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Article

Financial Development, Environmental Quality and Economic Growth

Shushu Li [1,†], Jinglan Zhang [2,†] and Yong Ma [3,†,*]

[1] Institute of Policy and Management, Chinese Academy of Sciences, Haidian District, No. 15 Zhong Guan Cun Beiyitiao, Beijing 100190, China; E-Mail: lishushu@casipm.ac.cn

[2] School of Finance, Renmin University of China, No. 59 Zhong Guan Cun Street, Haidian District, Beijing 100872, China; E-Mail: zhangjn2015@hotmail.com

[3] China Financial Policy Research Center, School of Finance, Renmin University of China, No. 59 Zhong Guan Cun Street, Haidian District, Beijing 100872, China

[†] These authors contributed equally to this work.

* Author to whom correspondence should be addressed; E-Mail: mayongmail@ruc.edu.cn; Tel.: +86-10-8250-0636.

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Abstract: In this study, the relationships between financial development, environmental quality and economic growth are studied based on data from 102 countries over the period 1980–2010 using the generalized method of moments (GMM) estimation. The econometric results show the following three basic conclusions: First, both financial development and environmental quality have a significant impact on economic growth and should be included in the production function of the economic growth model as important variables. Second, there is a significant and robust "inverted U-shaped" relationship between financial development and economic growth; with the improvement of the level of financial development, economic growth would first increase and then decrease, which is consistent with the results of previous studies. Third, there is also a significant and robust "inverted U-shaped" relationship between economic growth and carbon emissions, indicating that there exists a "critical point" at which achieving economic growth comes at the expense of environmental quality, and after passing the critical point, the deterioration of environmental quality will lead to a significant slowdown in economic growth. In addition, the econometric analysis in this paper also shows that there was a mutually promoting and strengthening relationship between financial development and environmental quality.

Specifically, the degree of financial development can further strengthen the promoting effect of environmental quality on economic growth; meanwhile, an improvement in environmental quality can also strengthen the promoting effect of financial development on economic growth. Financial development and environmental quality could influence economic growth through strengthening the marginal product effects of capital and labor, which further indicates the that both financial and environmental factors play an important role in modern economic development.

Keywords: financial development; environmental quality; economic growth

1. Introduction

The early literature on growth has generally only addressed the impact of capital, labor and technological progress on economic growth. However, theoretical developments over the last 20 years have shown that financial factors and environmental resources also play an important role in modern economic growth. Although research in this area has attracted growing attention in recent years, the empirical investigation of the relationships between the three within a unified framework is still largely absent.

Based on the existing literature, studies on the relationship between economic growth and environmental quality used to focus on the influence of economic growth on environmental quality. For example, Shafik and Bandyopadhyay [1] use eight indicators that measure environmental quality to investigate the relationship between economic growth and environmental quality, finding that income growth initially causes the deterioration of environmental quality, but with a continuously rising income, environmental quality begins to improve. Grossman and Krueger [2] study the relationship between environmental quality and economic development based on cross-nation data; their econometric results show that there is an "inverted U-shaped" relationship between the deterioration of environmental quality and economic development, *i.e.*, the early development of an economy leads to the deterioration of environmental quality, but after reaching a turning point, sustained economic development improves the environmental quality of the country. The above-described "inverted U-shaped" relationship between economic development and environmental quality has also been designated as the environmental Kuznets curve (EKC). Subsequently, many scholars, such as Selden and Song [3], De Bruyn *et al.* [4] and Friedl and Getzner [5], have used various parameters that measure the quality of environmental quality to conduct empirical studies on the "inverted U-shaped" relationship between economic growth and environmental quality. Selden and Song [3] use different pollutants like SO_2, NO_x, CO to investigate the "inverted U-shaped" relationship between economic growth and environmental conditions. The empirical results indicate that economic growth leads to an initial degradation of the environmental conditions, and after a certain point, it leads to an improvement in the quality of environment. De Bruyn *et al.* [4] use three environmental quality indicators (CO_2, NO_2 and SO_2) in four countries (the Netherlands, the U.K., the U.S. and West Germany) to conduct an empirical study on the relationship between economic growth and emissions, and the results show that there is a positive correlation between economic growth and pollution emissions; meanwhile, the changes in the economic structure and technological progress help reduce environmental pollution. In another econometric analysis, Friedl and Getzner [5] found that the relationship between Austria's economic growth in the period 1960–1999 and CO_2 emissions is in line with the EKC theory, with the "turning point" occurring in the mid-1970s mainly as a result of the rise in oil prices. Through econometric analysis, Jalil and Feridun [6] find that the EKC theory also applies to China. Similarly, in an econometric analysis on South Africa, Muhammad *et al.* [7] also show that the relationship between economic development and environmental quality displays a significant "inverted U-shaped" relationship. In a recent study, Li and Ma [8] employed panel data analysis to study the relationships among the urbanization rate, economic development and environmental change in China. Their results reveal a remarkable inverted-U-shaped relationship between the urbanization rate and changes in regional environmental quality, which not only further confirm the "environmental Kuznets curve hypothesis", but also expand it in that the inverted-U-shaped evolving relationship between environmental quality and economic growth (urbanization) seems to be universally applicable.

Literature regarding the relationship between financial development and environmental quality is limited. Tadesse [9] asserts that financial development should prompt technological innovation and thus improve environmental quality. Kumbaroğlu *et al.* [10] also show that, in a country with a well-developed financial system, active technological innovation typically produces a significant reduction in pollution emissions. In a similar vein, Stijn and Feijen [11] find that the development of financial institutions can reduce the cost of investments that are related to environmental protection projects, thus helping to improve the quality of the environment. Tamazian *et al.* [12] use panel data of the BRIC (Brazil, Russia, India and China) countries from the period 1992–2004 to study the relationship between environmental quality and financial development, and they find that the level of financial development is an important determinant of a country's environmental quality: the higher the level of the country's financial development, the higher the level of the country's environmental quality. After an econometric analysis of the panel data of 24 economies from the period 1993–2004, Tamazian and Rao [13] found that the development of the banking system and capital markets, in addition to direct foreign investment, are all beneficial in reducing per capita carbon dioxide emissions. Based on the panel data of the 12 Middle East and North Africa (MENA) countries from the period 1990–2011, Omri *et al.* [14] study the causal relationships among carbon dioxide emissions, financial development, trade and economic growth, and their findings show that a reduction in environmental quality generates negative external effects on economic growth through affecting human health and that high levels of financial development and trade openness stimulate technological innovation, therefore helping to reduce pollution emissions. Although these studies tend to show that there is a positive correlation between financial development and environmental quality, some empirical studies have found that there is a negative correlation between financial development and environmental quality or that financial development has no significant effect on environmental quality. For example, based on the analysis of the panel data of 22 countries from the period 1990–2006, Sadorsky [15] demonstrates that the development of financial markets increases consumer demand for energy and therefore is not conducive to improving environmental quality. Zhang [16] also finds that there is a positive relationship between financial development and carbon emissions in China. In a study on Turkey, Ozturk and Acaravci [17] find that, in the long run, financial development has no significant impact on per capita carbon dioxide emissions. In the case of Indonesia, Shahbaz *et al.* [18]

analyze the linkages among economic growth, energy consumption, financial development, trade openness and CO_2 emissions over the period of 1975–2011. The empirical findings indicate that economic growth and energy consumption increase CO_2 emissions, while financial development and trade openness decrease energy pollutants. In a similar vein, Leitão [19] evaluates the relationship between energy consumption and foreign direct investment (FDI) in Portugal over the period of 1990–2011. The empirical results illustrate a positive association between income per capita and energy consumption, which validates the hypothesis of the EKC model. In a recent study, Shahbaz *et al.* [20] find that there exists a long-run relation among energy consumption, economic growth, international trade, urbanization and carbon emissions in Portugal. Meanwhile, the EKC hypothesis has also been tested by applying the ARDL (Autoregressive distributed lag) model in the study of Shahbaz *et al.* [20].

