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RESEARCH ARTICLE

The interrelationships among financial development, economic growth and environmental sustainability: evidence from Ghana

Hamdiyah Alhassan[1,2] · **Paul Adjei Kwakwa**[3] · **Samuel Arkoh Donkoh**[1]

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Abstract

A well established and developed financial system encourages savings and investment which stimulates economic growth. However, the link between financial development and the environment is ambiguous. In general, the role that the environment plays in the finance-growth nexus has received less attention, to the best of our knowledge. Against this backdrop, this study aims to examine the interrelationships among economic growth, financial development and carbon dioxide emissions for Ghana over the period of 1971–2018. To correct for a possible endogeneity problem, the three-stage least-square (3SLS) technique was employed. The results revealed that there is a bidirectional relationship between financial development and economic growth; and a unidirectional relationship from financial development to carbon dioxide emission. However, carbon dioxide emission has a neutral effect on economic growth and financial development. Economic growth exhibits an inverted U-shaped relationship with carbon dioxide emission, confirming the existence of the environmental Kuznets curve hypothesis in Ghana. Policymakers should consider the critical roles of financial development in achieving environmentally friendly growth in Ghana.

Keywords Economic growth · Environmental sustainability · Financial development · Three-stage least-square · EKC hypothesis · Ghana

Introduction

For over two decades now, there has been intense discussion on the relationship between economic activities and environmental quality or sustainability. It has been argued that economic activities thrive on the environment. However, the overreliance on the environment or the pressure on the environment as a result of economic activities negatively affects the quality of the environment (Aboagye 2017; Dogan and Inglesi-Lotz 2020; Kwakwa 2019). The notion behind the (earlier) discussion has been to ensure that there is a balance between economic activities and the environment. In effect, it is important to maintain the quality of the environment while pursuing economic growth agenda; otherwise, environmental deterioration may jeopardise such agenda eventually (Adom et al. 2018; Gao et al. 2021). Inspired by this argument, some studies empirically examined the nexus between economic growth and carbon dioxide (CO_2) emission. Certain works sought to test whether there exists a one-way causality or feedback causality or no causal relationship between economic growth and carbon dioxide emission (Salahuddin et al. 2015; Adom et al. 2012; Mensah 2014; Appiah 2018). The findings from these studies have been conflicting making it difficult to reach a meaningful conclusion which gives room for further studies.

In addition, the sustainable development goals (SDGs) or agenda 2030 agreed upon by world leaders has intensified the discussion on the economic growth and environment connection. The SDGs seeks to among others end

Responsible Editor: Nicholas Apergis

✉ Paul Adjei Kwakwa
Pauladkwa@yahoo.com

Hamdiyah Alhassan
Abena567@yahoo.co.uk; ahamdiyah@uds.edu.gh

Samuel Arkoh Donkoh
sdonkoh@uds.edu.gh

[1] School of Applied Economics and Management Sciences, University for Development Studies, Tamale, Ghana

[2] Kazuhiko Takeuchi Centre for Sustainability and Resilience, University for Development Studies, Tamale, Ghana

[3] School of Management Sciences and Law, University of Energy and Natural Resources, Sunyani, Ghana

poverty while protecting the earth for future generations. To realise this, there is the need to ensure cleaner production and consumption so as not to destroy the environment. Thus, the debate around some of the goals of the SDGs, for instance, goal 13 details that environmental pollution such as emission of greenhouse gases leads to global warming and climate change which affects economic activities of developing countries like Ghana. Some have therefore emphasized that sub-Saharan African (SSA) countries will suffer more from climate change effect since the economies in the subregion are very much dependent on the environment for their economic activities (Alhassan et al. 2019; Chilunjika and Gumede 2021; Kogo et al. 2021).

Since agenda 2030 requires efforts by all countries, concrete efforts have been made by countries to ensure that these goals are reached. To make the agenda 2030 a reality, there is a consensus that finance is critical and thus financial development should be given critical attention (United Nations 2020). This goes to suggest that financial development will be needed for economic growth to end poverty, reduce hunger and reduce environmental degradation by ensuring there are sustainable cities and communities as well as responsible production and consumption. This is on the grounds that financial development is associated with easy access to funds that may help firms to be productive thereby enabling countries to achieve their growth agenda. In addition, through credit availability, financial development facilitates technological innovation that ultimately ensures that production and consumption activities by firms and households are efficient thereby leading to cleaner environment (Kwakwa 2021; Tahir et al. 2021; Gokmenoglu et al. 2021).

Indeed prior to the SDGs, there had been contestable notion regarding the financial development and economic growth connection since the early part of the twentieth century. There was the school of thought that said economic growth was responsible for financial development while another school of thought stood by the opposite. As indicated earlier, financial development drives economic growth by making funds readily available for firms' production (Schumpeter 1911; King and Levine 1993). Economic growth on the other hand can stimulate financial development via households and firms demands for financial products/services (Ehigiamusoe 2021). Empirical studies have given credence to both arguments (Kouki and Harrathi 2013; Menyari 2019; Odhiambo 2007; Gozgor 2015). Others then suspected that the relationship between the two may be affected by other variables and indeed their analysis suggested that institutional quality and real sector have a role to play when it comes to the relationship between the two (Ali et al. 2016). The possibility of environmental quality or otherwise influencing the financial development-growth nexus is yet to be explored empirically although the literature suggests such a possibility (Adom et al. 2012; Al-Mulali et al. 2015).

