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Research article

Impact of financial development on the energy intensity of developing countries

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ABSTRACT

Climate change is an important and urgent challenge facing the world, affecting the survival and development of human beings from multiple dimensions such as environment and economy. Carbon emissions are a barometer of climate change, and energy consumption is closely related to carbon emissions. Reducing energy consumption can reduce carbon emissions, thereby optimizing the human living environment. Compared with developed countries, the carbon emissions and energy consumption of developing countries are still growing strongly, so it's significant to study the energy consumption of developing countries. Energy intensity can be reduced through reducing energy intensity, and financial development can have an impact on energy intensity. So, using panel data from 67 developing countries from 1995 to 2018, this study selected six financial development indicators and uses the system Generalized Method of Moments (sys-GMM for short) establishes a dynamic panel model to study the impact of financial development on energy intensity from the six aspects of access, depth and efficiency of financial institutions and financial markets, which are more implementable and more realistic for formulating relevant financial policies to reduce energy intensity. We introduced the index of industrial structure upgrading and studied the interaction between financial development and financial development in the impact of financial development on energy intensity for the first time. The findings revealed that improving financial institutions' access, depth, and efficiency, as well as financial markets' access, depth, and efficiency, might dramatically lower developing countries' energy intensity. The improvement of industrial structure resulted in a reduction in the energy intensity of financial development. Furthermore, the 67 developing countries were grouped from five different perspectives, and the influence of financial development on energy intensity reduction was found to be robust. Therefore, the research results significantly reduce energy intensity for financial development in developing countries.

1. Introduction

The 2050 net-zero emissions target refers to the plan to reduce global carbon dioxide emissions to net zero by 2050. The energy sector is the source of about three-quarters of today's greenhouse gas emissions. According to the International Energy Agency (IEA), reducing these emissions is both the key to achieving net zero emissions by 2050 and the greatest challenge facing humanity. Thus, energy consumption and energy intensity have always been a focus. Energy consumption is directly proportional to carbon emissions (Shahbaz et al., 2018). The decrease in the growth rate of energy consumption benefits from the reduction of energy intensity. Furthermore, in order to lower energy intensity, it is critical to investigate the elements that influence it. According to BP (British Petroleum), world energy consumption rose 1.3% in 2019 over the prior year, below the 10-year average of 1.6% growth and well below the 2.8% growth rate recorded in 2018. Carbon emissions grew by 0.5% in 2019, which, while lower than the average growth rate of 1.1% over the past decade and below the 2.1% growth rate in 2018, only partially hedged the substantial growth in 2018 (BP, 2020). Global energy intensity decreased by 2% in 2019, and by only 1.6% when weather was taken into account, roughly the same as in 2018. However, this improvement is well below the average between 2010 and 2017, and well below the 3.6% standard required to achieve the IEA's Sustainable Development Scenario (SDS) in 2020–2040 (IEA, 2020).

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Regionally, almost all advanced economies have experienced a decline in energy demand, with a total decline of 1% in 2019, led by the European Union (2%) and the United States (0.8%). While developing countries have continued to increase their energy demand, China accounted for a staggering 90% of the net growth in global energy demand in 2019. Southeast Asia's energy demand grew strongly, at 3.4% in 2019. The decline in aggregate energy demand in advanced economies is directly due to improvements in energy efficiency, followed by indirect efficiency gains due to a shift to low-carbon energy sources with lower generation losses (IEA, 2020). In contrast, in developing countries, high energy consumption may be caused by the rapid growth of energy-intensive industries as they enter the heavy industrialization stage of industrial development, or it may be caused by the backward energy research and development technology and low energy efficiency of enterprises. As a result, research into the factors that influence energy intensity in emerging countries is required. In the existing literature, the influencing factors of energy consumption or energy intensity mainly include financial development, economic growth, technological progress, energy price, openness to the outside world, urbanization level, aging population, industrial structure, and globalization (Sadorsky, 2013; Shahbaz and Lean, 2012; Chang, 2015; Gillingham et al., 2016; Ahmed, 2017; Hanif, 2018; Pan et al., 2019c; Danish and Ulucak, 2021). Financial development, as a catalyst for modern technological progress, can effectively promote the improvement of energy efficiency (Shahbaz et al., 2020), but the majority of previous research on the Granger causality between financial development and energy consumption (Shahbaz et al., 2013; Shahbaz et al., 2017; Sehrawat et al., 2015; Furuoka, 2015; Kahouli, 2017; Dilek et al., 2020) has neither shown nor directly reflected the transmission path of financial development on energy intensity. Therefore, this research divided financial development into six dimensions and used the dynamic panel model to first study the direct impact of financial development on energy intensity, and then introduced the factor of industrial structure upgrading as an interactive effect with financial development to study its role in the impact of financial development on energy intensity.

Financial development is a multi-dimensional process, including financial institutions and the financial market. Financial institutions include banks, insurance companies, and other institutions. The financial market includes the stock market and the bond market. In order to reflect the diversity of financial development, Ratna et al. (2015) used principal component analysis to create financial development indexes in different dimensions according to the performance of financial institutions and financial markets in depth, access, and efficiency. Market size and liquidity is referred to as depth; the ability of individuals and companies to access financial services is referred to as access; the ability of institutions to provide financial services at a low cost and create long-term profits, as well as the amount of activity in capital markets, is referred to as efficiency. It includes the overall financial development index, financial institution index, financial market index, financial institution depth, financial institution access, financial institution efficiency, financial market depth, financial market access, and financial market efficiency. The overall financial development index is synthesized by financial institution index and financial market index through the principal component analysis method; the financial institution index is synthesized by the financial institution depth, access, and efficiency; and the financial market index is synthesized by the financial market depth, access, and efficiency (Ratna et al., 2015).

From the perspective of production, the transmission path of financial development affecting energy intensity is divided into three processes. First, the scale and liquidity of the financial system are measured by the depth of financial development, which includes the depth of financial institutions and the depth of financial markets. Developed financial institutions and capital markets can reduce the information asymmetry of investors and financiers and the blocking of financing channels in the financial market, and improve the financial system's resource allocation efficiency; that is, the financial system can direct financial resources from inefficient to efficient industries, resulting in effective resource allocation and maximum utilization (He et al., 2019). Therefore, the deeper the financial development, more financing channels can be provided for the renewable energy sector, and debt and equity financing can be provided for green renewable energy projects so as to encourage enterprises to research and develop clean energy and reduce energy intensity. Different renewable energy sectors have different financing channels. Small and micro enterprises can obtain private equity financing, while large companies in solar energy and nuclear energy need debt financing from banks and financial institutions (Zhang et al., 2016). Second, access to financial development, including access to financial institutions and financial markets, refers to the ability of individuals and companies in the overall financial system to obtain capital. The lowering of the financing threshold of the financial system has opened up a way for enterprises to finance and reduce the financing difficulties of enterprises. Under such conditions, enterprises are more likely to abandon energy-intensive production, carry out technological transformation and upgrading, and adopt energy-saving green technologies to reduce energy intensity in the context of global energy consumption reduction, energy conservation, and emission reduction. Third, financial development efficiency, which includes the efficiency of financial institutions and financial markets, refers to the financial system's ability to provide low-cost financial services to businesses and individuals, as well as the level of activity in capital markets. The high efficiency of financial development can effectively reduce the financing cost of enterprises, reduce financing constraints, strengthen budget constraints, alleviate investment shortages, and enable enterprises in high-energy industries to develop low-energy technologies and equipment (Anton and Nucu, 2020). Based on data from China's manufacturing industry, Xue and Wang (2021) concluded that lowering firms' financial pressures could assist them reduce their energy intensity level. Therefore, the improvement of financial development efficiency can reduce energy intensity for the industry, improve energy efficiency, and contribute to the realization of carbon neutrality for the country. However, from the perspective of consumption, the improvement of financial development level will be accompanied by the reduction of capital borrowing costs, which will make consumers tend to buy bulk commodities, such as automobiles, refrigerators and air conditioners, which will increase the country's energy consumption (Sadorsky, 2010), energy intensity may increase. To summarize, financial development has a variety of effects on energy intensity, and it is critical to investigate the effects of various financial development characteristics on energy intensity.