Overall, the existing literature on financial development, environmental quality and economic growth exhibits the following deficiencies: First, most of these studies only investigate the impact of financial development or economic growth on environmental quality, but do not perform an analysis by integrating the three into a unified framework. Second, most of the studies only address the impact of financial development or economic growth on environmental quality in one direction, while neglecting the question of whether environmental quality in turn impacts economic growth, and if so, in what ways.

In this context, the present study, which is based on the dynamic panel data of 102 countries from the period 1980–2010, performs an econometric analysis of the relationships among financial development, environmental quality and economic growth using the dynamic generalized method of moments (GMM) estimation. Compared with the existing studies, the theoretical contributions of this study are as follows: First, through incorporating financial development and environmental quality into the economic growth model, the effect of financial development and environmental quality on economic growth is systematically analyzed, which extends the traditional theory concerning environmental quality and economic growth; second, the question of how financial development and environmental quality impact economic growth through interactions is addressed; based on which, the impact of financial development and environmental quality on the marginal outputs formed by labor and capital are investigated, which helps to partially fill the gaps that exist in the current literature on these subjects.

The rest of this paper is organized as follows: the second section introduces the empirical methodology and data; the third section presents the systematic econometric analysis on the impact of financial development and environmental quality on economic growth; the final section summarizes.

2. Empirical Methodology and Data

2.1. Empirical Methodology

To investigate the relationship between financial development, environmental quality and economic growth, we extend the standard Cobb-Douglas production function by incorporating more variables with a particular focus on financial development and environmental quality: $F = AF\left(K, L, F, E; X\right)$, where *A* is technological progress; *K* and *L* are capital and labor, respectively; *F* and *X* denote financial development and environmental quality, respectively; and *X* denotes other sources of economic growth, such as economic structure, openness, capital formation, infrastructure, *etc*. Note that the main difference between our extended equation and the standard Cobb-Douglas production function is the introduction of financial and environmental variables, as well as other variables as inputs that affect the output. This approach is reasonable and already widely used in the literature, because, obviously, in reality, there are many factors that may affect output. In this regard, the conventional Cobb-Douglas production function, which mainly considers labor and capital as inputs, might be too stylized in reality.

Based on the extended Cobb-Douglas production function explained above, our econometric equation can be specified as:

$$GDP_{it} = \alpha_{i1} GDP_{i,t-1} + \alpha_{i2} environment_{it} + \alpha_{i3} finance_{it} + \alpha_{i4} labor_{it} + \alpha_{i5} capital_{it} + \alpha_{i6} X_{it} + \mu_i + \varepsilon_{it} \quad (1)$$

where the subscripts i and t represent, respectively, country and time period; GDP_{it} denotes economic development; $environment_{it}$ denotes environmental quality; *finance* denotes financial development; $labor_{it}$ denotes the labor input; $capital_{it}$ denotes the capital input; X denotes a series of control variables. μ_i denotes the country-specific effects; and ε_{it} is the error term that includes the time-specific effect.

Equation (1) is a typical linear regression equation. However, previous studies have shown that non-linear relationships might exist between the main variables under investigation. To address this issue, the squared term of environmental quality ($environment_{it}^2$) and the squared term of financial developments ($finance_{it}^2$) could be added into Equation (1), and the regression equation is then given by:

$$\begin{aligned} GDP_{it} = {} & \beta_{i1} GDP_{i,t-1} + \beta_{i2} environment_{it} + \beta_{i3} finance_{it} + \beta_{i4} labor_{it} + \beta_{i5} capital_{it} + \\ & \beta_{i6} environment_{it}^2 + \beta_{i7} finance_{it}^2 + \beta_{i8} X_{it} + \mu_i + \varepsilon_{it} \end{aligned} \quad (2)$$

Both Equations (1) and (2) are typical dynamic panel equations. Since the lag term of the dependent variables ($GDP_{i,t-1}$) may be correlated with the error term (*i.e.*, cov($GDP_{i,t-1}$, ε_{it}) ≠ 0), even if there is no serial correlation in ε_{it}, therefore, the traditional OLS estimation will be biased. Meanwhile, for the fixed effects estimator, although μ_i, the individual-level effects, are excluded from the intra-group data that are deviations from individual means, there might still exist a correlation between $\left(GDP_{i,t-1} - \overline{GDP_{i,t-1}}\right)$ and $\left(\varepsilon_{i,t-1} - \overline{\varepsilon}_{i,t-1}\right)$; thus, the fixed effects estimator will be inconsistent. For the generalized least squares (GLS) estimator by the random effects equation, after the variables are quasi-centralized, the estimation results will also biased because of the correlation between $\left(GDP_{i,t-1} - \theta\overline{GDP_{i,t-1}}\right)$ and $\left(\varepsilon_{i,t-1} - \theta\overline{\varepsilon}_{i,t-1}\right)$. To solve these problems, the GMM estimation proposed by Arellano and Bond [21] is used to estimate the equations in our paper. The GMM panel estimators allow us to address these econometric problems using lagged observations of the explanatory variables as instruments. As such, we can reliably examine the impact of the exogenous component of environmental quality and financial development on economic growth.

According to the GMM estimation, the first difference has to be conducted on Equations (1) and (2); then, the first difference of the explanatory variables is used as instrumental variables to perform the estimation. Specifically, the difference equation can be expressed as follows:

$$\Delta GDP_{it} = \alpha_{i1} \Delta GDP_{i,t-1} + \alpha_{i2} \Delta environment_{it} + \alpha_{i3} \Delta finance_{it} + \alpha_{i4} \Delta labor_{it} + \alpha_{i5} \Delta capital_{it} + \alpha_{i6} \Delta X_{it} + \Delta\varepsilon_{it} \quad (3)$$

$$\begin{aligned} \Delta GDP_{it} = {} & \beta_{i1} \Delta GDP_{i,t-1} + \beta_{i2} \Delta environment_{it} + \beta_{i3} \Delta finance_{it} + \beta_{i4} \Delta labor_{it} + \beta_{i5} \Delta capital_{it} + \\ & \beta_{i6} \Delta environment_{it}^2 + \beta_{i7} \Delta finance_{it}^2 + \beta_{i8} \Delta X_{it} + \Delta\varepsilon_{it} \end{aligned} \quad (4)$$

In practice, there are two types of GMM estimations: the first-differenced GMM estimators and the system GMM estimators. Typically, the first-differenced GMM estimators use lagged explanatory variables as the instrumental variables under the assumptions that the idiosyncratic error term is not serially correlated and the explanatory variables are weakly exogenous. However, as suggested by Alonso-Borrego and Arellano [22] and Blundell and Bond [23], the instruments available for the first-difference equation are weak instruments when the explanatory variables are persistent over time. Weak instruments may lead to serious finite sample biases. To deal with the problems associated with the first-differenced GMM estimators, additional moment conditions are proposed for an equation expressed in levels (Arellano and Bover [24]; Blundell and Bond [23]). When an equation in differences and an equation in levels are combined as a system, the estimators based on the moment conditions associated with this system are called system GMM estimators. Indeed, as pointed out by Bond *et al.* [25] and Hauk and Wacziarg [26], the system GMM estimators should be employed for panel data regressions to generate more consistent and efficient parameter estimates. Based on the above considerations, the system GMM estimator is used to estimate Equations (1) and (2).

Following Arellano and Bond [21] and Blundell and Bond [23], to examine the overall validity of the estimation, two specification tests are to be carried out: (1) the Sargan test for the over-identification restrictions, which is to test the overall validity of the instruments; under the null hypothesis that the instruments are valid, the test statistic is asymptotically distributed as chi-square with the degree of freedom being equal to the number of instruments minus the number of parameters estimated; and (2) The AR(2) test (*i.e.*, Arellano-Bond test of autocorrelation), which is to examine whether the error term is serially correlated. Under the null hypothesis that there is no second-order serial correlation, the test statistic is asymptotically distributed as standard normal. Only after passing the above two tests are the system GMM estimation results valid.