Literature shows studies have examined the effect financial development has on economic growth (Ho and Iyke 2020; Adu et al. 2013; Cheng et al. 2021; Purewal and Haini 2021; Fakher et al. 2021; Hussain et al. 2021; Usman et al. 2021) and environmental degradation (Nwani 2021a; Kwakwa 2021; Ntow-Gyamfi et al. 2020; Adom et al. 2018; Kihombo et al. 2021a) while others have explored the effect of economic growth on financial development (Adom 2019; Song et al. 2021) and environmental degradation (Asiedu et al. 2021; Alhassan 2021; Kwakwa 2021; Muhammad et al. 2021; Kirikkaleli 2020). The outcome from the empirical studies, majority of which has focused outside Africa, has been mixed making it difficult to arrive at a consensus for policy formulation. Moreover, these studies have focused on different countries and regions making it difficult to also generalise the causality among the variables for a particular country. What seems to have been ignored by extant studies is that even though causality analysis have in many cases found among other things a causality from carbon dioxide emission to financial development and growth (Adom et al. 2012; Farhani and Ozturk 2015; Al-Mulali et al. 2015; Kwakwa 2021), regression analyses have concentrated on the carbon dioxide (CO_2) emission effect of economic growth and the level of financial development. This also has left a gap regarding the empirical analysis of the effect that carbon emission may also have on economic growth and financial development. How can CO_2 emission affect economic growth and financial development? Since CO_2 emission is associated with global warming and climate change, it may affect the agricultural sector and other sectors that rely on the natural environment negatively. This is expected to hamper economic growth. The deterioration of the environment through CO_2 emission has the tendency of reducing the vibrancy of the financial sector since business activities that have borrowed from financial institutions may be adversely affected by environmental destruction. Also, Carse (2000) has noted that the rising concern for cleaner environment has implications on financial sectors. He argued that banks and other financial institutions are exposed to credit risk, legal risk and reputation risk as a result of environmental pollution which can negatively affect banks and other financial institutions. According to Carse (2000), environmental credit risk occurs when "banks are lending to customers whose businesses are adversely affected by the costs of cleaning up pollution or by changes in environmental regulations." Banks may also find themselves directly affected if they find that the value of the property that they have taken as collateral is impaired by contamination. The legal risk affects the financial sector when banks are slapped with financial damages when they flout relevant environmental laws including lending to a company or project which causes environmental problems and taking possession of contaminated or pollution-causing property as

a result of releasing security. Reputation risk may arise "if banks are seen as associated with large-scale projects that are viewed as socially or environmentally damaging, such as dam projects." On the other hand, Carse mooted that financial institutions can take advantage of the concern for environmental protection and grow by lending to firms that ought to embark on clean production and also issue green investment product to the general public.

The implication of the conflicting results mentioned earlier and the little to no evidence regarding the effect that carbon dioxide emission has on economic growth and financial development is that developing countries like Ghana are not in a position to rely on the existing empirical studies to make an informed decision. Since the 1980s, reforms in Ghana's financial sector have seen the financial sector of the country grow. Economic growth has also been impressive alongside higher carbon emissions over the years. The similar trend seen among the variables suggests that the variables may influence one another. Since there is no certainty of the direction of the effect regarding the nexus among the variables (carbon dioxide mission, development of the financial sector and economic growth), using Ghana's data to investigate the situation is crucial to guide policy formulation towards the promotion of growth, financial development and quality environment. However, existing studies on Ghana are yet to assess the interrelationship among the three variables. The study therefore assesses the interrelationship among carbon dioxide emission, financial development and economic growth in Ghana.

Key contributions to the literature from this study are that it adds to the relatively fewer studies on the drivers of carbon dioxide emission that have focused on sub-Saharan African countries. The second is that it is among the few studies to have examined how economic growth and financial development affect each other. Third, it is the first study to empirically test the direction of effect that carbon dioxide emission has on economic growth and financial development. Fourth, this study simultaneously through three-stage least-squares regression analysis assesses the connection among carbon emission, financial development and economic growth.

In the remaining part of the work, the "Brief review of related literature" section presents the literature review, the methodological issues are presented in the "Methodology" section, the "Results and discussions" section is dedicated to the presentation and discussion of results, and the "Conclusion and policy implications" section gives the conclusion of the work and offers policy recommendations.

Brief review of related literature

Determinants of economic growth

Achieving higher economic growth has become one of the leading priorities of every government (Kwakwa et al. 2021). This is because higher economic growth has the potential to transform the lives of the citizens of the country. Theories have been advanced to explain the differences in economic growth among countries (Dieebolt and Perrin 2016; Piętak 2014). Empirical analysis to ascertain growth differences has revealed a number of factors that determine economic growth. Thus, beyond the traditional capital and labour, it has emerged that education, natural resources, energy, foreign aid, trade openness, debt and financial development are quintessential for growth (Kwakwa et al. 2021). For instance, education is essential for economic growth by building human capacity for production (Manca 2012); financial development provides firms with credit facilities (Schumpeter 1911); trade facilitates the transfer of technology (Asiedu et al. 2021) and energy empowers machines for production (Hu et al. 2021). The evidences have been mixed. However, among sub-Saharan African countries, Gabriel and David (2021) established that trade increases economic growth while Yanikkaya (2003) found the opposite. While financial development was found to propel growth in emerging markets (Raghutla and Chittedi 2021), it was reported to reduce economic growth in Latin American countries (Gregorio and Guidotti 1995). Also, Azam and Feng (2021) found foreign aid to increase growth in developing countries but Nwani (2021b) found the opposite for South Asia and sub-Saharan Africa.

Discussions are made on the negative effect that environmental degradation such as carbon emissions has on economic activities (Di Falco et al. 2011; Rehman et al. 2021; Khan et al. 2021). However, regardless of the many factors that have been considered in the growth literature, the possible effect of carbon dioxide emission on economic growth has not been given much empirical attention. Similarly, growth studies in Ghana are growing (Adu 2013; Anaman and Osei-Amponsah 2007; Bonga-Bonga and Ahiakpor 2016; Alagidede and Muazu 2017). However, an estimation of the effect that carbon dioxide emission has on growth is yet to be given attention. Focusing on how carbon dioxide emission affects the country's economic growth will be helpful going into the future.