In addition, financial development is also inseparable from the upgrading of industrial structure. The upgrading of industrial structure has two connotations: First, under the condition of unchanged technological and economic conditions, the proportion of low-efficiency industries keeps decreasing, and that of high-efficiency industries keeps increasing through the optimization of resource allocation. Second, under the action of technological progress, the industrial structure evolves from a lower form to a higher form. The growth of the financial market can increase capital allocation efficiency, eliminate companies with high energy consumption but low production, and force high-energy-consumption businesses to adapt and upgrade. Financial development can help with industrial structure changes by providing financial support, while the optimized industrial structure will promote the sound development of finance and create a good capital environment for the adjustment of industrial structure. Therefore, the financial development affects energy intensity in two ways, and the industrial structure upgrade also indirectly affects it through the rule of "survival of the fittest." Labor-intensive industries are replaced by capital-intensive, technology-intensive and knowledge-intensive industries, and declining industries are eliminated. Industrial structure upgrade also guides and supports emerging industries, strengthens traditional industry technology innovation, reduces energy consumption, and improves energy efficiency. Based on the foregoing ideas, it is vital to investigate the influence of the interaction between financial development and industrial structure on

energy intensity, as well as whether the industrial structure increases or weakens the financial development's impact on energy intensity.

The purpose of this paper is to investigate the impact of various dimensions of financial development on energy intensity in developing countries, as well as the interaction between industrial structure upgrading and financial development affecting energy intensity, that is, whether industrial structure upgrading will enhance or weaken the impact of various dimensions of financial development on energy intensity, in order to give developing countries advice on how to design policies for energy saving and emission reduction. The following are the paper's unique features: First, the innovation of financial development measurement indicators. At the moment, the financial development indicators in the sector of energy finance are rather straightforward. Most scholars only use financial institution indicators or financial market indicators to measure financial development in their articles, but this has measurement errors for real financial development and is not systematic. This research employs six indicators from various dimensions to quantify financial development in a way that is more extensive and accurate than earlier studies. In addition, in order to verify the robustness of financial development to energy intensity, this paper also made innovations in the group test. Not only did the developing countries group the middle-to-high-income level and the low-income level according to the World Bank's income classification standard, but also from various countries The energy consumption trends, whether energy conservation and emission reduction measures are taken, the proportion of primary energy consumption to total energy, and the level of financial development are grouped. Second, in the research field of financial development on energy intensity, the extension of research techniques in the field of energy finance, the introduction of an interaction effect model, and the introduction of industrial structure upgrading as an interactive variable. In the previous literature, most of the mechanism analysis in the field of energy finance uses the mediation effect analysis. This paper, which is an extension of the research approach in this sector, employs the interaction effect to investigate the mechanism transmission of the impact of financial development on energy intensity.

The rest of this paper is laid out as follows. The literature review is in Section 2, the study technique and data are in Section 3, and the empirical analysis is in Section 4. The conclusion and discussion are presented in Section 5.

2. Literature review

Different viewpoints on the impact of financial development on energy intensity or consumption can be found in the extant relevant literature. One view is that more financial development will result in increased energy consumption or energy intensity (Ntow-Gyamfi et al., 2020). Sadorsky (2010, 2011) found that financial development promoted energy consumption in 22 rising economies and nine border economies in Eastern and Central Europe. Xu (2012) discovered that financial development has a favorable impact on energy consumption in 29 Chinese provinces. When the domestic credit/GDP of the private sector was employed as a financial development indicator, Islam et al. (2013) discovered that it had a beneficial effect on energy consumption in Malaysia. Kahouli (2017) studied six countries in the Southern Mediterranean and found that financial development in other countries would promote energy consumption except Egypt. Another view is that financial development will reduce energy consumption or energy intensity (Ouyang and Li, 2018). According to Assi et al. (2020), financial development lowered energy consumption in 28 nations with the highest degree of economic freedom. As per Chiu and Lee (2020), assuming national risks remain steady, financial development will aid in the reduction of energy consumption. The panel threshold regression model was used by Kamal et al. (2022) in 23 European Union (EU) nations, and the results showed that the restraining effect of banking, stock market, and overall financial development on energy intensity was dependent on the level of technical innovation; that is, within a certain threshold, development in banking, stock markets, and finance in general would significantly reduce energy intensity.

It has also been found that when different financial development indicators are selected, their influences on energy consumption or energy intensity are inconsistent (Benkraiem et al., 2019). Coban and Topcu (2013) looked examined 27 European Union (EU) countries and discovered that financial development, as assessed by a banking index or a stock index, increased energy consumption in elderly member states. The growth of the stock market had no substantial impact on energy consumption in the new member states, however the growth of the banking industry showed an inverted u-shaped association with energy consumption. Chang (2015) divided 53 countries into two groups: high-income and low-income, and discovered that financial development as measured by the banking index increased energy consumption in developed economies, emerging economies, and the non-high-income group in developing countries, whereas financial development as measured by the stock market decreased energy consumption of the high-income group in developed economies. It also increased energy use in emerging and developing economies. The impact of long-term and short-term financial development on energy consumption has also been researched by academics. Financial development, according to Al-mulali and Lee (2013), has a favorable long-term and short-term influence on energy consumption. According to Aslan et al. (2014), financial development had a positive impact on energy consumption only in the long run. Other studies have found a non-linear relationship between financial development and energy consumption (Mahalik et al., 2017; Gaies et al., 2019; Yue et al., 2019; Wang and Gong, 2020; Shahbaz et al., 2017).

Regarding the determination of indicators to measure financial development, when Ji and Zhang (2019) looked at the impact of financial development on the expansion of renewable energy and the upgrading of China's energy structure, they discovered that equity financing, not bond financing, was the primary source of funding for the renewable energy sector. Private bond and equity markets grew in comparison to the banking system. At high income levels, mutual funds and pension funds began to grow quickly, while the relative size of the public bond market shrank. Therefore, relying solely on a single, bank-centric indicator to measure financial development may be misleading (Ratna et al., 2015; Svirydzenka, 2016). For example, Chen et al. (2019) used the bank variable to represent financial development and discovered that financial development had a "U-shaped" relationship with non-OECD (Organisation for Economic Co-operation and Development) countries' energy intensity, but had little impact on OECD countries. Pan et al. (2019a, 2019b) investigated the association between financial development and energy intensity in Bangladesh using a single bank indicator. Financial development has an impact on Bangladesh's energy intensity, according to the study, with the encouraging effect lasting longer than the inhibitory effect.

Some researchers have concentrated their efforts on a single country while examining financial development and energy consumption. For example, Mahalik et al. (2017), Shahbaz and Lean (2012) each studied the relationship between financial development and energy consumption in one country or region. Other researchers have looked into the link between financial development and energy intensity in developed and developing countries. Canh et al. (2020) used panel data from 81 global economies from 1997 to 2013 to investigate the impact of financial development on energy intensity consumption from a multidimensional perspective, and found that the overall financial development index and financial institution index promoted energy intensity consumption, while the financial market index inhibited energy intensity consumption. Among the three categories of countries with high and low income levels, the effects of financial access, financial depth, and financial efficiency were different.

In summary, theoretical research on the impact of financial development on energy intensity at home and abroad has made some progress, but there are still some limitations. First, financial development indicators are single. Most research has used a single banking index, which

is not objective or rigorous enough to measure the impact of financial development on energy intensity. Secondly, research on the relationship between financial development and energy intensity has either studied a single country (Tang and Tan, 2014; Rafindadi and Ozturk, 2016), which has no reference value for other countries to formulate relevant policies, or has taken developed and developing countries as research objects together (Chang, 2015; Kamal et al., 2022; Chiu and Lee, 2020), without systematic research on developing countries. Finally, energy intensity is a better way to quantify energy efficiency than energy consumption (Pan, 2019a), and the impact of financial development on energy intensity is not well defined.