2.2. The Data

For the regression equation described in Section 2.1, economic growth as the dependent variable, mainly two proxy variables are used, GDP growth rate (denoted as *gdpg*) and the growth rate of per capita GDP (denoted as *gdpc*), to measure economic growth from the perspectives of the total amount and the average amount, respectively.

According to the objective of this study, the core explanatory variables are mainly financial development and environmental quality. For financial development, based on the common approach adopted by previous studies, the ratio of private credit/GDP was used as the proxy variable for the level of financial development. According to Levine *et al.* [27] and Beck *et al.* [28], private credit measures the most active part of the funds in financial activities; thus, using the ratio of private credit/GDP as the proxy variable for the level of financial development has theoretical advantages. In addition to private credit/GDP, in the robustness test, the percentage of money and quasi-money (M2) in GDP (M2/GDP) was also used as another proxy variable for the level of financial development in the analysis.

For another core explanatory variable, environmental quality (*environment*), also based on the common practices of previous studies, carbon dioxide emissions (per capita metric tons), was used as the proxy variable (reverse parameter) for the environmental quality of the country, mainly because, currently, carbon dioxide emissions are generally recognized as the main cause of global warming IPCC (Intergovernmental Panel on Climate Change) [29]. In addition, in the robustness test, carbon dioxide emissions per GDP (kg/2005 USD GDP) were used as another proxy variable for environmental quality in the analysis.

In selecting the sample countries, based on the availability of data, the final samples used in the econometric analysis of this study included the panel data of 102 countries for the period 1980–2010. In terms of income level, the samples included 35 high-income economies, 48 middle-income economies and 19 low-income economies (a list of the sample countries is presented in Appendix). In terms of the total economic amount, the total GDP of the sample countries accounted for 90% of the world's GDP over the same period; thus, these countries can be viewed as the worldwide sample of the countries with good representativeness.

The interpretation and the data sources of each of the regression variables in the econometric analysis of this study are shown in Table 1. The descriptive statistics of the variables are shown in Table 2.

Table 1. Definition of variables and data sources.

Variable		Definition	Source
Dependent variables	gdpg	GDP growth (annual %)	World Bank Database
	gdpc	GDP per capita growth rate (annual %)	
Core independent variables	environment1	CO_2 emissions (metric tons per capita)	
	environment2	CO_2 emissions (kg per 2005 USD of GDP)	
	environment^2	Quadratic term of CO_2 emissions	
	finance1	Domestic credit to private sector (% of GDP)	
	finance2	Money and quasi money (M2) as % of GDP	
	finance^2	Quadratic term of financial development	
Control variables	capital	Gross capital formation (% of GDP)	
	labor	Population growth (annual %)	
	inflation	Inflation, GDP deflator (annual %)	
	industry	Industry, value added (% of GDP)	
	service	Services, value added (% of GDP)	
	import	Imports of goods and services (% of GDP)	
	r	Deposit interest rate (%)	
	open	Capital account openness index	The Chinn–Ito Index
	insurance	Explicit deposit insurance system	Demirgüç-Kunt *et al.* [30]
	mobile	Mobile cellular subscriptions (per 100 people)	World Bank Database

Table 2. Summary statistics.

Variable	Definition	Observations	Mean	SD	Min	Max
gdpg	GDP growth (annual %)	3162	3.4505	4.5565	−50.2481	35.2241
gdpc	GDP per capita growth rate (annual %)	3162	1.6586	4.5082	−47.3142	36.7670
environment1	CO_2 emissions (metric tons per capita)	3162	4.1996	5.3643	0.0113	38.1611

Table 2. *Cont.*

Variable	Definition	Observations	Mean	SD	Min	Max
environment2	CO_2 emissions (kg per 2005 USD of GDP)	3318	0.6398	0.6084	0.0089	6.7828
finance1	Domestic credit to private sector (% of GDP)	3162	48.2951	43.3562	0.1983	311.0630
finance2	M2/GDP	3217	53.2262	37.9324	1.6172	283.3954
capital	Gross capital formation (% of GDP)	3162	22.3821	7.4101	−2.4244	60.1562
labor	Population growth (annual %)	3162	1.7480	1.2155	−7.5973	11.1807
inflation	Inflation, GDP deflator (annual %)	3162	36.3426	557.1083	−29.1727	26,765.8583
industry	Industry, value added (% of GDP)	3127	29.2499	11.9959	6.2985	106.2764
service	Services, *etc.*, value added (% of GDP)	3136	53.7829	13.5500	12.8720	84.2556
import	Imports of goods and services (% of GDP)	3162	40.0579	25.7354	0.0000	209.3877
r	Deposit interest rate (%)	3151	25.2898	383.5316	0.0100	17,235.8150
open	Capital account openness index	3162	0.0859	1.5285	−1.8750	2.4390
insurance	Explicit deposit insurance system	3162	0.2292	0.4204	0.0000	1.0000
mobile	Mobile cellular subscriptions (per 100 people)	3162	19.8577	35.3648	0.0000	192.5533

3. Econometric Results

3.1. Basic Results

As explained above, the system GMM estimation was used to estimate Equations (1) and (2). The results are shown in Table 3. In the second column of Table 3, Model 1 presents the regression results containing the first-order lag term of the dependent variable, the two core explanatory variables (domestic credit to private sector/GDP and CO_2 emissions (metric tons per capita)), labor (population growth rate) and capital formation (gross capital formation/GDP). In the third column of Table 3, Model 2 further adds the squared terms of the two core explanatory variables.

The regression results for Models 1 and 2 in Table 3 show that, consistent with the classical theory, capital formation (*capital*) and labor (*labor*) are both significantly and positively correlated with economic growth. For the coefficients of financial development (*finance*) and environmental quality (*environment*)that were focused on, the results in Table 3 show that the first-order terms (*finance*) and the second-order terms (*finance*^{2}) of financial development are all significant at the 1% confidence level and that the coefficients of the first-order terms are positive, while those of the second-order terms are negative, indicating that there is a significant "inverted U-shaped" relationship between financial development and economic growth, *i.e.*, with improvement in the level of financial development, GDP growth first increases and then decreases, exhibiting a "turning point". From the perspective of the impact of environmental quality on GDP growth, the regression results also show the similar "inverted U-shaped" relationship. This result means that, in the early stage of economic development, the increase in carbon dioxide emissions is an inevitable outcome that accompanies economic development; however, when crossing the critical point, the continuous increase in carbon dioxide emissions deteriorates environmental quality, leading to the declining economic growth rate.

Table 3. System generalized method of moments (GMM) estimations of Equations (1) and (2).

Dependent Variable: gdpg			**Dependent Variable: gdpc**		
Independent Variable	**Model 1**	**Model 2**	**Independent Variable**	**Model 3**	**Model 4**
L.gdpg [(2)]	0.0809 *** [(1)] (29.7706) [(3)]	0.0645 *** (47.4981)	L.gdpc [(2)]	0.0574 *** (28.1160)	0.1318*** (45.6665)
environment	−0.0195 *** (−3.4071)	0.0393 *** (8.6453)	environment	−0.0479 *** (−6.4767)	0.0808*** (7.1811)
finance	0.2899 *** (3.9904)	0.4930 *** (2.6464)	finance	0.2569 ** (2.0573)	1.7641*** (5.2734)
labor	0.7129 *** (44.3810)	0.6384 *** (24.2763)	labor	−0.3743 *** (−27.6467)	−4.0011*** (−68.2969)
capital	0.1128*** (40.9505)	0.1916 *** (151.5947)	capital	0.2153 *** (80.1879)	0.1421*** (55.2160)
$environment^2$		−0.0028 *** (−24.2657)	$environment^2$		−0.0071*** (−22.1337)
$finance^2$		−0.5686 *** (−7.0941)	$finance^2$		−1.4262*** (−9.9127)
constant	−0.6327 *** (−8.5465)	−2.1689 *** (−18.4742)	constant	−2.4861 *** (−33.0611)	5.0617*** (23.7905)
Wald	12,353.95	88,465.61	Wald	33,306.33	119,877.8
AR(2) [(4)]	−0.5712 (0.5679) [(5)]	−0.8100 (0.4179)	AR(2)	−0.8973 (0.3696)	−0.0864 (0.9312)
Sargan	100.3161 (0.9961) [(4)]	99.4290 (0.9962)	Sargan	98.3065 (0.8361)	99.1046 (0.7627)
Observations	3060	3060	Observations	3060	3060
Economies	102	102	Economies	102	102

[(1)] *,**,*** indicate statistically significant at the 10%, 5% and 1% levels, respectively; [(2)] L.gdpg and L.gdpc denote lagged variables of the two different dependent variables; [(3)] the statistics given in the parentheses under the coefficients of explanatory variables are Z-values; [(4)] AR(2) refers to the Arellano–Bond test of autocorrelation, which is to examine whether the error term is serially correlated; [(5)] the statistics in the parentheses of the AR(2)/Sagan test are *p*-values.