Determining factors of carbon dioxide emissions

The environmental degradation effect of greenhouse gases (GHGs) has been documented in the literature. Since carbon dioxide emission contributes a greater proportion of GHGs, there has been much focus on effort to reduce its emission. The discussion on the determinants of carbon dioxide emission usually has started with income or economic growth. Based on the environmental Kuznets curve (EKC) hypothesis, an expansion in economic activities puts pressure on the environment through energy consumption which increases carbon dioxide emission. However, at

a higher level of income, citizens of a country can afford energy-efficient equipment; they also demand for a cleaner environment which leads to lower carbon dioxide emission (Alhassan 2021). The plethora of studies to test this hypothesis have generated mixed outcomes (Gao et al. 2021; Dogan and Inglesi-Lotz 2020; Kihombo et al. 2021b).

Other variables noted to influence the level of carbon dioxide emissions are financial development. There are both arguments for and against financial development as a means of controlling the level of carbon dioxide. Financial development can increase carbon dioxide emission when cheaper access to credit increases energy consumption but decreases carbon dioxide emission when cheaper access to credit reduces energy consumption through the purchase of energy-efficient equipment. The empirical evidence provided by Raza et al. (2020), Adom et al. (2018) and Kwakwa (2021) supported the carbon dioxide emission increasing effect of financial development while Maji et al. (2017) and Lahiani (2020) among others reported the opposite effect.

Population pressure such as urbanization has often been mentioned in the literature to increase carbon dioxide emission since it is associated with heavy traffic congestion and clearance of forest covers. This has been confirmed in the works of Kwakwa and Alhassan (2018) and Amuakwa-Mensah and Adom (2017). Energy consumption is critical for economic growth. However, more consumption emits CO_2 emission which has been confirmed by Aboagye (2017) and Kwakwa et al. (2014).

Determining factors of financial development

Financial development has received the attention of researchers over the years because of the crucial role it plays in the growth and development process of an economy. Many economic factors including economic growth, trade openness and inflation have been mentioned to influence the level of financial development. An increase in economic growth is associated with demand for financial products thereby leading to an increase in financial development (Ehigiamusoe et al. 2019). Empirically, this has been confirmed by Adom (2019).

While inflation reduces financial development because it often leads to inefficient allocation of financial resource (Naceur et al. 2014), trade openness through the attraction of foreign investors increases financial development (Cohen 2007). The works of Kim et al (2010) confirmed inflation negatively affects the development of the financial sector while Huang and Temple (2005) confirmed the positive effect of trade. In the wake of combating global warming and climate change, Carse (2000) has indicated that financial institutions can benefit from this quest to reduce carbon emission by increasing their lending activities to firms that are into the production of green technologies. On the other hand, Carse (2000) stated that carbon dioxide emissions may reduce financial development through a number of risks associated with the credit that financial institutions give out to firms that may engage in environmentally damaging activities. The empirical evidence from regression analysis to assess this claim has been scarce.

Summary of literature review

There is a growing body of empirical literature on the drivers of economic growth, financial development and carbon dioxide emission; however, the evidence has been mixed in many cases. There is some evidence that economic growth affects both financial development and carbon dioxide emission. Financial development is also reported to affect economic growth and carbon dioxide emission; likewise, carbon dioxide is touted to influence economic growth and financial development. These findings therefore suggest there is an interrelationship among economic growth, financial development and carbon dioxide. However, empirical studies are yet to examine this interrelationship. Such neglect has the potential to affect the regression results. This study therefore analyses the interrelationship among economic growth, financial development and carbon dioxide emission which is seemingly lacking in the empirical literature.

Methodology

The main aim of this study is to examine the interrelationship among economic growth, financial development and carbon dioxide emission in Ghana. These three variables can be regarded as endogenous. Financial development may influence economic growth directly in terms of employment creation and increased investment, and indirectly through environmental degradation and vice versa (Dhrifi et al. 2020) showing that theoretically there is a causal relationship among the three variables. Due to the nature of the study, three different models will be specified: the economic growth model, financial development model and the carbon dioxide emission model.

Theoretical and empirical model for economic growth

Guided by the new growth theory (Beaudreau 2005; Romer 1990), which postulates that aggregate output (Y) is a function of capital stock (CAP), physical labour (HCD) and energy consumption (ENE), the functional relationship is expressed as:

$$Y_t = F(\mathrm{CAP}_t, \mathrm{HCD}_t, \mathrm{ENE}_t) \quad (1)$$

where t denotes time. Following Awodumi and Adewuyi (2020) and assuming a Cobb–Douglas production function, Eq. (1) can be restated as:

$$Y_t = A_t * \mathrm{CAP}_t^{\beta} * \mathrm{HCD}_t^{\alpha} * \mathrm{ENE}_t^{\pi} \quad (2)$$

where A is the technological progress, * represents multiplication sign, β, α and π are the coefficient elasticity of capital, labour and energy consumption respectively. Growth of the gross domestic product (GDP) was used as an indicator for aggregate output. According to the new growth theory, investment in capital accumulation, schooling and health enhances future earnings and increases productivity of workers leading to higher economic growth (Becker 1962; Manca 2012). Energy is argued to propel economic growth when used in production and transportation activities (Ouedraogo 2013; Apergis and Payne 2009; Hu et al. 2021). However, higher consumption of energy such as fossil energy results in higher level of carbon emissions which is detrimental to the environment (Kwakwa and Alhassan 2018; Dogan and Seker 2016; Jebli et al. 2016; Salari et al. 2021; Kirikkaleli and Adebayo 2021; Ali et al. 2021) and may affect economic growth. Carbon dioxide emission is projected to have a negative effect on economic activities because carbon emission is associated with global warming and climate change which affect the agricultural sector and other sectors that rely on the natural environment. This is expected to hamper economic growth. Consequently, to examine the growth effect of carbon emissions, CO_2 was included in the growth model.

