2.544)                      |
|                |                               | 0.795 **                     | 0.536 **                     |
|                |                               | (2.001)                      | (2.144)                      |
| c              | 0.588 ***                    | 0.594 ***                    | 0.641 **                     |
|                | (3.152)                      | (2.952)                      | (2.325)                      |
|                | (2.486)                      |                               |                               |
|                |                               | 0.286 *                      | 0.886 *                      |
|                |                               | (1.821)                      | (1.704)                      |
|                |                               | 0.436 **                     | 0.687 *                      |
|                |                               | (2.545)                      | (1.952)                      |
|                |                               | 0.765 **                     | 0.617 **                     |
|                |                               | (2.325)                      | (2.544)                      |
|                |                               | 0.795 **                     | 0.536 **                     |
|                |                               | (2.001)                      | (2.144)                      |
| Country        | yes                          | yes                          | yes                          |
| Year           | yes                          | yes                          | yes                          |
| R²             | 0.377                        | 0.485                        | 0.442                        |
|                | 0.488                        | 0.698                        | 0.357                        |
|                | 0.334                        | 0.699                        | 0.517                        |
|                | 0.704                        | 0.621                        | 0.695                        |
| F-test         | 96.75                        | 47.146                       | 83.792                       |
|                | 47.192                       | 102.632                      | 108.387                      |
|                | 52.684                       | 98.389                       | 85.514                       |
|                | 61.044                       | 91.513                       |                               |
| Obs            | 3220                         | 3220                         | 3220                         |
|                | 3220                         | 3220                         | 3220                         |
|                | 3220                         | 3220                         | 3220                         |

Note: cv denotes the control variable. c denotes the constant. Country denotes the country-fixed effects. Year denotes the year-fixed effects. Obs denotes the observation. ( ) denotes the value of t-statistic. * denotes 10% significant level. ** denotes a 5% significant level. *** denotes a 1% significant level.
Table 8. Results of effects of sustainable financial development on greenhouse gas emissions (middle-income countries).

| Variable   | Financial Development Index 1 | Financial Development Index 2 | Financial Development Index 3 |
|------------|--------------------------------|--------------------------------|--------------------------------|
|            | (53)                          | (54)                          | (55)                          |
|            | (56)                          | (57)                          | (58)                          |
|            | (59)                          | (60)                          | (61)                          |
|            | (62)                          | (63)                          | (64)                          |
| fd1_{t-1}  | -0.169 ***                    | -0.211 ***                    | -0.234 ***                    |
|            | (-4.585)                      | (-6.746)                      | (-4.195)                      |
|            | -0.148 ***                    | (-4.731)                      | (53)                          |
|            | (54)                          | (55)                          | (56)                          |
|            | (57)                          | (58)                          | (59)                          |
|            | (60)                          | (61)                          | (62)                          |
|            | (63)                          | (64)                          | (65)                          |
| fd2_{t-1}  | -0.197 ***                    | -0.221 ***                    | -0.167 ***                    |
|            | (-3.971)                      | (-2.988)                      | (-4.107)                      |
|            | -0.172 ***                    | (-4.345)                      | (66)                          |
|            | (67)                          | (68)                          | (69)                          |
| fd3_{t-1}  | 0.005 ***                     | 0.016 ***                     | 0.061 **                      |
|            | (5.381)                       | (4.769)                       | (2.312)                       |
| tech1_{t-1}| 0.011 ***                    | 0.013 ***                     | 0.031 ***                     |
|            | (3.567)                       | (3.131)                       | (3.973)                       |
| tech2_{t-1}| 0.009 ***                    | -0.019 ***                    | -0.017 ***                    |
|            | (-4.617)                      | (-4.461)                      | (-5.081)                      |
| tech3_{t-1}| 0.012                         | 0.022                         | 0.035                         |
|            | (1.364)                       | (1.441)                       | (1.268)                       |
| cv included| included                      | included                      | included                      |
| c          | 1.011 *                       | 0.822 ***                     | 0.813 *                       |
|            | (1.683)                       | (3.138)                       | (1.702)                       |
|            | (1.855)                       | (2.245)                       | (2.658)                       |
|            | (2.919)                       | (3.002)                       | (2.658)                       |
|            | (2.245)                       | (1.793)                       | (1.702)                       |
|            | (2.245)                       | (2.064)                       | (1.716)                       |
|            | (2.245)                       | (2.658)                       | (2.358)                       |
| Country    | yes                           | yes                           | yes                           |
| Year       | yes                           | yes                           | yes                           |
| R^2        | 0.682                         | 0.555                         | 0.494                         |
| F-test     | 45.154                        | 30.904                        | 64.963                        |
| Obs        | 3220                          | 3220                          | 3220                          |