According to the literature, in addition to GDP growth rate, per capita GDP growth rate is also used as an indicator of the proxy variable of economic growth. Therefore, Models 3 and 4 in Table 3 also show the regression results using the per capita GDP growth rate (*gdpc*) as a proxy variable of economic growth. The estimation results show that the "inverted U-shaped" relationships between financial development and economic growth and between environmental quality and economic growth also significantly exist. The sign of capital formation (*capital*) is still significantly positive. Although the coefficients of the population growth rate in Models 3 and 4 are both negative, it is not difficult to understand why; when there is excessive population growth, the per capita GDP growth rate is diminished by the expanding population base.

In terms of the model test, all of the regressions in Table 3 passed the Sargan test and the AR(2) test, indicating that the instrumental variables used in the estimation were appropriate and the regression results were not affected by the second-order serial correlation. Therefore, the estimations in Table 3 are valid.

3.2. Robustness Tests

The econometric analysis described above draws two basic conclusions: first, there is a significant "inverted U-shaped" relationship between financial development and economic growth; and second, there is also a significant "inverted U-shaped" relationship between environmental quality (CO_2 emissions) and economic growth. In this section, the robustness of the above conclusions is tested in various ways.

3.2.1. Robustness to Alternative Proxy Variables

As a common form of the robustness test, M2/GDP and carbon dioxide emissions (kg/2005 dollar GDP) were used as the proxy variables that alternatively measure the level of financial development and environmental quality, respectively, to once again perform the regression on Equations (1) and (2). The results are shown in Table 4. In Models 5 and 6, M2/GDP was used as the proxy variable for the level of financial development, while everything else remained unchanged; in Equations 6 and 7, carbon dioxide emissions (kg/2005 USD GDP) were used to replace carbon dioxide emissions (per capita metric tons) as the proxy variable for environmental quality, while everything else remained unchanged. In the last two columns of Table 4, the regression results of simultaneously using M2/GDP and CO2 emissions as proxy variables are shown.

From Table 4, we can see that the results obtained from using alternative proxy variables in the regression analysis did not change the econometric results drawn above, *i.e.*, both financial development and environmental quality exhibited a significant "inverted U-shaped" relationship with economic growth. In addition, all of the equations passed the Sargan test and AR(2) test, indicating that the instrument variables used in the regression process were effective and the regression results were not affected by second-order serial correlation. Therefore, the regression results are reliable.

Table 4. Robustness to alternative proxy variables.

Independent Variables	**Dependent Variable: gdpg**					
	Model 5	**Model 6**	**Model 7**	**Model 8**	**Model 9**	**Model 10**
L.gdpg (2)	0.0879 *** (1) (21.8951) (3)	0.0723 *** (59.5417)	0.1057 *** (34.3728)	0.1303 *** (60.4975)	0.0995 *** (30.0145)	0.1241 *** (27.8455)
environment1	−0.0627 *** (−15.3875)	0.1001 *** (11.5607)				
environment2			−0.1028 *** (−2.7802)	0.9021*** (19.9065)	−4.9029 *** (−63.5323)	0.6585 *** (5.9481)

Table 4. *Cont.*

Independent Variables	Dependent Variable: gdpg					
	Model 5	**Model 6**	**Model 5**	**Model 8**	**Model 5**	**Model 10**
finance1			0.2569 ** (2.0573)	1.7641 *** (5.2734)		
finance2	0.2899 *** (3.9904)	0.4930 *** (2.6464)			0.3021 *** (3.3383)	11.1377 *** (21.7699)
labor	0.5588 *** (54.6108)	0.4614 *** (20.3969)	0.6989 *** (32.2791)	0.1838 *** (15.0836)	0.6662 *** (23.7204)	0.2037 *** (6.0736)
capital	0.1663 *** (53.1042)	0.1406 *** (72.4035)	0.2339 *** (53.3628)	0.0991 *** (23.9178)	0.1789 *** (63.8613)	0.0369 *** (5.4481)
environment^2		−0.0076 *** (−41.0953)		−0.2182 *** (−25.1482)		−0.2228 *** (−8.6132)
finance^2		−1.1229 *** (−4.3224)		−2.0909 *** (−9.0462)		−5.8221 *** (−19.6019)
constant	−1.7409 *** (−24.9908)	−1.1032 *** (−6.4769)	−3.7283 *** (−20.2628)	−0.7542 *** (−6.4633)	0.9149 *** (12.6061)	−1.7966 *** (−9.1668)
Wald	38,556.66	20,8966.89	17,940.81	22,172.9	32,428.57	6290.65
AR(2)	−0.4759 (0.6342) [(4)]	−0.6838 (0.4941)	−0.3229 (0.7468)	−0.0292 (0.9767)	−0.3523 (0.7247)	0.0076 (0.9939)
Sargan	102.5982 (0.7485) [(4)]	102.2055 (0.9931)	97.6946 (0.8469)	102.4900 (0.7059)	103.0166 (0.7164)	99.9790 (0.9957)
Observations	3120	3120	3120	3120	3064	3064
Economies	104	104	104	104	104	104

[(1)] *,**,*** indicate statistically significant at the 10%, 5% and 1% levels, respectively; [(2)] L.gdpg denotes the lagged variable of the dependent variable; [(3)] the statistics given in the parentheses under the coefficients of explanatory variables are Z-values; [(4)] the statistics in the parentheses of the AR(2)/Sagan test are *p*-values.

3.2.2. Robustness to Different Stages of Economic Development

In the econometric analysis based on cross-country data, the following question was in need of an answer: would the regression results vary with the difference in the level of economic development? Regarding this question, we divided the 102 sample countries into the three sub-samples consisting of high-income economies, middle-income economies and low-income economies according to the classification criteria of the World Bank, and we then subjected them to regression analysis. The results are shown in Table 5.

Table 5 shows that, after taking the nonlinear impact of financial development and environmental quality on economic growth into account, the regression results for high-income and middle-income economies were similar to the results above: definite "inverted U-shaped" relationships between financial development and economic growth and between environmental quality, as well as economic growth. Meanwhile, labor and capital formation also exerted significantly positive effects on economic growth. Among the regressions focusing on low-income economies, only Model 15 showed a significantly negative result on labor (*labor*), while the other coefficients of the regression variables remained unchanged. For low-income economies, under the serious shortages of capital and technology, population growth increases the burden on society as a whole and, thus, was not conducive to economic growth. In Model 16, except for the one lag term (*L.gdpg*) of the dependent variables that was significantly negative, the remaining coefficients of the regression variables were all not significant, and the regression coefficients of some variables exhibited abnormal fluctuation, mainly because the sample size of the low-income economies (only 19 countries) was somewhat small and, thus, vulnerable to the impact of extreme values. To solve this problem, the extreme values can be removed; for the specific analysis, refer to Section 3.2.4.

Table 5. Robustness to different stages of economic development.