3. Research methods and data

3.1. Sample selection and data sources

The study sample was the developing countries in 1995–2018. Based on the availability and accuracy of the data, we eliminated data deletion in developing countries, and considering the rich oil exporter of crude oil inventory, could their financial development, there is no significant impact on energy intensity, eliminate in the process of empirical. In the end, a total of 67 developing country samples were used for the study, with a total of 1,608 observations. Among them, the Energy Information Administration (EIA) in the United States provided data on energy consumption; financial development data came from IMF data and the World Bank World Development Indicator Database (WDIs); and GDP, trade openness, industrialization degree, economic growth, aging degree, and industrial structure upgrading data came from WDIs. Energy price data came from the BP (British Petroleum) World Energy Statistical Yearbook 2020 edition. Table 1 provides information about the variables used in this study. Meanwhile, all data used in the empirical study of this paper are stored in the uploaded Supplementary Material. Please take them by yourself if necessary.

3.2. Variable selection and description

3.2.1. Explained variables

Energy intensity was the explained variable and is represented by EI_{it} in the regression model. We chose the ratio of primary energy consumption to GDP to indicate energy intensity, which is the most common method of expression in the literature.

3.2.2. Core explanatory variables

Financial development was the core explanatory variable. As for the index selection of financial development, it does not have a unified definition among academics. We chose six indicators to represent financial development in the empirical research part, based on Canh et al. (2020).'s research: financial institution access (FIA), financial institution depth (FID), financial institution efficiency (FIE), financial market access (FMA), financial market depth (FMD), and financial market efficiency (FME). Financial development indicators employed in the robustness test were the financial institution index (FI), financial market index (FM), and overall financial development index (FD). In addition, referring to Pan et al. (2019a; 2019b), Chang (2015) and Sadorsky (2010), we selected the domestic credit/GDP (DCTPS) index of the private sector to represent financial development in the robustness test.

3.2.3. Interactive variables

Generally speaking, an interaction effect refers to an effect produced by two or more factors acting in dependence on each other (Blalock, 1965). Financial development and industrial structure upgrading influence each other and develop together. On the one hand, financial development influences industrial structure upgrading through functions such as capital agglomeration, capital allocation, professional information disclosure, and risk diversification, but it also promotes industrial structure upgrading by speeding up technological innovation, promoting industrial integration, and improving risk management. The upgrading of the industrial structure, on the other hand, is a source of power for promoting my country's economic progress. The improvement of the level of economic development will promote the transformation of the financial operation mode and the expansion of the demand for financial services, making financial services more diversified, diversified and modern, thus improving the financial developed function. Financial development and industrial structure upgrading also affect energy intensity from different perspectives. Therefore, the interaction effect is the first choice in this paper to study the transmission mechanism of the impact of financial development on energy intensity.

The industrial structure was upgraded to an interactive variable, which is represented by $cyjg_{it}$ in the regression model. The upgrading of industrial structure was the ratio of the output value of the tertiary industry to the output value of the secondary industry. The larger the value, the larger the scale of the tertiary industry relative to the secondary industry, which also indicates the adjustment and optimization of the

Table 1. Variables used in the regression model.

Variable type	Variable symbol	Variable name	Variable definition	Data source
Explained variable	*EI*	Energy intensity	Primary energy consumption/GDP	*EIA;WB-WDIs*
Control variables	*Industry*	Degree of industrialization	Industrial added value/GDP	*WB-WDIs*
	Trade	Trade openness	Trade volume (total imports and exports of goods and services)/GDP	*WB-WDIs*
	ggdp	GDP growth	GDP growth rate	*WB-WDIs*
	Pop65	Degree of aging	Population over 65/ total population	*WB-WDIs*
	lnop	Energy prices	logarithm of WTI price per barrel of crude oil	*BP*
Interactive variable	*cyjg*	Upgrading of industrial structure	Output value of tertiary industry/ output value of secondary industry	*WB-WDIs*
Core explanatory variable	*FD*	Overall financial development	-	*IMF-FD*
	FI	Financial institution development	-	*IMF-FD*
	FM	Financial market development	-	*IMF-FD*
	FIA	Financial institution access	-	*IMF-FD*
	FID	Financial institution depth	-	*IMF-FD*
	FIE	Financial institution efficiency	-	*IMF-FD*
	FMA	Financial market access	-	*IMF-FD*
	FMD	Financial market depth	-	*IMF-FD*
	FME	Financial market efficiency	-	*IMF-FD*
	dctps	Financial development	Private sector domestic credit/GDP	*WB-WDIs*

Description: EIA stands for U.S. Energy Information Administration; *WB-WDIs* stands for World Bank Database of World Development Indicators; BP is the World Energy Statistical Yearbook 2020 edition; *IMF-FD* is financial development database under the International Monetary Fund.

industrial structure. In regression models, the ratio was reduced by a factor of 10 in order to give the data a comparable magnitude.

3.2.4. Control variables

We chose five control factors impacting energy intensity based on Chen et al. (2019) and Canh et al. (2020) studies on financial development and energy: trade openness ($Trade_{it}$), degree of industrialization ($Industry_{it}$), economic growth ($ggdp_{it}$), ageing ($Pop65_{it}$) and energy prices ($lnop_{it}$). The volume of trade (total imports and exports of goods and services)/GDP was used to measure trade openness. The degree of industrialization was measured by industrial added value/GDP. Economic growth was expressed by the GDP growth rate. The degree of aging was measured by the population over 65/total population; The logarithm of the price per barrel of WTI (West Texas Intermediate) crude oil was used to measure energy prices.

3.3. Regression model design and explanation

We built an empirical model using energy intensity as the explained variable, financial development as the core explanatory variable, and industrialization, trade openness, aging degree, and energy price as the control factors to investigate the impact of financial development on energy intensity. We introduced the lag period of the energy intensity of explained variables into the model as an explanatory variable to build a dynamic panel data model, because important variables may be omitted in the model or there may be endogeneity caused by correlation between explanatory variables and disturbance terms. Eq. (1) corresponding to the model is listed below:

$$EI_{it} = \alpha_0 + \alpha_1 EI_{i,t-1} + \alpha_2 FD_{it} + \alpha_3 Industry_{it} + \alpha_4 Trade_{it} + \alpha_5 Pop65_{it} + \alpha_6 \ln op_{it} + \alpha_7 ggdp_{it} + \varepsilon_{it} \quad (1)$$

where i and t refer to countries (i = 1,...., 67) and time (t = 1995..., 2018), respectively; α_i represents the coefficient matrix; EI_{it} represents the energy intensity; $EI_{i,\ t-}$ represents the lagged phase term of energy intensity; FD_{it} represents financial development; $Industry_{it}$ represents the industrialization degree; $Trade_{it}$ represents trade openness; $Pop65_{it}$ represents the aging degree; $lnop_{it}$ represents the energy price; and $ggdp_{it}$ represents economic growth,ε_{it}, as the residual term.

Considering that the sample data involves time and cross-sectional dimensions, this paper uses panel data for quantitative analysis. The advantage of panel data is that it can not only overcome the problem of multicollinearity in time series analysis, but also improve more data information. However, panel data often have endogeneity problems. Instrumental variables (IV) are an excellent technique to tackle the endogeneity problem caused by missing variables and causality, however finding adequate instrumental variables is difficult. Therefore, this paper uses the sys-GMM (system generalized moment estimation method) (Blundell and Bond, 1998), which can effectively solve the potential endogeneity problem and weak instrumental variable problem.

4. Empirical result analysis

To make the sys-GMM(system Generalized Method of Moments) model of the dynamic panel two-step system effective, two tests had to be passed: the validity test of the instrumental variable and autocorrelation test of the residual term sequence. For the validity of the instrumental variable, the *Sargan* test was selected as the over-identification constraint test. The *Sargan* test p value was greater than 0.1, indicating that the instrumental variable was legitimate, as shown by the estimation results in Tables 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, and 13. The residual sequence autocorrelation test could be judged by the P value of AR (2), which is provided in Tables 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, and 13. If the P value of AR (2) is greater than 0.1, the residual sequence autocorrelation test has been passed. The regression results in the table meet the requirements, indicating that the sys-GMM (system Generalized Method of Moments) estimation method adopted in this paper is effective and reliable.

4.1. Descriptive statistics of variables

Table 2 shows the descriptive statistical data. It can be seen that the number of cross sections n = 67, and the period T = 24, so n > T. Therefore, the data set used contained short panel data, which could be estimated by using the sys-GMM (system Generalized Method of Moments) model. The table shows the data's mean, standard error, minimum, and maximum values.