Note: cv denotes the control variable. c denotes the constant. Country denotes the country-fixed effects. Year denotes the year-fixed effects. Obs denotes the observation. ( ) denotes the value of t-statistic. * denotes 10% significant level. ** denotes a 5% significant level. *** denotes a 1% significant level.
Table 9. Results of effects of sustainable financial development on greenhouse gas emissions (low-income countries).

| Variable | Financial Development Index 1 | Financial Development Index 2 | Financial Development Index 3 |
|----------|-------------------------------|-------------------------------|-------------------------------|
|          | (65)                         | (66)                         | (67)                         |
|          | (68)                         | (69)                         | (70)                         |
|          | (71)                         | (72)                         | (73)                         |
|          | (74)                         | (75)                         | (76)                         |
| fd1_{t−1} | 0.211 *** (3.792)            | 0.212 *** (5.179)            | 0.189 *** (5.395)            |
|          | 0.071 (1.366)                | 0.078 (1.283)                | 0.045 (3.806)                |
|          | 0.221 *** (6.019)            | 0.169 *** (3.008)            | 0.112 *** (4.325)            |
|          | 0.177 *** (3.712)            | 0.217 *** (3.219)            | 0.221 *** (4.368)            |
| fd2_{t−1} |                               |                              | 0.189 *** (5.395)            |
|          |                               |                              | 0.045 (3.806)                |
|          |                               |                              | 0.112 *** (4.325)            |
|          |                               |                              | 0.221 *** (4.368)            |
| fd3_{t−1} | 0.073 *** (2.743)            | 0.088 ** (2.191)             | 0.077 * (1.801)              |
| tech1_{t−1} | 0.141 *** (2.798)          | 0.107 *** (4.537)            | 0.139 *** (1.131)            |
| tech2_{t−1} |                               |                              |                              |
| tech3_{t−1} | 0.105 *** (4.085)          | 0.092 *** (3.611)            | 0.083 *** (5.126)            |
| tech4_{t−1} |                               |                              |                              |
| cv       | included                     | included                     | included                     |
| c        | 0.337 ** (2.108)             | 0.745 *** (3.196)            | 0.364 ** (2.167)             |
|          | (2.283)                      | (3.367)                      | (2.283)                      |
|          | 0.266 ** (3.367)             | 1.062 *** (3.196)            | 1.138 (1.472)                |
|          | 1.138 (1.472)                | 1.138 (1.472)                | 1.045 (2.222)                |
|          | 0.442 *** (3.072)            | 0.252 *** (2.653)            | 0.505 *** (3.882)            |
|          | 0.252 *** (2.653)            | 0.505 *** (3.882)            | 1.045 (2.222)                |
|          | 0.083 *** (5.126)            | 0.083 *** (5.126)            | 0.074 (−1.161)               |
|          |                               |                              |                              |
| Country  | yes                          | yes                          | yes                          |
| Year     | yes                          | yes                          | yes                          |
| R^2      | 0.687 (2.108)                | 0.579 (3.196)                | 0.688 (2.167)                |
|          | 0.515 (2.167)                | 0.515 (2.167)                | 0.515 (2.167)                |
|          | 0.371 (3.167)                | 0.371 (3.167)                | 0.371 (3.167)                |
|          | 0.376 (3.167)                | 0.376 (3.167)                | 0.376 (3.167)                |
|          | 0.606 (3.167)                | 0.606 (3.167)                | 0.606 (3.167)                |
|          | 0.701 (2.167)                | 0.701 (2.167)                | 0.701 (2.167)                |
|          | 0.623 (3.167)                | 0.623 (3.167)                | 0.623 (3.167)                |
|          | 0.404 (3.167)                | 0.404 (3.167)                | 0.404 (3.167)                |
|          | 0.638 (3.167)                | 0.638 (3.167)                | 0.638 (3.167)                |
| F-test   | 38.634 (2.108)               | 25.514 (3.196)               | 36.014 (2.167)               |
|          | 35.796 (3.167)               | 35.796 (3.167)               | 35.796 (3.167)               |
|          | 30.546 (3.167)               | 30.546 (3.167)               | 30.546 (3.167)               |
|          | 27.904 (3.167)               | 27.904 (3.167)               | 27.904 (3.167)               |
|          | 42.677 (3.167)               | 42.677 (3.167)               | 42.677 (3.167)               |
|          | 32.974 (3.167)               | 32.974 (3.167)               | 32.974 (3.167)               |
|          | 33.416 (3.167)               | 33.416 (3.167)               | 33.416 (3.167)               |
|          | 28.632 (3.167)               | 28.632 (3.167)               | 28.632 (3.167)               |
|          | 34.196 (3.167)               | 34.196 (3.167)               | 34.196 (3.167)               |
|          | 26.456 (3.167)               | 26.456 (3.167)               | 26.456 (3.167)               |
| Obs      | 3220 (2.108)                 | 3220 (3.196)                 | 3220 (2.167)                 |
|          | 3220 (3.167)                 | 3220 (3.167)                 | 3220 (3.167)                 |
|          | 3220 (3.167)                 | 3220 (3.167)                 | 3220 (3.167)                 |
|          | 3220 (3.167)                 | 3220 (3.167)                 | 3220 (3.167)                 |
|          | 3220 (3.167)                 | 3220 (3.167)                 | 3220 (3.167)                 |