Independent Variable	**Dependent Variable: gdpg**					
	High Income Economies		**Middle Income Economies**		**Low Income Economies**	
	Model 11	**Model 12**	**Model 13**	**Model 14**	**Model 15**	**Model 16**
L.gdpg [2]	0.4622 *** [1]	0.3066 ***	0.1610 ***	0.1333 ***	0.0747	−0.1324 *
	(27.5998) [3]	(40.4096)	(12.8467)	(11.8811)	(1.0761)	(−1.8493)
environment	0.7303 ***	0.3747 ***	−0.2990 **	0.3674 **	−3.2415	81.3823
	(10.3869)	(9.6990)	(−2.1546)	(2.0590)	(−0.1602)	(0.3680)
finance	1.4916 ***	3.2633 ***	3.1511	9.2762 ***	3.7587	170.2443
	(3.8314)	(5.8444)	(1.1921)	(2.6479)	(0.1696)	(0.5382)
labor	−4.4284 ***	0.3208 ***	0.3620 *	0.3485 **	−3.8426 **	−0.0928
	(−7.5613)	(4.3529)	(1.6773)	(2.1177)	(−2.0098)	(−0.1093)
capital	0.1363 ***	0.0615 ***	0.1251 ***	0.1553 ***	0.1617	0.0686
	(3.0608)	(5.3021)	(7.7633)	(5.3112)	(1.2263)	(0.1904)
environment^2		−0.0140 ***		−0.0695 ***		−184.5800
		(−12.5720)		(−2.7106)		(−0.4671)
finance^2		−1.7121 ***		−5.9579 ***		−313.2198
		(−6.4942)		(−4.7215)		(−0.4664)
constant	−5.0789 ***	−2.5981 ***	−1.0238	−3.4305 ***	10.5141 **	−17.8876
	(−4.9510)	(−6.4581)	(−1.0713)	(−4.8496)	(2.0223)	(−0.4244)
Wald	3472.92	5834.99	1975.94	4760.46	13.5045	428.6179
AR(2)	−0.5792	−1.3617	0.6515	0.5121	0.2668	−1.4458
	(0.5624) [4]	(0.1733)	(0.5147)	(0.6086)	(0.7896)	(0.1482)
Sargan	32.8834	33.9501	46.2677	44.1980	11.2770	12.3100
	(0.9864) [4]	(1.0000)	(0.9999)	(1.0000)	(1.0000)	(1.0000)
Observations	1050	1050	1440	1440	570	570
Economies	35	35	48	48	19	19

[1] *,**,*** indicate statistically significant at the 10%, 5% and 1% levels, respectively; [2] L.gdpg denotes the lagged variable of the dependent variable; [3] the statistics given in the parentheses under the coefficients of explanatory variables are Z-values; [4] the statistics in the parentheses of the AR(2)/Sagan test are *p*-values.

3.2.3. Robustness to Varying the Data Frequency

To investigate whether the results of the regression have sensitivity to the selection of the data frequency, in accordance with the standard practice of the literature, the data sampling method consisting of a one-year interval or average was used in the robustness test; the results are shown in Table 6. Of these results, Models 17 and 18 used the one-year interval data sampling method on the data since 1980, while Models 19 and 20 used the five-year moving average method on the raw data. Table 6 shows that, regardless of the data sampling methods, the significant "inverted U-shaped" relationship between the core explanatory variables and the dependent variable still existed. Meanwhile, the positive impact of labor and capital formation on economic growth did not change. In addition, Models 17–20 all passed the Sargan test and AR(2) test, indicating that the regression results are valid.

Table 6. Robustness to varying the data frequency.

Independent Variable	**Dependent Variable: gdpg**			
	Data with One Year Interval		**Five Year Moving Average**	
	Model 17	**Model 18**	**Model 19**	**Model 20**
L.gdpg [(2)]	0.0297 *** [(1)] (10.4561) [(3)]	0.0342 *** (6.8717)	0.3972 *** (104.2220)	0.5568 *** (195.0148)
environment	−0.0654 *** (−11.7759)	0.4595 *** (12.3631)	−0.0479 *** (−12.4608)	0.5144 *** (39.9912)
finance	1.5969 *** (25.5877)	0.6107 ** (2.3596)	0.2891 *** (6.2157)	0.8665 *** (5.5223)
labor	1.0667 *** (82.4509)	1.1472 *** (30.9290)	0.6414 *** (52.0333)	1.1450 *** (40.8714)
capital	0.1905 *** (61.4800)	0.0938 *** (14.3250)	0.0997 *** (54.8334)	−0.0826 *** (−15.8238)
environment^2		−0.0187 *** (−12.8595)		−0.0171 *** (−27.4982)
finance^2		−0.7283 *** (−7.2443)		−1.0224 *** (−11.7147)
constant	−3.0062 *** (−39.0922)	−1.5733 *** (−6.3873)	−1.0787 *** (−24.0416)	0.0871 (1.0391)
Wald	35,917.02	8434.43	62,322.99	67,230.43
AR(2)	−0.4134 (0.6793) [(4)]	−0.5237 (0.6005)	−0.5746 (0.5656)	−0.6233 (0.5331)
Sargan	99.8839 (0.6228) [(4)]	98.6775 (0.2982)	99.8087 (0.9204)	98.8270 (0.9981)
Observations	1530	1530	2652	2652
Economies	102	102	102	102

[(1)] *,**,*** indicate statistically significant at the 10%, 5% and 1% levels, respectively; [(2)] L.gdpg denotes the lagged variable of the dependent variable; [(3)] the statistics given in the parentheses under the coefficients of explanatory variables are Z-values; [(4)] the statistics in the parentheses of the AR(2)/Sagan test are *p*-values.

3.2.4. Robustness to Excluding Extreme Values

In the econometric analysis, the influence of extreme values on the regression results must be addressed. Therefore, in this section, the upper and lower extremes that constituted the highest 5% and the lowest 5% of all of the sample values of the indicators of financial development, environmental quality and economic growth were excluded, and the regression analysis was performed again. In Table 7, Models 21 and 22 show the regression results on financial development after the extreme values of the indicators were excluded; Models 23 and 24 were the regression results on environmental quality after the extreme values of the indicators were excluded; and Models 25 and 26 are the regression results on economic growth after the extreme values of the indicators were excluded. Table 7 shows that, after the removal of the extreme values, the regression results were similar to those described above, meaning that labor and capital formation exhibited significant positive correlations with economic growth, and environmental quality and financial development displayed the significant "inverted U-shaped" relationships with economic growth. All equations passed the Sargan test and AR(2) test, indicating that the estimations of the equations are valid.

Table 7. Robustness to excluding extreme values.

Independent Variable	Dependent Variable: gdpg					
	Excluding Extreme Values of Financial Development		Excluding Extreme Values of Environmental Quality		Excluding Extreme Values of Economic Growth	
	Model 21	Model 22	Model 23	Model 24	Model 25	Model 26
L.gdpg [(2)]	0.1642 *** [(1)] (51.2965) [(3)]	0.1295 *** (69.3490)	0.1100 *** (45.2626)	0.0795 *** (13.7967)	0.0212 *** (3.9461)	0.0125 *** (5.4435)
environment	−0.0427 *** (−8.0102)	0.1521 *** (11.0118)	−0.2735 *** (−20.0216)	0.4240 *** (10.9799)	−0.0220 *** (−3.6583)	0.0299 ** (2.5109)
finance	0.2244 ** (2.1352)	2.2790 *** (25.8167)	0.5318 *** (8.9428)	1.7528 *** (4.3331)	0.2386 *** (3.0219)	0.5983 * (1.8319)
labor	0.3735 *** (16.0225)	1.1277 *** (46.7177)	0.2006 *** (11.9296)	0.5074 *** (30.3040)	0.6500 *** (34.2763)	0.6840 *** (14.1456)
capital	0.1354 *** (42.1055)	0.0811 *** (34.8072)	0.1389 *** (41.9320)	0.1081 *** (8.7879)	0.1542 *** (45.5409)	0.1765 *** (34.3058)
$environment^2$		−0.0107 *** (−43.2611)		−0.0209 *** (−12.4364)		−0.0016 *** (−4.9657)
$finance^2$		−0.9393 *** (−14.1445)		−0.9430 *** (−4.8747)		−0.6220 *** (−4.4774)
constant	−0.7023 *** (−7.8271)	−1.6356 *** (−24.1371)	0.2933 *** (4.6316)	−1.4566 *** (−5.4503)	−1.2370 *** (−19.9746)	−1.7911 *** (−7.4674)
Wald	38,326.99	86,032.87	139,541.51	1955.86	6026.09	23,338.14
AR(2)	−0.0331 (0.9736) [(4)]	−0.1912 (0.8484)	0.5334 (0.5938)	0.2082 (0.8351)	−0.7137 (0.4754)	−0.8035 (0.4217)
Sargan	84.0367 (0.9841) [(4)]	82.7677 (0.3940)	88.3785 (0.3507)	87.2111 (0.9999)	79.7031 (1.0000)	79.4718 (1.0000)
Observations	2610	2610	2700	2700	2490	2490
Economies	87	87	90	90	83	83