From the observation value (*N*), except for a few variables with missing data, the observed value of most variables is 1608. From the mean and median (*P50*) of variables, in addition to several proxy variables of financial development, such as FMA (financial market access), FMD (financial market depth), FME (financial market efficiency), dctps (Private sector domestic credit/GDP), the mean and median of other variables are not much different, indicating that the concentration of the data is high and the development level of the corresponding variables in each country is consistent. In terms of standard errors (*S.d*), the dispersion is low for all variables except the variable dctps (Private sector domestic credit/GDP). To make the data comparable, the variable dctps (Private sector domestic credit/GDP) is scaled down by a factor of 100 in the empirical analysis. From the perspective of the maximum value, the gap between the maximum value and the minimum value of the same variable is still very large, which is closely related to the development of each country. Overall, the descriptive statistics of the data meet the requirements of the system generalized moment estimation method.

4.2. Full-sample regression analysis

Table 3 reports the dynamic panel two-step sys-GMM estimates of financial development for the energy intensity in 67 developing countries from 1995 to 2018. The lag first-order coefficient of energy intensity was significantly positive at 1% level, indicating that the energy intensity of the previous year significantly affects the energy intensity level of the next year. Model (1)–(6) added six financial development indicators to regression model. The findings show that at the 1% level, financial development has a significantly negative impact on energy intensity; that is, improvements in financial institution access, depth, and efficiency, as well as financial market access, depth, and efficiency, can all significantly reduce energy intensity. However, by comparison, it could be found that the impact of indicators from three different dimensions of financial institutions on energy intensity was higher than that of indicators related to

Table 2. Descriptive statistics of variables.

Variable	N	Mean	*P50*	S.d	Min	Max
EI	1608	0.121	0.0780	0.129	0.0150	1.130
ggdp	1604	0.0420	0.0440	0.0410	-0.364	0.352
lnop	1608	0.0380	0.0390	0.00600	0.0270	0.0460
Trade	1590	0.790	0.756	0.354	0.148	2.204
Industry	1595	0.275	0.266	0.0940	0.0130	0.727
Pop65	1608	0.0650	0.0480	0.0440	0.0190	0.210
cyjg	1577	0.204	0.192	0.104	0.0290	0.933
FD	1608	0.240	0.199	0.147	0	0.753
FI	1608	0.329	0.300	0.149	0	0.746
FM	1608	0.142	0.0500	0.179	0	0.732
FIA	1608	0.193	0.134	0.182	0	0.883
FIE	1608	0.221	0.176	0.194	0	0.985
FMA	1608	0.146	0.0280	0.205	0	1
FMD	1608	0.133	0.0210	0.257	0	1
FME	1608	0.143	0.0550	0.185	0	0.854
dctps	1580	37.54	27.34	31.97	0	166.5

Table 3. Regression results of the full sample.

Explained variable: *EI (GMM)*	(1)	(2)	(3)	(4)	(5)	(6)
L.EI	0.8555***	0.8426***	0.8851***	0.8906***	0.8762***	0.8774***
	[0.0008]	[0.0014]	[0.0007]	[0.0007]	[0.0010]	[0.0010]
ggdp	-0.0521***	-0.0535***	-0.0372***	-0.0383***	-0.0411***	-0.0353***
	[0.0012]	[0.0016]	[0.0008]	[0.0008]	[0.0006]	[0.0012]
lnop	-0.6262***	-0.7799***	-0.8041***	-0.8770***	-0.8441***	-0.9017***
	[0.0109]	[0.0277]	[0.0129]	[0.0097]	[0.0097]	[0.0117]
Trade	-0.0029***	-0.0081***	-0.0028***	-0.0023***	-0.0039***	-0.0016***
	[0.0005]	[0.0006]	[0.0005]	[0.0003]	[0.0004]	[0.0004]
Industry	0.0191***	0.0566***	0.0450***	0.0432***	0.0585***	0.0545***
	[0.0016]	[0.0022]	[0.0017]	[0.0010]	[0.0023]	[0.0025]
Pop65	0.5647***	0.4255***	0.2848***	0.2561***	0.3168***	0.2750***
	[0.0035]	[0.0049]	[0.0022]	[0.0026]	[0.0033]	[0.0041]
FIA	-0.0605***					
	[0.0007]					
FID		-0.1483***				
		[0.0013]				
FIE			-0.0252***			
			[0.0005]			
FME				-0.0078***		
				[0.0005]		
FMD					-0.0641***	
					[0.0006]	
FMA						-0.0569***
						[0.0041]
_cons	0.0159***	0.0415***	0.0300***	0.0209***	0.0227***	0.0260***
	[0.0007]	[0.0010]	[0.0006]	[0.0006]	[0.0010]	[0.0008]
Observations	1318	1383	1383	1383	1383	1383
NO of country	67	67	67	67	67	67
NO of IVs	69	71	71	71	71	71
AR (2) test (p-value)	0.5832	0.7584	0.7261	0.7470	0.7010	0.7428
Sargan test (p-value)	0.3757	0.3795	0.4096	0.3684	0.3565	0.3750

Standard errors in brackets,*** 1% ** 5% * 10%,*p < 0.1, **p < 0.05, ***p < 0.01.

financial markets. This is because the development level of financial institutions in developing countries is earlier than that of financial markets, and enterprises mainly rely on indirect financing. The problem of business credit limitations has been alleviated as financial scale has grown. The reduction of financial threshold and the improvement of financial efficiency have enhanced technological investment in research and development. As a result, investment in technology driven by financial development has upgraded the country's economy-wide energy consumption equipment, where energy is used efficiently and production losses are reduced, thereby increasing equipment efficiency and reducing energy intensity. A negative GDP growth coefficient at 1% indicates that economic growth will significantly reduce energy intensity, which is consistent with the empirical results of Chen et al. (2019). The impact of energy price on energy intensity was significantly negative at 1% level, indicating that the increase of energy price will restrain energy consumption and thus reduce energy intensity, which is consistent with the research results of Cornillie and Fankhauser (2004). The greater the trade openness, the lower the energy intensity. At the 1% significance level, the trade openness increased by 1%, and the energy intensity decreased by 0.0016%–0.0081%. The influence coefficient of industrialization degree on energy intensity was significantly positive at 1% level, which is consistent with the reality. Among the primary, secondary and tertiary industries, the secondary industry was energy-intensive, while industry and manufacturing were the pillar industries of the secondary industry, and the heavy industry was a typical energy-consuming industry. The degree of industrialization correspondingly promoted the increase of energy intensity (Sadorsky, 2013). The effect of the aging degree on the energy intensity was significant and positive at the 1% level. This could be due to the elderly's increased energy use after retirement, which had no influence on GDP growth, according to Brounen et al. (2012) and Bardazzi and Pazienza (2017).

4.3. Sample regression analysis

4.3.1. The first grouping

We assume that the impact of financial development on energy intensity varies between high and low oil-consuming countries, so sixty-seven developing countries were divided into two groups according to whether the percentage of oil consumption in primary energy consumption exceeded 50%. The impact of financial development on energy intensity under high and low oil consumption was studied. The amount of oil consumed in each country's main energy consumption from 1995 to 2018 was averaged and divided into categories, with 41 developing countries accounting for more than half of all oil consumption and 26 countries accounting for less than half of all oil consumption.

4.3.1.1. Regression analysis of countries with high oil consumption. Table 4 reports the results of the impact of financial development on energy intensity in high oil consumption countries. The results of model (1)–(6) show that financial institution access, financial institution depth, financial institution efficiency, financial market access, financial market

Table 4. Regression results of countries with high oil consumption.