Note: cv denotes the control variable. c denotes the constant. Country denotes the country-fixed effects. Year denotes the year-fixed effects. Obs denotes the observation. ( ) denotes the value of t-statistic. * denotes 10% significant level. ** denotes 5% significant level. *** denotes 1% significant level.
As shown in Tables 7–9, after controlling for the variables of technological progress, the direction of the effects of sustainable financial development on greenhouse gas emissions still remained in high-income countries and low-income countries. That is, while sustainable financial development in high-income and low-income countries cannot significantly reduce greenhouse gas emissions, sustainable financial development in middle-income countries can. Specifically, for high-income countries, after controlling for generalized technological progress and environmental technological progress, the promoting effect of sustainable financial development on greenhouse gas emissions becomes smaller. After controlling technology choice progress and foreign direct investment technology spillover, the effect of sustainable financial development on greenhouse gas emissions is expanding. Among them, the promotion effect of sustainable financial development on greenhouse gas emissions has significantly decreased after controlling environmental technological progress. This shows that the main way for high-income countries to reduce greenhouse gas emissions is through environmental technology progress. This result is supported by Manta et al. [94] and Koshta et al. [95]. One possible reason is that high-income countries have a high level of sustainable financial development and strong innovation ability. Its innovation ability promotes the green development of high-income countries. For low-income countries, after controlling for generalized technological progress, technological choice progress, and foreign direct investment technology spillover, the promoting effect of sustainable financial development on greenhouse gas emissions is significantly expanded. When sustainable environmental technological progress is included, the regression coefficient of sustainable financial development and greenhouse gas emissions decreases significantly, but the coefficient becomes non-significant. The technological progress of low-income countries in the sample has not become the path to sustainable financial development to curb greenhouse gas emissions. One possible reason is that low-income countries are rich in resources, such as African countries that are abundant in fossil fuels but lack innovation and much less sophisticated financial development. Sustainable financial development can significantly reduce greenhouse gas emissions for middle-income countries. After controlling the technological progress of heterogeneity, this inhibitory effect has not changed direction. With the sustainable economic development of middle-income countries in recent years, green-oriented financial payments focus more on the innovation and application of environmental technology. Environmental technological progress and technological choice progress significantly inhibit greenhouse gas emissions.