In this study, financial development was used as a proxy for technological progress (A). A well-developed and functional financial system helps to transmit resources between lenders and borrowers, enabling the efficient allocation of resources which promotes economic growth (Schumpeter 1911; Levine et al. 2000; Hussain et al. 2021; Usman et al. 2021). Following the works of Boyd et al. (2001), one period lagged of economic growth ($\mathrm{GDP}_{\_1}$) was added to the growth model to inspect the effect of previous economic growth on future growth. Incorporating the variables proposed to influence economic growth into Eq. (2) gives Eq. (3) expressed as:

$$\mathrm{GDP}_t = \mathrm{CAP}_t^{\beta} * \mathrm{HCD}_t^{\alpha}\mathrm{ENE}_t^{\pi} * \mathrm{FID}_t^{\varphi} * \mathrm{CO}_{2t}^{\Omega} * \mathrm{GDP}_{-1\mathrm{t}} \quad (3)$$

Log linearizing Eq. (3) yields.

$$\begin{aligned}\ln\mathrm{GDP}_t = {} & \rho + \beta\ln\mathrm{CAP}_t + \alpha\ln\mathrm{HCD}_t + \pi\ln\mathrm{ENE}_t \\ & + \varphi\ln\mathrm{FID}_t + \Omega\ln\mathrm{CO}_{2t} + \lambda\ln\mathrm{GDP}_{\_1t} + \varepsilon_t\end{aligned} \quad (4)$$

where $\mathcal{E}_t$ is the stochastic error term and ρ is the constant term.

Theoretical and empirical model for financial development

Another theoretical framework guiding this study is the demand-following hypothesis which postulates that economic growth promotes financial development as an increase in income encourages citizens to increase their demand for financial products and services which may increase growth in the financial sector (Baltagi et al. 2009; Ehigiamusoe et al. 2019). Based on this theory, the baseline model is expressed as:

$$\mathrm{FID}_t = \beta_0 + \beta_1\mathrm{GDP}_t + \epsilon_t \quad (5)$$

where FID is financial development, β_0 is the constant term, GDP represents economic growth and ϵ_t is the stochastic error term. Another important policy variable that has an impact on financial development is inflation (INF). Previous works have argued that high and unstable inflation rate may adversely influence financial development (Ehigiamusoe et al. 2019; Khan et al. 2006). This is because high and unstable inflation rate erodes the real rate of return on money, which leads to inefficient resource allocation and diminishing intermediary activity (Ehigiamusoe et al. 2019; Naceur et al. 2014). From the economic viewpoint, trade openness (TRA) is an important variable that impacts the nature and level of financial development. There is a general consensus on the perceived relevance of trade openness to attract foreign investors in the host country (Cohen 2007). This exposes domestic banking sectors to foreign financial markets, which can enhance institutional reforms and help financial institutions to be more competitive in achieving a higher degree of financial development (Mishkin 2009). To analyse the effect of environmental degradation on financial development, CO_2 was included in the model. The deterioration of the environment through carbon dioxide emission is expected to have an adverse effect on financial development since a degraded environment has the tendency of reducing the vibrancy of the financial sector (Carse 2000) as business activities that have borrowed from financial institutions may be adversely affected by environmental destruction. Guided by the works of Boyd et al. (2001), one period lagged of financial development (FID_{t-1}) was added to the model to assess the impact of past financial sector performance on future financial development. Except for inflation rate, all the other variables expected to influence financial development are transformed into natural logarithms which gives:

$$\begin{aligned}\ln\mathrm{FID}_t = {} & \beta_0 + \beta_1\ln\mathrm{GDP}_t + \beta_2\mathrm{INF}_t + \beta_3\ln\mathrm{TRA}_t \\ & + \beta_4\ln\mathrm{CO}_{2t} + \beta_1\ln\mathrm{FID}_{t-1} + \epsilon_t\end{aligned} \quad (6)$$

Theoretical and empirical model for carbon dioxide emissions

According to Grossman and Krueger (1991), the relationship between economic growth and environmental degradation conforms to an inverted U-shaped curve, termed the environmental Kuznets curve (EKC) hypothesis in the economic

literature. The EKC's hypothesis posits that at the initial stage of development, economic activity results in the deterioration of environment until a certain point, beyond which an increase in income level leads to a recovery of environmental quality (Stern 2003; Sinha and Shahbaz 2018). Following the EKC hypothesis, the relationship between CO_2 emission and economic growth is expressed as:

$$CO_{2t} = GDP_t * GDP_t^2 * e_t \tag{7}$$

where CO_2 denotes carbon dioxide emission and represents environmental degradation, GDP stands for income and GDP^2 is the square of income to reflect the non-linear relationship between income and the level of environmental destruction. The stochastic error is denoted by e and t represents time. To analyse the CO_2 emission effect of financial development (FID), Eq. (7) was extended to include financial development. The impact of financial development is ambiguous. Efficient and developed financial systems enhance environmental quality by offering loans at lower interest to fund and adopt innovative green projects and technologies which is expected to reduce carbon emissions (Zakaria and Bibi 2019). In contrast, financial development can increase carbon emission through its positive effects on economic growth. Higher growth requires more energy to be consumed for transportation and production activities, which may affect the environment (Kwakwa and Alhassan 2018). Consequently, this study includes energy consumption to examine its role in Eq. (7). Inefficient usage of energy by firms and households may lead to higher emission of carbon dioxide which pollutes the environment. In contrast, efficient usage of energy will reduce the emissions of carbon dioxide, which in turn improves the quality of the environment (Kwakwa and Alhassan 2018; Sharma 2011; Pei et al. 2021).