Explained variable: *EI (GMM)*	(1)	(2)	(3)	(4)	(5)	(6)
L.EI	0.8946***	0.8993***	0.8612***	0.8841***	0.8904***	0.8847***
	[0.0023]	[0.0025]	[0.0031]	[0.0011]	[0.0013]	[0.0013]
FIA	-0.0786***					
	[0.0057]					
FIE		-0.0313***				
		[0.0014]				
FID			-0.2498***			
			[0.0100]			
FMA				-0.0806***		
				[0.0057]		
FME					-0.0042***	
					[0.0011]	
FMD						-0.0725***
						[0.0039]
_cons	0.0514***	0.0650***	0.1010***	0.0605***	0.0567***	0.0584***
	[0.0024]	[0.0033]	[0.0051]	[0.0020]	[0.0022]	[0.0016]
Control variables	YES	YES	YES	YES	YES	YES
Observations	888	848	888	888	888	888
NO of country	41	41	41	41	41	41
NO of IVs	73	71	73	73	73	73
AR (2) test (p-value)	0.4188	0.2917	0.4055	0.3130	0.3780	0.3867
Sargan test (p-value)	0.9951	0.9965	0.9985	0.9946	0.9953	0.9983

Standard errors in brackets,*** 1% ** 5% * 10%,*p < 0.1, **p < 0.05, ***p < 0.01.

depth, and financial market efficiency all significantly reduced energy intensity at the level of 1%. The depth of financial institutions and their efficiency had a greater impact on energy intensity than the depth of financial markets and their efficiency, except that the access of financial institutions had a slightly weaker impact on energy intensity than the access of financial markets, according to the coefficient of variables. Indirect financing mainly by banking is still the main way of enterprise financing. The scale expansion and threshold reduction of financial institutions provide technical support for enterprise technology research and development, transformation, and upgrading.

4.3.1.2. Regression analysis of low oil consumption countries. Table 5 shows the effects of financial development on energy intensity in nations with low oil consumption. Six financial development indicators in

Table 5. Regression results of low oil consumption countries.

Explained variable: *EI (GMM)*	(1)	(2)	(3)	(4)	(5)	(6)
L.EI	0.8515***	0.8839***	0.8517***	0.8283***	0.8658***	0.8652***
	[0.0075]	[0.0079]	[0.0101]	[0.0127]	[0.0087]	[0.0062]
FIA	-0.0470***					
	[0.0050]					
FIE		-0.0311***				
		[0.0037]				
FID			-0.1201***			
			[0.0141]			
FMA				-0.0791***		
				[0.0109]		
FME					-0.0108***	
					[0.0027]	
FMD						-0.0499***
						[0.0083]
_cons	0.0297***	0.0298***	0.0251	0.0646***	0.0542***	0.0308***
	[0.0048]	[0.0112]	[0.0160]	[0.0142]	[0.0082]	[0.0052]
Control variables	YES	YES	YES	YES	YES	YES
Observations	535	535	535	535	560	535
NO of country	26	26	26	26	26	26
NO of IVs	71	71	71	71	73	71
AR (2) test (p-value)	0.5229	0.5388	0.4193	0.4334	0.9469	0.4336
Sargan test (p-value)	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

Standard errors in brackets, *** 1% ** 5% * 10%, *p < 0.1, **p < 0.05, ***p < 0.01.

Table 6. Regression results of low-income countries.

Explained variable: *EI (GMM)*	(1)	(2)	(3)	(4)	(5)	(6)
L.EI	0.8579***	0.8551***	0.7994***	0.8519***	0.8645***	0.8648***
	[0.0016]	[0.0015]	[0.0034]	[0.0032]	[0.0015]	[0.0010]
FIA	-0.0418***					
	[0.0023]					
FIE		-0.0405***				
		[0.0020]				
FID			-0.5513***			
			[0.0203]			
FMA				-0.1443***		
				[0.0121]		
FME					-0.0113**	
					[0.0051]	
FMD						-0.0209***
						[0.0028]
_cons	0.0395***	0.0670***	0.0680***	0.0570***	0.0499***	0.0471***
	[0.0020]	[0.0028]	[0.0062]	[0.0035]	[0.0022]	[0.0024]
Control variables	YES	YES	YES	YES	YES	YES
Observations	617	617	617	617	617	617
NO of country	33	33	33	33	33	33
NO of IVs	67	67	67	67	67	67
AR (2) test (p-value)	0.9306	0.9150	0.9743	0.9175	0.0766	0.9075
Sargan test (p-value)	0.9994	0.9987	0.9998	0.9986	0.9989	0.9999

Standard errors in brackets,*** 1% ** 5% * 10%,*p < 0.1, **p < 0.05, ***p < 0.01.

models (1)–(6) lowered energy intensity significantly, producing a result similar to the high oil-consumption group. Except for the fact that access to financial institutions had a lesser impact on energy intensity than financial market indicators, the other two financial institution indicators had a stronger impact on energy intensity than financial market indicators. In addition, the absolute value of the influence coefficient of financial development indicators on energy intensity in the low oil consumption group is lower than that of the corresponding indicators in the high oil consumption group, indicating that financial development has a higher degree of reducing energy intensity in high oil consumption countries. The reason is that countries with high oil consumption are relatively low in oil consumption. Countries not only have low energy utilization efficiency and unreasonable industrial structure, but also the energy structure is mostly dominated by fossil energy. In countries with

Table 7. Regression results of middle- and high-income countries.

Explained variable: *EI (GMM)*	(1)	(2)	(3)	(4)	(5)	(6)
L.EI	0.8232***	0.8308***	0.8273***	0.7619***	0.7720***	0.8102***
	[0.0064]	[0.0061]	[0.0082]	[0.0099]	[0.0088]	[0.0065]
FIA	-0.0056***					
	[0.0014]					
FIE		-0.0025				
		[0.0019]				
FID			-0.0054**			
			[0.0025]			
FMA				-0.0202***		
				[0.0048]		
FME					-0.0171***	
					[0.0021]	
FMD						-0.0155***
						[0.0030]
_cons	-0.0196***	-0.0241***	-0.0191***	-0.0266***	-0.0296***	-0.0291***
	[0.0021]	[0.0032]	[0.0029]	[0.0031]	[0.0024]	[0.0031]
Control variables	YES	YES	YES	YES	YES	YES
Observations	735	702	735	636	636	669
NO of country	34	34	34	34	34	34
NO of IVs	73	71	73	67	67	69
AR (2) test (p-value)	0.3611	0.5059	0.3637	0.2604	0.2848	0.7630
Sargan test (p-value)	1.0000	0.9999	1.0000	0.9998	0.9996	0.9997

Standard errors in brackets,*** 1% ** 5% * 10%,*p < 0.1, **p < 0.05, ***p < 0.01.

high oil consumption, the various dimensions of financial development play a larger role in driving enterprise transformation and upgrading, as well as research and development of new energy sources. As the largest energy variety, oil consumption represented a high proportion of fossil energy consumption. Financial development, according to empirical findings, might greatly reduce the intensity of fossil energy usage.

4.3.2. The second grouping

We predict that the impact of financial development on energy intensity may differ in nations with varying levels of economic development. Therefore, according to the World Bank's income classification standards for countries around the world in June 2020, this paper divides 67 developing countries into two subsamples, including 34 High-middle-income countries and 33 low-income countries. Classification by income level is helpful to study the different effects of financial development on the energy intensity in countries with different income levels.

4.3.2.1. Analysis of sample regression results of low-income countries.

Table 6 shows the regression results of samples from 33 low-income countries. Table 6 (1)–(6) shows that the impact of six financial development indicators on energy intensity was significantly negative at the 1% level; that is, financial development had a negative impact on the growth in energy intensity in low-income developing nations (Canh et al., 2020). Vigorously developing the financial sector and helping to financially support the real economy can effectively improve energy efficiency and reduce energy consumption per unit of GDP.

4.3.2.2. Analysis of regression results of samples from middle- and high-income countries.

Table 7 shows the regression result of samples from 34 middle- and high-income countries. It can be seen from Table 7 (1)–(6) that financial development had a significantly negative impact on energy intensity in middle- and high-income developing countries. For high-income countries, financial capital was the trigger for the transition from fossil fuels to modern renewable energy, which could effectively reduce energy consumption and improve efficiency (Best, 2017). It can be seen from Tables 6 and 7 that the financial development of low-income countries and middle- and high-income countries will reduce energy intensity from six dimensions, but there are differences in the degree. The influence of the other five financial development indicators on energy intensity is stronger in low-income developing nations than in middle- and high-income developing countries, with the exception of financial market efficiency. The reason may be that the residents of developing countries with low incomes will not buy high-energy consumables because of their low income, and the improvement of financial development will bring convenience to corporate financing, reduce financing costs and diversify corporate risks, so that companies can concentrate on research and development. Improve production technology and reduce energy intensity. Although financial development reduces energy intensity in high-income countries, residents with high income levels will buy high-end products with high energy consumption, such as automobiles and air conditioners (Sadorsky, 2010), reducing the degree of financial development in reducing energy intensity significantly.