5. Conclusions

The issue of greenhouse gas emissions has caused a globally heated debate. Therefore, this paper selects 162 countries as a sample to analyze the effect of sustainable financial development on greenhouse gas emissions by using panel data over the period of 2000–2019 and employing the mediation effect model. The empirical results show that sustainable financial development increases greenhouse gas emissions for the world as a whole. Moreover, by dividing the world into high-income countries, middle-income countries, and low-income countries, we reanalyze the effect of sustainable financial development on greenhouse gas emissions. The empirical results suggest that the sustainable financial development of high-income countries and low-income countries increases greenhouse gas emissions, while the sustainable financial development of middle-income countries restrains greenhouse gas emissions. In addition, we also examine the mediation effect of heterogeneous technological progress. It is found that generalized technological progress can significantly increase greenhouse gas emissions. Environmental technology progress and technology choice progress have a significant inhibitory effect on greenhouse gas emissions. Foreign direct investment in technology spillover has no significant effect on greenhouse gas emissions. It is also found that the updating of environmental technology has a dilution effect in high-income countries. To a certain extent, it dilutes the effect of sustainable financial development on the increase in greenhouse gas emissions. The sustainable financial development of middle-income countries significantly inhibits greenhouse gas emissions.
gas emissions through the mediation effect of technological choice progress. Generalized technological progress in low-income countries has a mediating effect. It promotes the effect of sustainable financial development on the increase of greenhouse gas emissions.

Based on the empirical evidence this paper provided, some corresponding suggestions are given. Firstly, because of the positive effect of current forms of finance on greenhouse gas emissions, it is suggested that green sustainable finance should be developed, and green financial instruments should be innovated. This can meet the green investment and financing needs of enterprises and stimulate enterprises to develop green industries so as to reduce greenhouse gas emissions. Secondly, energy-saving and greenhouse gas emissions-reduction technology should be vigorously developed, which can inhibit the scale expansion of polluting production. This can also reduce greenhouse gas emissions. Thirdly, due to the heterogeneity of the influence of financial development on greenhouse gas emissions in low-, middle-, and high-income countries, each group of countries should adapt to local circumstances and establish financial types with their own features in order to minimize greenhouse gas emissions.

Furthermore, there are four ways in which this study adds to the literature. Firstly, to quantify sustainable financial development, this article employs three separate financial development indicators. When compared to previous studies, which only employed one financial development indicator to analyze this proposition, this method can more thoroughly explore the influence of financial development on greenhouse gas emissions. Secondly, this article demonstrates that sustainable financial development has two effects: an effect on technology upgrading and an effect on overall expansion. Sustainable financial development has the potential to decrease greenhouse gas emissions indirectly via technology innovation and other channels. Thirdly, the majority of previous studies used technical innovation as the only control variable. However, the heterogeneity of technological progress has been seldom examined within the context of sustainable financial development and greenhouse gas emissions. As a result, this study represents empirical analysis using the mediation effect model and focuses on the significance of sustainable financial development in technological growth. This demonstrates how technological advancements may assist sustainable financial development in more efficiently reducing greenhouse gas emissions. Finally, there are features and distinctions among the world’s different income countries. Thus, in addition to analyzing sustainable financial development, technological progress, and greenhouse gas emissions across different income countries, this paper analyzes them separately for three different income groups in order to contribute to the pertinent current literature.

Finally, there are several limitations to this article that may open the door to more research opportunities for relevant specialists in the future. Firstly, future studies might employ time-series related econometric approaches such as the panel vector autoregressive model and the panel vector error correction model to explore the influence of financial development on greenhouse gas emissions, which may lead to more intriguing findings since financial instability is an unavoidable phenomenon in the course of financial development. Secondly, other variables such as population, fossil energy consumption that may impact greenhouse gas emissions that are not considered in this work may exist. Future studies might include these missing variables and re-examine the influence of financial development on greenhouse gas emissions, perhaps yielding more interesting findings.

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