Urbanization is a key feature of Ghana's economy now. Hence, to achieve green growth, urbanization must be taken into account in formulating appropriate green growth policies. Moreover, previous studies have also established that changes in urbanization can affect energy use and thus emission of CO_2. Rapid urbanization is generally associated with high demand for transportation services which increase vehicular movement and more usage of fossil fuel which increases carbon dioxide emissions. Urbanization may also reduce carbon dioxide emissions through economies of scale associated with the concentration of people and firms. Following Alhassan (2021) and assuming a Cobb–Douglas production function, the EKC model is extended to include the variables posited to influence carbon dioxide emissions in Ghana. Also, transforming all the variables into natural logarithm, Eq. (7) is modified and expressed as Eq. (8):

$$\ln CO_{2t} = \alpha + \rho_1 \ln GDP_t + \rho_2 \ln GDP_t^2 + \rho_3 \ln FID_t + \rho_4 \ln ENE_t + \rho_5 \ln URB_t + e_t \tag{8}$$

Econometric model

As previously discussed, economic growth, financial development and carbon dioxide emissions are endogenous. Financial development may influence economic growth directly in terms of employment creation and increased investment, and indirectly through environmental degradation (Dhrifi et al. 2020), showing that theoretically there is a causal relationship among the three variables. To disentangle direct and indirect channels, the three-way linkages among economic growth, financial development and carbon dioxide emission are empirically examined by adopting the following three simultaneous equations:

$$\ln GDP_t = \rho + \beta \ln CAP_t + \alpha \ln HCD_t + \pi \ln E_t + \varphi \ln FID_t + \Omega \ln CO_{2t} + \lambda \ln GDP_{\_1t} + \varepsilon_t \tag{9}$$

$$\ln FID_t = \beta_0 + \beta_1 \ln GDP_t + \beta_2 INF_t + \beta_3 \ln TRA_t + \beta_4 \ln CO_{2t} + \beta_1 \ln FID_{t-1} + \epsilon_t \tag{10}$$

$$\ln CO_{2t} = \alpha + \rho_1 \ln GDP_t + \rho_2 \ln GDP_t^2 + \rho_3 \ln FID_t + \rho_4 \ln ENE_t + \rho_5 \ln URB_t + e_t \tag{11}$$

Employing the OLS estimation techniques to estimate the elasticities of Eqs. (9), (10) and (11) will yield invalid estimators. This is because the specification of the simultaneous equations model violates the OLS assumption of zero variance between the error term and the exogenous variables (Greene 2003). The most appropriate econometric model is the three-stage least-squares (3SLS) simultaneous equations model (Zellner and Theil 1962). The 3SLS approach accounts for both simultaneous equation bias and cross-equation contemporaneous correlation of the disturbances (error terms) caused by unobserved factors. Compared to the 2SLS approach, the 3SLS estimates are consistent, asymptotically normal and efficient than single equation estimates (Greene 2003). In addition, the 3SLS combines the instrumental approach in which valid instruments are used with the generalised least-squares technique to obtain consistent parameter estimates and counteract the cross-equation correlation of the disturbance terms (Zellner and Theil 1962). Under the 3SLS estimation, all dependent variables are explicitly taken to be endogenous variables and are correlated with the error terms and all other variables in the system are treated as exogenous variables and uncorrelated with the error terms. Furthermore, the exogenous variables are taken to be instruments for the endogenous variables (Zellner and Theil 1962).

Prior to the estimation of the 3SLS model, a unit root test is conducted to evaluate the stationarity properties of the variables as time series (variables) are mostly non-stationary at levels. Estimation of non-stationary series at a level with OLS may lead to spurious regression. The study used the augmented Dickey and Fuller (ADF) (1979) test, the Phillips and Perron (1988) test and the Zivot-Andrews test to check the presence of unit

root in the variables. The reason for employing the ADF and PP tests is that it can account for the possibility of higher auto-correlation embodied among variables in a multivariate framework. The Zivot-Andrews unit root test (which deals with structural breaks) is also done to ascertain results from the ADF and the PP tests. After the unit root test, this study employed the autoregressive distributed lag (ARDL) bounds testing cointegration technique (Pesaran et al. 2001) to examine the long-run relationships among the selected variables. Unlike the Johnsen cointegration test, the ARDL bounds test is appropriate for variables with different order of integration: I (0), I (1) or mutually integrated.

Data description

Time series data covering the period 1971–2018 is used for the study. The data is accessed from the World Bank's (2021)World Development Indicator. The endogenous variables CO_2 emission is represented by carbon dioxide emissions in metric tons per capita, financial development by domestic credit to the private sector as a percentage of GDP, and economic growth (GDP) by real gross domestic product per capita at constant 2010 US$. The control variables used in the estimations were human capital development (HCD) proxied by secondary school enrolment (% gross), energy consumption measured by energy use in kilogrammes of oil equivalent per capita, capital proxied by gross fixed capital formation as a percentage of GDP, and trade openness measured by trade as a percentage of GDP. The other variables include urbanization measured by urban population as a percentage of total population and inflation rate measured by consumer prices (% annual).

Results and discussions

The results in Table 1 reveal that the average value of carbon dioxide emission is 0.344 metric tons per capita and the mean value of domestic credit to the private sector as a percentage of GDP is approximately 30%. However, the average real gross domestic product per capita is US$1050.49 and the gross fixed capital formation as a percentage of GDP is 16.45%. Furthermore, the average secondary school enrolment (% gross) is 42.57%, energy consumption is 340 kg of oil equivalent per capita and trade openness as a percentage of GDP is 55.86%. Finally, the average inflation rate is about 29.95%.

The results of the ADF and PP unit root tests are presented in Table 2. The results reveal that, except inflation rate (INF) which is stationary at level, all the other variables have unit roots in levels. However, the other variables were found to be stationary in their first difference. In all, inflation rate is integrated of order zero (I(0)) and economic growth, carbon dioxide emission, financial development, urbanization, trade openness, capital, human capital development and energy consumption are integrated of order one (I(1)).

The Zivot-Andrews unit root test results in Table 3 also show all variables are stationary at first difference except inflation which is stationary at levels. Given that the results reveal I(0) and I(1) process for the selected series, the ARDL bound test was used to check the cointegrating relationship and the results are presented in Table 4. It is evident from the results that the calculated F-statistics is higher than the upper bounds critical values when economic growth, financial development and carbon dioxide emission are used as the dependent variables. This suggests that the null hypothesis (no cointegration among variables) is rejected, implying that there is a long-run relationship among the variables.

After establishing a long-run relationship among the variables, the 3SLS technique was employed to jointly estimate the parameters of the structural model. Table 5 presents the long-run estimates of the 3SLS model in Eq. (4), (6) and (8). The results for each model is presented and discussed as follows.