4.3.3. The third grouping

In December 2015, countries reached the Paris Climate Agreement in Paris, France, which established the goal of achieving global carbon neutrality. Then, around the time of the 26th United Nations Climate Change Conference (COP26), about 150 countries submitted their updated Nationally Determined Contributions (NDC) and long-term Greenhouse Gas Emission Development Strategies (MCS) for the mid-21st century. Many countries have put forward new commitments detailing their contributions to the global effort to achieve climate goals, such as China's commitment to 'peak carbon' by 2030 and go 'carbon neutral' by 2060, and over 50 countries and the entire EU (European Union) have committed to reaching net-zero emissions (IEA, 2021). According to Net Zero Tracker data records, the samples of two groups of countries were divided into two groups according to whether countries have set carbon neutral, Net Zero or Zero carbon reduction targets and written them into laws or policy studies or issued statements (Hale et al., 2021) to study the impact of financial development on energy intensity under different emission-reduction targets.

Table 8. Regression results of countries with emission-reduction targets and in progress.

Explained variable: *EI (GMM)*	(1)	(2)	(3)	(4)	(5)	(6)
L.EI	0.9008***	0.9183***	0.8639***	0.8935***	0.9287***	0.8950***
	[0.0083]	[0.0096]	[0.0092]	[0.0116]	[0.0091]	[0.0100]
FIA	-0.0269***					
	[0.0023]					
FIE		-0.0131***				
		[0.0029]				
FID			-0.0867***			
			[0.0135]			
FMA				-0.0323***		
				[0.0041]		
FME					-0.0040**	
					[0.0016]	
FMD						-0.0358***
						[0.0042]
_cons	0.0168***	0.0240***	0.0065	0.0143**	0.0162***	0.0126**
	[0.0054]	[0.0053]	[0.0044]	[0.0063]	[0.0059]	[0.0060]
Control variables	YES	YES	YES	YES	YES	YES
Observations	599	627	599	599	627	627
NO of country	30	30	30	30	30	30
NO of IVs	71	73	71	71	73	73
AR (2) test (p-value)	0.5121	0.5852	0.5381	0.4746	0.5651	0.5586
Sargan test (p-value)	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

Standard errors in brackets,*** 1% ** 5% * 10%,*p < 0.1, **p < 0.05, ***p < 0.01.

Table 9. Regression results of countries without emission-reduction targets.

Explained variable: *EI (GMM)*	(1)	(2)	(3)	(4)	(5)	(6)
L.EI	0.8877***	0.8855***	0.8685***	0.8865***	0.8902***	0.8899***
	[0.0017]	[0.0017]	[0.0020]	[0.0019]	[0.0017]	[0.0017]
FIA	-0.0171***					
	[0.0013]					
FIE		-0.0209***				
		[0.0009]				
FID			-0.0990***			
			[0.0052]			
FMA				-0.0396***		
				[0.0107]		
FME					-0.0066***	
					[0.0007]	
FMD						-0.0147***
						[0.0024]
_cons	0.0181***	0.0265***	0.0293***	0.0212***	0.0196***	0.0192***
	[0.0015]	[0.0027]	[0.0044]	[0.0025]	[0.0020]	[0.0023]
Control variables	YES	YES	YES	YES	YES	YES
Observations	763	763	763	763	763	763
NO of country	37	37	37	37	37	37
NO of IVs	71	71	71	71	71	71
AR (2) test (p-value)	0.5048	0.5552	0.5199	0.5048	0.5002	0.5057
Sargan test (p-value)	0.9984	0.9990	0.9991	0.9992	0.9985	0.9988

Standard errors in brackets,*** 1% ** 5% * 10%,*p < 0.1, **p < 0.05, ***p < 0.01.

Table 10. Regression results of countries in the rising stage.

Explained variable: *EI (GMM)*	(1)	(2)	(3)	(4)	(5)	(6)
L.EI	0.8780***	0.8739***	0.8398***	0.8589***	0.8743***	0.8761***
	[0.0029]	[0.0033]	[0.0032]	[0.0023]	[0.0022]	[0.0026]
FIA	-0.0069***					
	[0.0023]					
FIE		-0.0137***				
		[0.0026]				
FID			-0.2076***			
			[0.0119]			
FMA				-0.0697***		
				[0.0064]		
FME					-0.0064***	
					[0.0014]	
FMD						-0.0551***
						[0.0049]
_cons	0.1109***	0.1163***	0.1197***	0.1056***	0.1122***	0.1021***
	[0.0025]	[0.0033]	[0.0048]	[0.0024]	[0.0029]	[0.0035]
Control variables	YES	YES	YES	YES	YES	YES
Observations	770	770	808	770	770	808
NO of country	39	39	39	39	39	39
NO of IVs	71	69	69	71	69	69
AR (2) test (p-value)	0.6913	0.4574	0.4422	0.6828	0.4684	0.4614
Sargan test (p-value)	0.9989	0.9984	0.9939	0.9986	0.9983	0.9987

Standard errors in brackets,*** 1% ** 5% * 10%,*p < 0.1, **p < 0.05, ***p < 0.01.

4.3.3.1. Regression analysis of countries with emission reduction targets and in progress. In countries with emission reduction targets, Table 8 shows the influence of continued financial development on energy intensity. Financial development indicators of different dimensions were successively added into model (1)–(6). The results show that both the three dimensions of financial institutions and the three dimensions of the financial market had a role in reducing energy intensity to varying degrees.

4.3.3.2. Regression analysis of countries without emission reduction targets. Table 9 reports the regression results of the impact of financial development on energy intensity in countries without emission reduction

Table 11. Regression results of countries in the declining stage.

Explained variable: *EI (GMM)*	(1)	(2)	(3)	(4)	(5)	(6)
L.EI	0.8677***	0.8785***	0.8784***	0.8629***	0.8783***	0.8584***
	[0.0075]	[0.0067]	[0.0075]	[0.0085]	[0.0060]	[0.0087]
FIA	-0.0087*					
	[0.0047]					
FIE		-0.0169***				
		[0.0022]				
FID			-0.0041			
			[0.0053]			
FMA				-0.0080*		
				[0.0044]		
FME					-0.0047***	
					[0.0008]	
FMD						-0.0033
						[0.0036]
_cons	0.0120**	0.0103**	0.0073	0.0185***	0.0087***	0.0211***
	[0.0049]	[0.0045]	[0.0046]	[0.0056]	[0.0034]	[0.0058]
Control variables	YES	YES	YES	YES	YES	YES
Observations	575	575	575	629	575	602
NO of country	28	28	28	28	28	28
NO of IVs	71	71	71	73	71	73
AR (2) test (p-value)	0.9552	0.8836	0.9593	0.4852	0.9590	0.4819
Sargan test (p-value)	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

Standard errors in brackets,*** 1% ** 5% * 10%,*p < 0.1, **p < 0.05, ***p < 0.01.

targets. Different financial development variables were gradually added to models (1)–(6), with the findings showing that financial development lowered energy intensity significantly. From the regression results in Tables 8 and 9, it can be seen that the financial development of countries with emission reduction targets and in progress and countries without emission reduction targets will reduce energy intensity, but there is no significant difference in the extent to which financial development reduces energy intensity, we believe that this is related to the time when various countries implement energy-saving emission reduction measures. The Paris Agreement in 2015 put forward emission reduction requirements for countries around the world, and the time for each country to issue emission reduction announcements and take measures is basically after 2020 (Hale et al., 2021). As a result, the financial development of nations with emission reduction targets has a bigger impact on energy

Table 12. Regression results of countries with a low financial development level.