[(1)] *,**,*** indicate statistically significant at the 10%, 5% and 1% levels, respectively; [(2)] L.gdpg denotes the lagged variable of the dependent variable; [(3)] the statistics given in the parentheses under the coefficients of explanatory variables are Z-values; [(4)] the statistics in the parentheses of the AR(2)/Sagan test are *p*-values.

3.2.5. Robustness to Adding Control Variables

In the real world, because the dependent variables are often affected by many factors, in any particular empirical study, in addition to the core explanatory variables that constitute the focus, it is necessary to include other factors that may exert an impact on the dependent variables; specifically, various control variables are included. From the perspective of the equation setting, the inclusion of control variables not only improves the explanatory power of the equation, but also makes it possible to further assess the significance and sensitivity of the explanatory variables. Therefore, they become an important measure in the stability test of empirical studies. Thus, in this section, based on the basic equations, various control variables have been added to assess the robustness of the regression results.

To clearly show the introduction process of control variables and its effect on the regression results, the regression results were manifested by adding the control variables in a stepwise manner. In Columns 2–4 of Table 8, Models 27–29 show the results of the regression analysis after controlling the macroeconomic variables (inflation rate, degree of industrialization, degree of service, total imports of goods and services/GDP), financial variables (deposit interest rates, capital account openness, explicit deposit insurance) and social variables (lease of mobile cellular wireless telephone communication systems), respectively. The results indicate that the first-order terms of financial development and environmental quality were significantly positive at the 1%, 5% or 10% confidence levels, while their second-order terms were significantly negative at the 1% confidence level. The results once again demonstrate that the basic conclusions of this study did not change because of the introduction of the control variables and that the relevant results are robust.

The results after the introduction of the control variables show that the degree of industrialization, of the development of the service sector, capital account openness, the deposit insurance system and the lease of mobile cellular wireless telephone communication systems (per hundred people) remained significantly positive in all of the equations, while the inflation rate and the deposit rate in all equations remained significantly negative. These results indicate that the deepening of industrialization, the development of the service sector, the enhancement of capital account openness and the establishment of explicit deposit insurance will have a positive effect on economic growth, while the increases in inflation and interest rate tend to have an inverse effect. Overall, these results are not only consistent with intuition and experience, but also are in accordance with the predictions based on the classical economic theory. With respect to the equation test, all of the equations passed the Sargan test and AR(2) test, indicating that the estimations of the equations are all valid.

Table 8. Robustness to adding control variables.

Independent Variable	**Dependent Variable: gdpg**		
	Model 27	**Model 28**	**Model 29**
L.gdpg [(2)]	0.0922 *** [(1)] (21.1122) [(3)]	0.1226 *** (22.4339)	0.1279 *** (22.2780)
environment	0.0393 * (1.9291)	0.0638 ** (2.3199)	0.0663 ** (1.9757)
finance	3.3653 *** (4.8577)	0.7678 *** (2.7124)	0.7355 ** (2.0001)
labor	0.3199 *** (5.5826)	0.2649 *** (2.9056)	0.2834 *** (2.6737)
capital	0.0946 *** (12.2839)	0.0753 *** (7.6938)	0.0950 *** (10.8887)

Table 8. *Cont.*

Independent Variable	Dependent Variable: gdpg		
	Model 27	**Model 28**	**Model 29**
environment^2	−0.0065 *** (−12.5161)	−0.0088 *** (−13.9001)	−0.0102 *** (−15.9973)
finance^2	−2.2021 *** (−8.0958)	−1.2528 *** (−6.7345)	−1.4577 *** (−6.2921)
inflation	−0.0004 *** (−10.8475)	−0.0005 *** (−8.9226)	−0.0005 *** (−4.8967)
industry	0.0149 ** (2.1154)	0.0126 ** (2.0477)	0.0256 *** (2.8292)
service	0.0220 ** (2.3610)	0.0146 ** (2.0119)	0.0528 *** (4.7947)
import	0.0241 *** (3.8598)	0.0164 *** (2.6455)	0.0123 (1.6268)
r		−0.0001 *** (−16.3607)	−0.0001 *** (−8.0340)
open		0.5625 *** (6.8484)	0.5148 *** (5.8103)
insurance		0.2059 ** (2.3013)	0.2055 * (1.8640)
mobile			0.0039 *** (4.4395)
constant	−2.6083 *** (−4.5951)	−0.6790 (−1.1798)	−3.3419 *** (−3.4469)
Wald	64,694.58	1,044,456.2	1,332,363.61
AR(2)	−0.5279 (0.5975)$^{(4)}$	−0.2171 (0.8281)	−0.1810 (0.8564)
Sargan	97.2702 (0.9977) $^{(4)}$	97.8257 (1.0000)	96.8657 (1.0000)
Observations	3028	3017	3017
Economies	102	120	102

(1) *,**,*** indicate statistically significant at the 10%, 5% and 1% levels, respectively; (2) L.gdpg denotes the lagged variable of the dependent variable; (3) the statistics given in the parentheses under the coefficients of explanatory variables are Z-values; (4) the statistics in the parentheses of the AR(2)/Sagan test are *p*-values.

3.3. Further Discussion

Overall, the robustness tests described above confirmed the reliability of the basic conclusion of this study, *i.e.*, financial development and environmental quality each have a significant "inverted U-shaped" relationship with economic growth. In this section, the possible impact of financial development and environmental quality on labor and capital was further analyzed. In this regard, based on Equation (29), the interacting terms of environmental quality and financial development (*environment* × *finance*), environmental quality and labor (*environment* × *labor*), environmental quality and capital formation (*environment* × *capital*), financial development and labor (*finance* × *labor*) and financial development and capital formation (*finance* × *capital*)were introduced. The regression results are shown in Table 9.

Table 9 shows that, among all of the equations, the first-order terms of financial development and environmental quality were all significantly positive at the 1% confidence level, while their second-order terms were significantly negative at the 1% confidence level, *i.e.*, the previously found results of the two "inverted U-shaped" relationships were still upheld. From the perspective of the coefficients of the interacting terms that are attended to in particular in this section, except for the regression coefficients of capital formation and environmental quality, which were significantly negative, the coefficients of the remaining interacting terms were all significantly positive. The estimation results of Models 32–34 also indicate that financial development indirectly promoted economic growth through the marginal product effects of labor and capital formation; similarly, the improvement in environmental quality also enhanced the marginal product effects of capital formation on economic growth. In Model 31, the coefficient of the labor indicator was significantly negative, and the coefficient of the interacting term of environmental quality and labor was significantly positive, with the marginal effect of labor on economic growth being calculated as −0.4501; in relation to the estimation result after the introduction of the interacting term of environmental quality and labor (Model 29), the deterioration of environmental quality altered the promotion effect of labor on economic growth, which means that the labor increase dragged down economic growth. In addition, from the estimation results of Model 30, the coefficient of the interacting term of the two core explanatory variables (*environment* × *finance*) was significantly positive, indicating the existence of the mutually reinforcing relationship between financial development and environmental quality, *i.e.*, enhancing financial development can strengthen the effect of environmental quality improvement on economic growth, and the improved environmental quality can further strengthen the effect of financial development on economic growth. Meanwhile, all of the equations passed the Sargan test and AR(2) test, indicating that the regression estimates are all valid.