Economic growth model

The second column of Table 5 presents the estimation results of the economic growth equation. The results reveal the development of the financial sector positively affect economic growth. Specifically, a 10% increase in financial development promotes economic growth in the long run by 0.75%, ceteris paribus. This result supports the finance-led

Table 1 Descriptive statistics of the variables

Moments and sample size	CO_2	GDP	HCD	LAB	FID	INF	TRA	ENE	URB
Mean	0.344	1050.493	16.475	42.566	8.674	29.945	56.807	340.035	40.592
Maximum	0.599	1808.327	30.049	74.679	15.882	122.875	116.048	408.254	56.060
Minimum	0.208	693.9491	3.750	33.298	1.542	7.126	6.320	266.120	29.174
Standard deviation	0.113	297.142	7.803	12.180	5.022	27.717	28.565	35.751	8.763
Observations	47	47	47	47	47	47	47	47	47

Table 2 ADF and PP unit root test results

Variables	Augmented Dickey-Fuller (ADF)		Decision	Phillips-Peron (PP)		Decision
	Level	First difference		Level	First difference	
lnGDP	−1.216 (0.907)	−4.973*** (0.000)	I(1)	−1.298 (0.888)	−4.973*** (0.000)	I(1)
$lnCO_2$	−2.223 (0.477)	−9.134*** (0.000)	I(1)	−1.867 (0.671)	−9.134*** (0.000)	I(1)
lnCAP	−1.584 (0.799)	−6.494*** (0.000)	I(1)	−1.694 (0.753)	−6.494*** (0.000)	I(1)
lnHCD	−0.918 (0.954)	−9.853*** (0.000)	I(1)	−0.797 (0.966)	−9.853*** (0.000)	I(1)
lnFID	−1.837 (0.687)	−5.513*** (0.000)	I(1)	−2.126 (0.532)	−5.513*** (0.000)	I(1)
lnURB	5.193 (1.000)	−4.418*** (0.002)	I(1)	2.759 (1.000)	−4.418*** (0.002)	I(1)
lnTRA	−1.506 (0.936)	−4.575*** (0.001)	I(1)	−1.418 (0.856)	−4.575*** (0.001)	I(1)
lnENE	−1.724 (0.740)	−6.093*** (0.000)	I(1)	−2.002 (0.600)	−6.093*** (0.000)	I(1)
INF	−4.152*** (0.005)	−8.948*** (0.000)	I(0)	−4.052*** (0.007)	−9.292*** (0.000)	I(0)

*** and * denote significance at 1% and 10% respectively. *p* value is shown in parentheses

Table 3 Zivot-Andrews unit root test results

Variables	Levels t-statistic	Break year	First difference t-statistic	Break year
lnGDP	−3.2497	1979	−4.7128***	1984
$lnCO_2$	−4.8438	1985	−7.2594***	1999
lnCAP	−3.1059	1993	−6.2980***	1994
lnHCD	−3.2292	1989	−7.6404***	1991
lnFID	−3.8777	1996	−7.6151***	1984
lnURB	−4.3225	2011	−7.3261***	1986
lnTRA	−4.8730	1980	−7.3274***	1983
lnENE	−4.8651**	2000	-6.5179***	2006
INF	1.8501	2011	−6.1885***	2008

*** and ** denote significance at 1% and 5% respectively

Table 4 Cointegration test- Pesaran/Shin/Smith (2001) ARDL bounds test

Statistics	Growth model (GDP, FID, CO_2, CAP, HCD, ENE)		Conclusion
F statistic	4.933***		Cointegrated
α levels	I(0) bound	I(1) bound	
10%	2.360	3.350	
5%	2.620	3.790	
1%	3.410	4.680	
	Financial development model (FID, GDP, CO_2, INF, TRA)		
F statistic	4.259***		Cointegrated
α levels	I(0) bound	I(1) bound	
10%	2.450	3.520	
5%	2.860	4.010	
1%	3.740	5.060	
	Carbon dioxide emission model (CO_2, GDP,GDP^2, FID, ENE, URB)		
F statistic	5.597***		Cointegrated
α levels	I(0) bound	I(1) bound	
10%	2.260	3.350	
5%	2.620	3.790	
1%	3.410	4.680	

*** denotes significance at 1%

growth hypothesis which posits that an efficient and well-functioning financial system will promote economic growth via efficient allocation of resources from unproductive to productive sectors (Kandil et al. 2017). The positive effect of financial development on Ghana's economic growth could be attributed to the liberalization and restructuring of the financial sector since the early 1990s. Following the restructuring of the sector, Ghana's financial sector has been robust (World Bank 2021). Financial liberalization enhances monetary transmission mechanism, increases savings and investments, and spurs financial deepening which promotes economic growth through the provision of credit. It is therefore not surprising that financial development is recorded to have positive effect on economic growth. Ho and Iyke (2020), Adu et al. (2013) and Quartey and Prah (2008) validated the finance-led growth hypothesis for Ghana.

Consistent with existing literature, human capital development proxied by gross secondary school enrolment has positive effect on economic growth. A 10% increase in human capital development increases economic growth by 2.4%. The positive relationship between gross secondary school enrolment and economic growth is an indication that improving human capital will promote economic growth in Ghana. These results are in conformity to the neoclassical and endogenous growth models which posit that improvements in labour via education and health increases labour productivity and encourage innovativeness, which in turn promote economic growth. Provision of quality education and expansion of schools to increase enrolment have been

Table 5 Determinants of economic growth, financial development and carbon dioxide emission in Ghana