Explained variable: *EI (GMM)*	(1)	(2)	(3)	(4)	(5)	(6)
L.EI	0.9030***	0.9054***	0.8880***	0.9068***	0.9089***	0.8927***
	[0.0015]	[0.0014]	[0.0017]	[0.0014]	[0.0017]	[0.0024]
FIA	-0.0453***					
	[0.0021]					
FIE		-0.0179***				
		[0.0009]				
FID			-0.2100***			
			[0.0100]			
FMA				-0.1565***		
				[0.0058]		
FME					-0.0542**	
					[0.0250]	
FMD						-0.0124
						[0.0089]
_cons	0.0390***	0.0488***	0.0580***	0.0383***	0.0394***	0.0631***
	[0.0019]	[0.0025]	[0.0029]	[0.0020]	[0.0023]	[0.0037]
Control variables	YES	YES	YES	YES	YES	YES
Observations	702	702	702	702	702	735
NO of country	33	33	33	33	33	33
NO of IVs	71	71	71	71	71	73
AR (2) test (p-value)	0.5943	0.6175	0.6262	0.6030	0.5989	0.9492
Sargan test (p-value)	0.9998	0.9996	0.9998	0.9999	0.9997	0.9996

Standard errors in brackets, *** 1% ** 5% * 10%, *p < 0.1, **p < 0.05, ***p < 0.01.

Table 13. Regression results of countries with a high financial development level.

Explained variable: *EI (GMM)*	(1)	(2)	(3)	(4)	(5)	(6)
L.EI	0.8845***	0.8843***	0.8719***	0.8622***	0.8800***	0.8817***
	[0.0067]	[0.0075]	[0.0114]	[0.0058]	[0.0116]	[0.0096]
FIA	-0.0001					
	[0.0024]					
FIE		-0.0057**				
		[0.0023]				
FID			-0.0186***			
			[0.0038]			
FMA				-0.0214***		
				[0.0024]		
FME					-0.0078***	
					[0.0008]	
FMD						-0.0176***
						[0.0016]
_cons	-0.0208***	-0.0155***	-0.0121**	-0.0132***	-0.0176***	-0.0207***
	[0.0025]	[0.0017]	[0.0049]	[0.0039]	[0.0054]	[0.0025]
Control variables	YES	YES	YES	YES	YES	YES
Observations	681	713	713	681	681	681
NO of country	34	34	34	34	34	34
NO of IVs	71	73	73	71	71	71
AR (2) test (p-value)	0.3848	0.3927	0.3900	0.3586	0.4408	0.3771
Sargan test (p-value)	1.0000	1.0000	1.0000	1.0000	1.0000	0.9999

Standard errors in brackets,*** 1% ** 5% * 10%,*p < 0.1, **p < 0.05, ***p < 0.01.

intensity than countries without emission reduction targets, according to the empirical regression results.

4.3.4. The fourth grouping

We presumed that there might be differences in the impact of financial development on energy intensity in countries where energy consumption is still rising versus countries where energy consumption is beginning to decline, so we divided 67 developing countries into two groups based on whether primary energy consumption is increasing or decreasing, and the impact of financial development on energy intensity was investigated. Grouped according to the trend of primary energy consumption over time from 1995 to 2018, 39 countries were still on the rise in primary energy consumption, while 28 countries were on the decline.

4.3.4.1. Analysis of regression results of countries in the rising stage. The regression results of the impact of financial development on energy intensity in rising countries are presented in Table 10. Financial development indicators were gradually added to models (1)–(6), with the findings indicating that financial development would lower energy intensity significantly.

4.3.4.2. Analysis of national regression results in the declining stage.- Table 11 reports the regression results of the impact of financial development on energy intensity in declining countries. Financial development indicators of various dimensions were sequentially added to models (1)–(6), with the findings indicating that at the 1% level, financial development would dramatically reduce energy intensity. Financial development has both contributed to the lowering of energy intensity in developing countries with rising energy consumption and developing countries with dropping energy consumption, according to the regression results in Tables 10 and 11, but the difference is not significant.

4.3.5. The fifth grouping

In the full sample regression, all six financial development indicators significantly reduced energy intensity. In order to investigate the impact of different degrees of financial development on energy intensity, 67 developing countries were separated into high- and low-level financial development countries. The use of the sys-GMM (system Generalized Method of Moments) model must be a long panel. Thus, the overall financial development indicators of 67 developing countries from 1995 to 2018 were ranked by means, and the countries were divided into 33 low-level financial development countries and 34 high-level financial development countries from the middle value.

Table 14. Regression results of a full sample.

Explained variable: *EI (GMM)*	(1)	(2)	(3)	(4)
L.EI	0.8187***	0.8179***	0.8763***	0.8813***
	[0.0024]	[0.0020]	[0.0010]	[0.0010]
FD	-0.1916***			
	[0.0037]			
FI		-0.1597***		
		[0.0027]		
FM			-0.0727***	
			[0.0011]	
dctps				-0.0355***
				[0.0006]
_cons	0.0421***	0.0439***	0.0265***	0.0180***
	[0.0014]	[0.0008]	[0.0006]	[0.0007]
Control variables	YES	YES	YES	YES
Observations	1318	1318	1383	1362
NO of country	67	67	67	67
NO of IVs	69	69	71	71
AR (2) test (p-value)	0.5985	0.5470	0.7331	0.3601
Sargan test (p-value)	0.3864	0.3425	0.3857	0.4174

Standard errors in brackets, *** 1% ** 5% * 10%, *p < 0.1, **p < 0.05, ***p < 0.01.

Table 15. Regression results of the income group.

Explained variable: *EI (GMM)*	(1)	(2)	(3)	(4)
Low-income countries				
L.EI	0.8085***	0.8325***	0.8010***	0.8278***
	[0.0067]	[0.0064]	[0.0060]	[0.0059]
FD	-0.0300***			
	[0.0050]			
FI		-0.0072***		
		[0.0026]		
FM			-0.0361***	
			[0.0023]	
dctps				-0.0081***
				[0.0012]
_cons	-0.0280***	-0.0240***	-0.0282***	-0.0223***
	[0.0038]	[0.0030]	[0.0033]	[0.0032]
Control variables	YES	YES	YES	YES
Observations	669	702	669	696
NO of country	34	34	34	34
NO of IVs	69	71	69	71
AR (2) test (p-value)	0.7976	0.4983	0.7542	0.5035
Sargan test (p-value)	0.9997	0.9999	0.9996	0.9999
Middle- and high-income countries				
L.EI	0.8301***	0.8359***	0.8589***	0.9188***
	[0.0038]	[0.0021]	[0.0013]	[0.0014]
FD	-0.2495***			
	[0.0116]			
FI		-0.1412***		
		[0.0052]		
FM			-0.0629***	
			[0.0092]	
dctps				-0.0285***
				[0.0028]
_cons	0.0591***	0.0581***	0.0526***	0.0407***
	[0.0069]	[0.0031]	[0.0031]	[0.0026]
Control variables	YES	YES	YES	YES
Observations	617	617	617	666
NO of country	33	33	33	33
NO of IVs	67	67	67	71
AR (2) test (p-value)	0.9674	0.9526	0.9234	0.5300
Sargan test (p-value)	0.9998	0.9987	0.9990	0.9996

Standard errors in brackets, *** 1% ** 5% * 10%, *p < 0.1, **p < 0.05, ***p < 0.01.

4.3.5.1. Regression analysis of countries with low level of financial development. Table 12 reports the regression results of low-level financial development on energy intensity. Models (1)–(6) were successively added with different financial development indicators, and the results show that financial development indicators of different dimensions consistently reduced energy intensity, which was significant at the 1% level.

4.3.5.2. Regression analysis of countries with high level of financial development. Table 13 reports high levels of financial development of the country's financial development impact on the energy intensity results of regression models (1)–(6) in order to join the different dimensions of financial development indicators. The findings reveal that financial institution access, financial institution, depth, financial institution efficiency, financial market access, financial market depth, and financial market efficiency all lowered energy intensity to varying degrees. When compared to the influence of financial development on energy intensity in countries with a low level of financial development, nations with a higher level of financial development lowered energy intensity to a lesser extent.