Table 9. System GMM estimation: adding interactive terms.

Independent Variable	**Dependent Variable: gdpg**				
	Model 30	**Model 31**	**Model 32**	**Model 33**	**Model 34**
L.gdp [(2)]	0.0704 *** [(1)] (14.9907) [(3)]	0.0780 *** (14.8061)	0.0716 *** (14.9182)	0.0813 *** (12.8071)	0.0688 *** (18.0420)
environment	0.4824 *** (8.4453)	0.7667 *** (14.9493)	1.0161 *** (15.8450)	0.7048 *** (15.9121)	0.5253 *** (19.6975)
finance	3.3042 ** (2.4473)	3.9359 *** (7.2363)	3.4236 *** (5.4277)	4.0848 *** (4.3084)	1.9379 *** (4.3637)
labor	0.0024 (0.0637)	−0.6186 *** (−10.2417)	0.1331 *** (4.0880)	−1.0456 *** (−9.0960)	0.0593 ** (2.1583)
capital	0.2667 *** (44.5644)	0.2249 *** (54.2153)	0.2512 *** (13.4691)	0.1664 *** (42.5461)	0.1194 *** (11.9812)
$environment^2$	−0.0226 *** (−26.0466)	−0.0212 *** (−23.3323)	−0.0213 *** (−21.1392)	−0.0227 *** (−30.7839)	−0.0141 *** (−27.0172)
$finance^2$	−2.5849 *** (−10.1412)	−1.2633 *** (−7.1238)	−0.7681 *** (−3.5510)	−2.5992 *** (−7.7201)	−2.1417 *** (−13.3156)

Table 9. *Cont.*

Independent Variable	Dependent Variable: gdpg				
	Model 30	**Model 31**	**Model 32**	**Model 33**	**Model 34**
inflation	−0.0001 *** (−4.5682)	−0.0005 *** (−5.1296)	−0.0005 *** (−7.1236)	−0.0001 *** (−2.9847)	−0.0002 *** (−5.9496)
industry	−0.1615 *** (−15.6147)	−0.3345 *** (17.3368)	−0.2625 *** (−15.8062)	−0.1733 *** (−18.8223)	0.1556 *** (−19.9750)
service	−0.2068 *** (−10.8240)	−0.4825 *** (−19.9932)	−0.4824 *** (−34.3292)	−0.2328 *** (−13.4562)	−0.1924 *** (−25.6692)
import	0.0541 *** (9.8773)	0.0469 *** (11.1058)	0.0463 *** (7.6199)	0.0792 *** (12.4651)	0.0639 *** (20.6706)
r	−0.0001 (−1.5918)	−0.0004 *** (−31.4737)	−0.0005 *** (−38.7805)	0.0002 *** (−5.2860)	−0.0001 ** (−2.2010)
open	0.2718 *** (3.5085)	0.9445 *** (12.7171)	0.9151 *** (9.9054)	0.1027 * (1.8355)	0.4110 *** (7.0427)
insurance	7.8932 *** (36.1892)	10.2671 *** (39.4602)	11.9170 *** (45.6088)	8.8700 *** (33.5655)	6.6664 *** (26.8534)
mobile	−0.0324 *** (−20.5683)	−0.0229 *** (−15.2388)	−0.0264 *** (−16.3252)	−0.0255 *** −17.4847)	−0.0231 *** (−20.0805)
environment × finance	0.6089 *** (19.0306)				
environment × labor		0.1695 *** (36.7527)			
environment × capital			−0.0020 ** (−2.3705)		
finance × labor				2.6201 *** (14.7228)	
finance × capital					0.1819 *** (9.4827)
constant	6.4761 *** (6.9373)	26.6133 *** (14.5808)	22.6099 *** (17.2301)	9.7596 *** (10.0061)	8.1646 *** (12.3469)
Wald	117,398.12	564,637.1	210,224.2	389,749.54	482,577.6
AR(2)	−0.8908 (0.3730) (4)	−0.8788 (0.3795)	−0.8434 (0.3990)	−0.6655 (0.5057)	−0.8643 (0.3874)
Sargan	95.6225 (0.7970) (4)	93.3969 (0.7840)	91.7868 (0.7983)	93.0121 (0.8474)	93.4458 (1.0000)
Observations	3017	3017	3017	3017	3017
Economies	102	102	102	102	102

(1) *,**,*** indicate statistically significant at the 10%, 5% and 1% levels, respectively; (2) L.gdpg denotes the lagged variable of the dependent variable; (3) the statistics given in the parentheses under the coefficients of explanatory variables are Z-values; (4) the statistics in the parentheses of the AR(2)/Sagan test are *p*-values.

4. Conclusions

Based on the dynamic panel data of 102 countries from the period 1980–2010, the relationships among financial development, environmental quality and economic growth were studied using the GMM estimation. The econometric results show that there was a robust and significant "inverted U-shaped" relationship between financial development and economic growth, *i.e.*, by increasing the level of financial development, economic growth first increased and then decreased, which is consistent with the results reported in the standard literature. Meanwhile, there was also a robust and significant "inverted U-shaped" relationship between carbon dioxide emissions and economic growth, indicating that there existed a critical point in exchanging for economic growth at the expense of environmental quality; after crossing the critical point, the deterioration of environmental quality will lead to a significant slowdown in economic growth.

In addition to the basic conclusions described above, the econometric analysis in this paper also shows that there was a mutually promoting and strengthening relationship between financial development and environmental quality. Specifically, the degree of financial development can further strengthen the promoting effect of environmental quality on economic growth; meanwhile, an improvement in environmental quality can also strengthen the promoting effect of financial development on economic growth. In addition, financial development and environmental quality could influence economic growth through strengthening the marginal product effects of capital and labor, which further indicates that both financial and environmental factors play an important role in modern economic development. In this regard, both financial development and environmental quality should be included in the production function of the economic growth model as important variables.

Apart from the main conclusions described above, it is also found that the degree of industrialization, the development of the service sector, capital account openness, the deposit insurance system and the lease of mobile cellular wireless telephone communication systems remained significantly positive in all of the equations, while the inflation rate and the deposit rate in all equations remained significantly negative. These results indicate that the deepening of industrialization, the development of the service sector, the enhancement of capital account openness and the establishment of explicit deposit insurance had positive effects on economic growth, while the increases in inflation and interest rate seem to have a negative impact on economic growth. Overall, these results are not only consistent with intuition and experience, but also in accordance with the predictions based on the classical economic theory.

There are four policy implications that can be drawn from our analysis:

First, to achieve sustainable economic growth, an appropriate level of financial development should be pursued, since neither an underdeveloped financial system nor an overdeveloped financial system is conducive to economic growth. In fact, a naive financial system is usually associated with financial repression, while an overdeveloped financial system may have a crowding-out effect on the real economy by attracting too much resources, both of which are harmful for economic growth.

Second, the "inverted U-shaped" relationship between carbon dioxide emissions and economic growth means that although in the early stages of economic development, the strategy of pursuing economic growth by sacrificing environmental quality might be economically acceptable, in the long run, it will definitely result in serious environmental problems and, thus, have a significant negative impact on economic growth. Therefore, from the perspective of long-term and sustainable economic growth, environmental protection is of crucial importance for every country.

Third, considering that there exist wide interactive relationships among financial development, environmental quality and other production factors in the process of economic growth, a complete blueprint for sustainable economic development must take these interactions into account by effectively exploring the benefits of these interactions while avoiding their harmful effects.