Variables	Economic growth (lnGDP) model	Financial development (lnFID) model	Carbon dioxide emission ($lnCO_2$) model
lnGDP	-	0.689* (0.372)	16.329** (7.577)
$lnGDP^2$	-	-	−1.094** (0.533)
lnFID	0.075*** (0.021)		−0.229*** (0.085)
$lnCO_2$	0.076 (0.056)	−0.309 (0.290)	
lnCAP	−0.018 (0.017)	-	
lnHCD	0.241*** (0.062)	-	
lnENE	0.027 (0.056)	-	0.303** (0.154)
lnINF		−0.002 (0.001)	-
lnTRA		0.330*** (0.083)	
lnURB		-	0.998*** (0.174)
lnGDP_1	0.610*** (0.074)	-	
lnFID_1	-	0.567*** (0.094)	
Constant	1.645*** (0.480)	−5.493* (2.966)	−66.670** (27.333)
Observations	47	47	47
R-square	0.983	0.931	0.861
Wald Chi-square	2617.88***	681.28.***	399.88***

***, ** and * denote significance at 1%, 5%, and 10% respectively

a focus of past and present governments of the country. The outcome from this study is an indication the resources churned into the educational sector has been helpful in promoting economic growth. Ghana's educational sector has witnessed great transformation at the pre-tertiary and tertiary levels. There is an increased number of schools at both levels likewise enrolment. Efforts have also been made to equip teachers especially at the pre-tertiary level with the necessary skills to impart knowledge to students. This development could be associated with the reported results on Ghana's growth. This result is in line with Kwakwa et al. (2021) who reported that human labour is critical for undertaking economic activities. As expected, the lagged value of economic growth has positive and significant sign implying that the previous economic growth increases future economic growth.

Carbon emission is seen to have an insignificant effect on economic growth. Thus, Ghana's economy in terms of growth does not suffer from carbon dioxide emission. It is possible to attribute this finding to the fact that the share of agriculture in Ghana's economic growth has been reducing. Kwakwa et al. (unpublished) have found that the agricultural sector in Ghana is negatively affected by carbon emission. Therefore, the fact that the agricultural sector in the country (which suffers at the hands of climate change and global warming associated with carbon emission) is gradually reducing its dominance in the country could be the reason why this outcome is recorded. Since the service sector and the industrial sector do not have much linkage to climate change, their dominance in the country will reduce the negative effect that climate change may have had on the agricultural sector thereby weakening the effect of carbon emission on the country's economic growth.

Financial development model

In column 3, Table 5, which presents the results of the financial development equation, it is seen that economic growth positively affects financial development, showing that the growth-led financial development argument is confirmed in this study. Specifically, a 10% increase in economic growth increases financial development by 6.89%, ceteris paribus. The findings are an indication that expansion in economic activities probably encourages firms and households to demand more of financial services and products which increase growth in the financial sector. Ghana's financial sector can be said to have benefitted from the recent pace of economic growth in the country. The demand for consumer durables in Ghana seems to increase with the level of economic growth (Kwakwa et al. 2020). It is commonplace in the country that individuals often resort to financial institutions for financial assistance to make such purchases. The result confirms the finding of Adom (2019) who reported economic growth positively drives financial development in Ghana.

The coefficient of trade openness is positive and significant at 1%. A 10% increase in trade openness increases financial development by 3.3%, ceteris paribus. The positive elasticity suggests that international trade promotes financial

development in Ghana. Trade openness exposes domestic financial institutions to intense international competition which promote efficiency and improve transparency in the financial sector. This can be true for Ghana's financial sector which has seen a high entrance rate of a number of foreign banks since the late 1990s when trade liberalization was taken to another level after the structural adjustment programme. This finding concurs with previous studies by Seetanah et al. (2010) and Takyi and Obeng (2013) who established that trade openness promotes financial development. Expectedly, previous level of financial development enhances future development of the financial sector.

Inflation rate has a negative and insignificant effect on financial development, showing that inflation rate has no significant effect on the development of the financial sector in Ghana. It is expected that high inflation rate associated with high opportunity cost of holding money will impede the efficiency in financial institutions. However, the insignificant effect of inflation rate on financial development could be that the level of inflation rate has not reached a level that may influence firms' and households' decision to use financial products and services. Sustaining single-digit inflation has eluded authorities in the country. As a result, the frequent fluctuations between single-digit and double-digit inflation may flummox individuals who would like to take certain decision of holding money or depositing it at a financial firm. This result contradicts the findings of Ehigiamusoe et al. (2019) and Khan et al. (2006).

The coefficient of carbon dioxide emission is negative although insignificant. This is an indication that the financial sector in Ghana does not suffer from carbon dioxide emission. Consequently, the argument presented by Carse (2000) that financial development may be negatively affected by environmental pollution (carbon emission) through credit risk, legal risk and reputation risk or positively affected by same through massive lending to combat environmental pollution does not hold for Ghana. This could be that the level of carbon dioxide emission might not have reached a level that may trigger any of the effects proposed by Carse (2000).

Carbon dioxide emission model

The results in column 4, Table 5 indicate that economic growth has a non-linear effect on carbon dioxide emission. Specifically, GDP has a positive effect, while the GDP square has a negative effect on carbon dioxide emission. This implies that there is an inverted U-shaped relationship between GDP and CO_2 emission. Thus, the early stage of economic development deteriorates the environment, but after a certain threshold level, further development enhances environmental quality. This is a validation of the existence of the EKC hypothesis in Ghana. The result corroborates the conclusion made by Kwakwa and Alhassan (2018) that Ghana's economic growth over the study period seems to protect the environment. In Ghana, the rising middle class due to improved economic performance has increased the demand for energy-efficient and green technologies, which not only result in energy efficiency but also improve environmental quality by emitting fewer emissions into the environment. Also, individuals and firms are becoming environmentally conscious. This finding agrees with the findings of Alam et al. (2016) and Ali et al. (2021).