4.4. Robustness test

4.4.1. Core explanatory variables replaced by full samples

In order to verify the robustness of the benchmark regression results in this paper, the core explanatory variables were replaced by financial institution indicators, financial market indicators, overall financial development indicators, and the domestic credit of the private sector to represent financial development. Table 14 displays the results. The overall financial development index is modeled as a function of energy intensity in Model (1); Model (2) is the regression of the financial institution index to energy intensity; Model (3) is the regression of the financial market index to energy intensity. Model (4) is the regression of the private sector domestic credit to energy intensity. When compared to Table 3, it can be seen that the significance and symbol of the impact of

Table 16. Interaction effect model estimation results.

Explained variable: *EI (GMM)*	(1)	(2)	(3)	(4)
L.EI	0.8528***	0.8564***	0.8721***	0.8765***
	[0.0010]	[0.0009]	[0.0008]	[0.0006]
cyjg	-0.0688***	-0.0520***	-0.0898***	-0.0469***
	[0.0049]	[0.0024]	[0.0030]	[0.0014]
FD	-0.1391***			
	[0.0030]			
cyjg×FD	**-0.2260*** **			
	[0.0287]			
FI		-0.1079***		
		[0.0028]		
cyjg×FI		**-0.0843*** **		
		[0.0169]		
FM			-0.0750***	
			[0.0031]	
cyjg×FM			**-0.2935*** **	
			[0.0236]	
dctps				-0.0357***
				[0.0006]
cyjg×dctps				**-0.0795*** **
				[0.0096]
_cons	0.0549***	0.0499***	0.0513***	0.0315***
	[0.0019]	[0.0011]	[0.0010]	[0.0004]
Control variables	YES	YES	YES	YES
Observations	1369	1369	1369	1349
NO of country	67	67	67	67
NO of IVs	73	73	73	73
AR (2) test (p-value)	0.4552	0.4487	0.4748	0.3613
Sargan test (p-value)	0.4452	0.4320	0.3812	0.4306

Standard errors in brackets, *** 1% ** 5% * 10%, *p < 0.1, **p < 0.05, ***p < 0.01.

financial development on energy intensity have not changed, showing that the study conclusion of this paper is robust.

4.4.2. Core explanatory variables replaced by income components

The income component sample was examined for robustness in order to assess the robustness of the research conclusions and to eliminate measurement bias. Table 15 shows that the regression results in Tables 6 and 7 are consistent, and the results are robust. When studying emerging economies and developing countries, divided them into two groups: high-income and low-income, and found that financial development, whether measured by a banking index or a stock market index, had a positive impact on energy consumption, which contradicted the findings of this study.

4.5. Analysis of the impact mechanism of financial development on energy intensity

The p value of AR (2) is reported in Table 16. The results revealed that the residual term had no second-order autocorrelation issues. The *Sargan* test was also utilized in this study to see if the instrumental variables in the model were over-identified. Sargan statistics had all p-values greater than 0.1, indicating that the null hypothesis "all instrumental variables are valid" could not be rejected. The above test results demonstrate the rationality of model setting and the validity of instrumental variables.

Table 16 (1)–(4) reports the regression results of the cross-product between different financial development indicators and industrial structure upgrading. Model (1) is the regression results after the overall financial development and industrial structure upgrading. Model (2) is The regression results after the intersection of financial institution indicators and industrial structure upgrades, model (3) is the regression results after the intersection of financial market indicators and industrial structure upgrades, and model (4) is the intersection of private sector domestic credit indicators and industrial structure upgrades. later regression results. The entire financial development of model (1) has the highest impact on energy intensity, highlighting the importance of comprehensive financial development, according to the regression coefficient. Furthermore, the influence of financial development combined with industrial structure upgrading on energy intensity has increased, implying that a one-unit increase in financial development will reduce energy intensity by a bigger amount with the blessing of industrial structure upgrading. On the whole, the regression coefficients of all the multiplication terms of models (1)–(4) are -0.2260, -0.0843, -0.2935, -0.0795, and the coefficient signs are all negative signs, which are consistent with the regression coefficient signs of each financial development indicator. Consistent, indicating that all financial development indicators and industrial structure upgrading interaction coefficients are significantly negative at the 1% level, that is, industrial structure upgrading has a role in promoting financial development and reducing energy intensity. On the one hand, one of the ways to upgrade the industrial structure is to reduce the proportion of the secondary industry and increase the proportion of the tertiary industry. The tertiary industry is mostly industries with low energy consumption such as service industry and commerce, while the secondary industry is mostly heavy industry with high energy consumption. Accelerating the optimization of industrial structure and vigorously developing the tertiary industry has promoted financial development and reduced energy intensity. On the other hand, the upgrading of industrial structure can also be implemented by eliminating backward enterprises with high energy consumption, high pollution and low efficiency, and vigorously developing emerging industries with high efficiency, environmental protection and greenness. The upgrading of the industrial structure has opened a fast channel for financial development to reduce energy intensity.

5. Conclusions and implications

5.1. Conclusions

The impact of financial development on energy intensity was examined using panel data from 67 developing nations from 1995 to 2018. The two-step GMM estimation method was utilized to overcome the endogeneity problem and make the regression more believable. The empirical findings reveal that financial development indicators across six categories had a significant impact on energy intensity reduction. When other financial development variables were used to replace the main regression financial development indicators for robust regression, the results were still significant. Therefore, economic growth, lower energy prices, and greater openness to trade will significantly reduce energy intensity, while greater industrialization and an ageing population will increase it. The finding that financial development reduces energy intensity is remains convincing when grouping and regression by nation, that is, grouping 67 developing countries from various perspectives.

In addition, to investigate the influence mechanism of financial development on energy intensity, industrial structure upgrading was used as an interacting variable. It was found that upgrading industrial structure could promote financial development and reduce energy intensity.

5.2. Implications

Four policy recommendations are provided based on the preceding empirical findings. First, we should improve the level of financial development from two aspects: financial institutions and financial markets. From the aspects of financial access to increase the number of financial institutions, reduce financial barriers to entry, develop financial

support of renewable energy, develop green finance, and implement green credit, green bonds, green insurance, and green fund financial instruments, small and medium-sized enterprises should be enabled through direct financing and indirect financing to raise money. At the same time, efforts should be made in regard to financial depth and financial efficiency. We should not only expand the scale of financial development, but also adjust the financial structure, improve financial efficiency, actively promote the development of financial markets and green innovation of financial products, strictly control credit input to industries with a high energy consumption and low output, and accelerate the pace of credit withdrawal of backward production capacity.

Second, financial development can provide financial support for the transformation and upgrading of low-end inefficient enterprises, as well as for enterprises to carry out scientific research and realize technological innovation. Promoting financial efficiency, stock market expansion, and credit market reform will reduce borrowing and financing costs in the public and private sectors, and can indirectly support the development of renewable energy by introducing advanced energy-saving technologies into energy-intensive sectors through more efficient and cheaper financing opportunities. The upgrading of energy use structure and the release of energy-saving potential will promote the continuous improvement of energy use efficiency (Wang et al., 2020).

Third, we should accelerate the industrial structure optimization and adjustment. The ratio of the third industry and secondary industry output value is a measure of the upgrading of industrial structure contained in the financial industry. Because the financial industry is included in the secondary industry, we should focus on its core development when upgrading the industrial structure. Additionally, we should encourage the healthy and orderly transition and upgrading of industrial structures, and emphasize the role of industrial structure upgrading in lowering the energy intensity of financial development.

Fourth, we should open up more to the outside world, actively introduce foreign advanced technology, and speed up the upgrade of energy consumption equipment. We should view low-energy-consumption products as an important standard of imported raw materials, pay attention to the manufacturing industry's division of labor, collaborate with each another, and make efforts to accomplish the aim of "double carbon" and sustainable development as we open up. In addition, governments can enact carbon tax policies to force the green transformation of industries so that public utilities, businesses, and individuals can reduce the use of fossil fuels and increase the use of clean energy, contributing to the goal of net-zero emissions by 2050.

Declarations

Author contribution statement

Yu Ma: Conceived and designed the experiments; Analyzed and interpreted the data.

Yingying Zhao : Performed the experiments; Analyzed and interpreted the data; Wrote the paper.

Rong Jia: Analyzed and interpreted the data.

Wenxuan Wang: Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data.

Bo Zhang: Conceived and designed the experiments; Wrote the paper.

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The authors declare no conflict of interest.

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