Finally, according to our econometric results, apart from financial development and environmental quality, there are also a wide variety of factors that are helpful for economic growth, such as the development of the secondary industry and the service sector, the opening of capital account, the establishment of deposit insurance system and the construction of wireless telephone communication systems. This means that the upgrading of economic structure, the increase in openness, the setup of financial institutions and the development of social infrastructure are all conducive to economic growth.

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Author Contributions

In this paper, Li Shushu designed the research program, made the choice of modeling strategy and completed the writing of the introduction and policy analysis. Zhang Jinglan and Ma Yong collected the data, conducted the econometric analysis and completed the analysis of the corresponding parts.

Conflicts of Interest

The authors declare no conflict of interest.

Appendix

Table A1. List of sample economies used in the empirical analysis.

Classification	List of Sample Economies
High income	Antigua and Barbuda, Australia, Austria, Bahamas, Bahrain, Barbados, Belgium, Botswana, Canada, Chile, Cyprus, Denmark, Finland, France, Greece, Iceland, Ireland, Israel, Italy, Japan, Korea, Luxembourg, Malta, the Netherlands, New Zealand, Portugal, Saudi Arabia, Singapore, Spain, Sweden, Switzerland, Trinidad and Tobago, United Kingdom, United States, Uruguay
Middle income	Algeria, Argentina, Belize, Bolivia, Brazil, Cameroon, China, Colombia, Congo, Costa Rica, Cote d'Ivoire, Dominica, Dominican Republic, Ecuador, Arab Rep. Egypt, El Salvador, Fiji, Gabon, Ghana, Grenada, Guatemala, Guyana, Honduras, India, Indonesia, Islamic Rep. Iran, Jordan, Malaysia, Mauritius, Mexico, Morocco, Nigeria, Pakistan, Panama, Peru, Philippines, Senegal, Seychelles, South Africa, Sri Lanka, St. Lucia, St. Vincent and the Grenadines, Sudan, Swaziland, Thailand, Tunisia, Turkey, Venezuela
Low income	Bangladesh, Benin, Burkina Faso, Burundi, Central African Republic, Chad, Comoros, Dem. Rep. Congo, Ethiopia, Gambia, Kenya, Madagascar, Malawi, Mali, Nepal, Niger, Rwanda, Sierra Leone, Togo

References

1. Shafik, N.; Bandyopadhyay, S. *Economic Growth and Environmental Quality: Time-Series and Cross-Country Evidence*; World Bank Publications: Washington, DC, USA, 1992.
2. Grossman, G.; Krueger, A. Economic Growth and the Environment. *Q. J. Econ.* **1995**, *110*, 353–377.
3. Selden, T.M.; Song, D. Environmental quality and development: Is there a Kuznets curve for air pollution emissions? *J. Environ. Econ. Manag.* **1994**, *27*, 147–162.
4. De Bruyn, S.M.; van den Bergh, J.C.J.M.; Opschoor, J. Economic growth and emissions: Reconsidering the empirical basis of environmental Kuznets curves. *Ecol. Econ.* **1998**, *25*, 161–175.
5. Friedl, B.; Getzner, M. Determinants of CO_2 emissions in a small open economy. *Ecol. Econ.* **2003**, *45*, 133–148.
6. Jalil, A.; Feridun, M. The impact of growth, energy and financial development on the environment in China: A cointegration analysis. *Energy Econ.* **2011**, *33*, 284–291.
7. Muhammad, S.; Tiwari, A.; Muhammad, N. The Effects of Financial Development, Economic Growth, Coal Consumption and Trade Openness on Environment Performance in South Africa. Energy Policy **2013**, *61*, 1452–1459.
8. Li, S.; Ma, Y. Urbanization, Economic Development and Environmental Change. *Sustainability* **2014**, *6*, 5143–5161.
9. Tadesse, S.A. *Financial Development and Technology*, Working Paper No.749; William Davidson Institute: Ann Arbor, MI, USA, 2005.
10. Kumbaroğlu, G.; Karali, N.; Arıkan, Y. CO_2, GDP and RET: An aggregate economic equilibrium analysis for Turkey. *Energy Policy* **2008**, *36*, 2694–2708.
11. Stijn, C.; Feijen, E. *Financial Sector Development and the Millennium Development Goals (No. 89)*; World Bank Publications: Washington, DC, USA, 2007.
12. Tamazian, A.; Chousa, J.; Vadlamannati, K. Does higher economic and financial development lead to environmental degradation: Evidence from BRIC countries. *Energy Policy* **2009**, *37*, 246–253.
13. Tamazian, A.; Rao, B.B. Do economic, financial and institutional developments matter for environmental degradation? Evidence from transitional economies. *Energy Econ.* **2010**, *32*, 137–145.
14. Omri, A.; Daly, S.; Rault, C.; Chaibi, A. Financial development, environmental quality, trade and economic growth: What causes what in MENA countries. *Energy Econ.* **2015**, *48*, 242–252.
15. Sadorsky, P. The impact of financial development on energy consumption in emerging economies. *Energy Policy* **2010**, *38*, 2528–2535.
16. Zhang, Y.J. The impact of financial development on carbon emissions: An empirical analysis in China. *Energy Policy* **2011**, *39*, 2197–2203.
17. Ozturk, I.; Acaravci, A. The long-run and causal analysis of energy, growth, openness and financial development on carbon emissions in Turkey. *Energy Econ.* **2013**, *36*, 262–267.
18. Shahbaz, M.; Hye, Q.M.A.; Tiwari, A.K.; Leitão, N.C. Economic growth, energy consumption, financial development, international trade and CO_2 emissions in Indonesia. *Renew. Sustain. Energy Rev.* **2013**, *25*, 109–121.
19. Leitão, N.C. Energy consumption and foreign direct investment: A panel data analysis for Portugal. *Int. J. Energy Econ. Policy* **2015**, *5*, 138–147.

20. Shahbaz, M.; Dube, S.; Ozturk, I.; Jalil, A. Testing the Environmental Kuznets Curve Hypothesis in Portugal. *Int. J. Energy Econ. Policy* **2015**, *5*, 475–481.
21. Arellano, M.; Bond, S. Some tests of specification for panel data: Monte Carlo evidence and an application to employment equations. *Rev. Econ. Stud.* **1991**, *58*, 277–297.
22. Alonso-Borrego, C.; Arellano, M. Symmetrically Normalized Instrumentalvariable Estimation Using Panel Data. *J. Bus. Econ. Stat.* **1996**, *17*, 36–49.
23. Blundell, R.; Bond, S. Initial conditions and moment restrictions in dynamic panel-data models. *J. Econ.* **1998**, *87*, 115–143.
24. Arellano, M.; Bover, O. Another Look at the Instrumental Variable Estimation of Error-components Models. *J. Econ.* **1995**, *68*, 29–51.
25. Bond, S.; Bowsher, C.; Windmeijer, F. Criterion-based Inference for GMM in Autoregressive Panel Data Models. *Econ. Lett.* **2001**, *73*, 379–388.
26. Hauk, W.; Wacziarg, R. A Monte Carlo study of growth regressions. *J. Econ. Growth* **2009**, *14*, 103–147.
27. Levine, R.; Loayza, N.; Beck, T. Financial Intermediation and Growth: Causality and Causes. *J. Monet. Econ.* **2000**, *46*, 31–77.
28. Beck, T.; Lundberg, M.; Majnoni, G. Financial intermediary development and growth volatility: Do intermediaries dampen or magnify shocks? *J. Int. Money Financ.* **2006**, *25*, 1146–1167.
29. IPCC. *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*; Solomon, S., Qin, D., Manning, M., Chen, Z., Marquis, M., Averyt, K.B., Tignor, M., Miller, H.L., Eds.; Cambridge University Press: Cambridge, UK, 2007; p. 996.
30. Demirgüç-Kunt, A.; Detragiache, E. Cross-country empirical studies of systemic bank distress: A survey. *Natl. Inst. Econ. Rev.* **2005**, *192*, 68–83.