Financial development negatively affects carbon dioxide emission. A 10% rise in financial development decreases carbon dioxide emissions by 2.29%, ceteris paribus. This implies that financial development causes a reduction in CO_2 emission. This is an indication that the liberalization and restructuring of the financial system have helped channel loanable funds to firms and households to enable them to invest in environment friendly projects and technologies, which enhance environmental quality. Furthermore, a liberalized financial system can improve the quality of the environment by enhancing the stock of capital available for investment in green energy that is expected to reduce carbon dioxide emissions. Although figures are not readily available, many banks in the country such as CalBank, Stanbic, Fidelity Bank, Absa Bank and Ecobank have committed themselves to support climate change combating programmes like the ECOFRIDGES by the United Nations Environment Programme, United for Efficiency (U4E) and SUNREF, a European Union green financing supported programme. The emission reduction impact of financial development confirms the empirical evidence by Zafar et al. (2019), Kirikkaleli (2020) and Sadorsky (2011) but is in sharp contrast to Adom et al. (2018) and Kwakwa et al. (2018). The differences in the findings can be as a result of the variations in data source, period of study and the country of focused.

Another variable that has a significant positive effect on carbon dioxide emission is energy consumption. A 10% increase in energy consumption increases carbon dioxide emission by 3.30%, ceteris paribus. The environmental degrading effect of energy consumption is expected because increased energy usage emits more carbon dioxide. Since fossil fuels constitute a significant share of energy consumption in Ghana, the higher consumption of energy for economic activities can result in higher carbon dioxide emissions. The positive effect of energy consumption on carbon dioxide emission is consistent with previous studies by Safi et al. (2021), Li et al. (2021), Kwakwa and Alhassan (2018), Dogan and Seker (2016) and Jebli et al. (2016).

The results show that urbanization exerts a positive effect on CO_2 emission in Ghana. When urbanization increases by 10%, carbon dioxide emission increases by 9.98% ceteris

paribus. The outcome is an indication that urbanization is harmful to the environment in the long run, confirming the urban transition theory. In Ghana, rapid urbanization driven by rural–urban migration has significantly increased the demand for goods and services such as transportation, food, housing and sanitation. This has led to heavy traffic congestion resulting in higher consumption of fossil energy which emits carbon dioxide. Likewise, a greater percentage of the vegetation cover is lost through the clearing of land for food production and residential facilities, which in turn degrades the environment. Moreover, the enormous waste generated during the production and consumption of goods is not managed sustainably, because sanitation infrastructure is not enough to meet the growing waste thereby degrading the environment. This finding is in tandem with several studies including Kwakwa and Alhassan (2018) as well Amuakwa-Mensah and Adom (2017).

Conclusion and policy implications

This study examines the interrelationship among economic growth, financial development and carbon dioxide emissions for the case of Ghana for the period of 1971–2018. Specifically, the study evaluates the impact of financial development on economic growth with emphasis on the role played by environmental quality in such relationship. The 3SLS technique was used to account for potential problem of simultaneity and endogeneity bias due to unobserved factors. Findings supported a bidirectional causal relationship between financial development and economic growth and unidirectional causal effect from financial development to carbon dioxide emissions. Results show a neutral effect of carbon dioxide emission on economic growth and financial development. The other determinants of financial development are trade openness and the past history of financial development. The results reveal that trade openness and previous financial performance promotes financial development. Likewise, the results also indicate that human capital and previous growth of gross domestic product promotes economic growth. For the drivers of CO_2 emission, the results established that while financial development decreases carbon dioxide emission, energy consumption and urbanization increase it.

The results obtained from this study have serious implications for policy in Ghana. An important conclusion emanating from this study is that financial development proxied by the domestic credit to the private sector is critical for environmental quality and economic growth in Ghana. On the basis of this evidence, policies that improve access to affordable credit to firms and households will spur the needed innovation, investment and adoption of energy-efficient and green technology which have the tendency to promote environmental quality and sustainable economic growth. At the moment, Ghana's interest rate remains high despite the reduction in the central bank's policy rate as well as inflation. Officials need to pay attention to other areas including the treasury bill rate which is also high and as a result may make it difficult for banks to reduce their rate. The Central Bank needs to intensify its persuasive skills to let banks reduce their interest rate on loans that is meant for environmentally friendly production and consumption activities. A reward package may be instituted and given to such banks that comply. Firms and households should be equipped with environmental education to encourage the usage of clean energy and energy-efficient technology. Investment in renewable energy development through public–private partnership will go a long way to ensure ecological sustainability in the long run. Since energy is found to increase carbon emission but has become part of society, the government should enhance its policy to encourage the development of renewable energy resources. This will stimulate access to clean, reliable and affordable energy for carrying out economic activities. In addition, the adoption and implementation of open trade policies should be encouraged to enhance innovativeness and efficiency in the financial sector.

The study further established that human capital development plays a key role in the growth process, suggesting that education policy that increases both the quality and quantity of the labour force will spur growth in Ghana. Attention needs to be paid to the concern that some have raised over the quality of Ghana's education. Although the Free SHS policy is a positive one which has led to increased enrolment, the teething issues that could mar the wonderful picture behind this policy should be addressed without delay. Teachers' motivation should not be overlooked as well to ensure quality is not compromised.

Ongoing plans for the country to increase its share of renewable energy in electricity production and total energy consumption should be pursued aggressively. Authorities need to not to lose focus on that since the realization of this shall help reduce carbon emission. The result of the income effect on carbon dioxide emission is an indication that the environmental Kuznets curve hypothesis holds for Ghana. In addition, since economic growth has been found to benefit the financial sector, environment policymakers need to safeguard and ensure there is an improvement in the green growth of the economy. Efforts to make urban towns sustainable in Ghana is not encouraging. To help reduce carbon dioxide emission, massive attention is needed to invest in urban infrastructure to reduce carbon dioxide emission. There should be regular planting of trees in urban towns towards the protection of the environment.

Further works on the interrelationship among growth, financial development and carbon emission may consider sectoral analysis to unearth deeper understanding.

Author contribution All authors conceived research idea. HA built and analysed the data; PAK did literature review and discussed results; all authors read and approved the final manuscript.

Data availability The datasets analysed during the current study are available in the World Bank's World Development Indicators repository (https://databank.worldbank.org/source/world-development-indicators#).

Declarations

Ethics approval and consent to participate Not applicable

Consent for publication Not applicable

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