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Abstract

To overcome the limitations of the traditional approach which uses linear causality to examine whether the supply-leading and demand-following theories hold. As certain countries will be found not to follow the theory by using the traditional approach, this paper first suggests using all the proxies of financial development and economic growth as well as both multivariate and bivariate linear and nonlinear causality tests to analyze the relationship between financial development and economic growth. The multivariate nonlinear test not only takes into consideration both dependent and joint effects among variables, but is also able to detect a multivariate nonlinear deterministic process that cannot be detected by using any linear causality test. We find five more countries in which the supply-leading hypothesis and/or demand-following hypothesis hold true than with the traditional approach. However, there is still one country, Pakistan, for which no linear or nonlinear causality is found between its financial development and economic growth.

To overcome this limitation, this paper suggests including cointegration in the analysis. This leads us to conclude that either supply-leading or demand-following hypotheses or both hold for all countries without any exception. There will be some types of relationships between economic growth and financial development in any country such that either they move together or economic growth causes financial development or financial development causes economic growth without any exception. The finding in our paper is may be useful for governments, politicians, and other international institutions in their decision making process for the development of the countries and reducing poverty.

JEL classification: G20; O40; C12

Keywords: Financial development, economic growth, cointegration, linear causality, nonlinear causality, developing countries, supply-leading hypothesis, demand-following theory.

1. Introduction

Scholars and policy makers are interested in knowing whether financial development could lead to economic growth which in turn helps the development of the countries and reduces poverty. The debate on the direction of the causality between financial development and economic growth has been on-going since the 19th century. There are two major theories which explain the causal relationship between financial development and economic growth: the demand-following theory (Robinson, 1952) and the supply-leading theory (Schumpeter, 1934 and Patrick, 1966). The first suggests that financial development will follow economic growth, because when the economy grows, it generates new demands for financial services, and thus, the financial system will growth. On the other hand, the supply-leading theory suggests that financial development promotes economic growth, and thus, financial development has a positive effect on economic growth.[1]

There are three major ways in which the financial system can influence economic growth (Patrick, 1966). First, by prompting changes in its ownership and in its composition through intermediation among various types of asset-holders. Financial institutions can help to allocate tangible wealth more efficiently. Secondly, financial institutions encourage a more efficient allocation of new investment-additions to capital stock from savers and entrepreneurial investors, by moving from relatively less to relatively more productive uses. Finally, financial institutions can induce an increase in the rate of accumulation of capital by providing convenient saving, investment, and transaction services which increase incentives to save, invest, and work.

However, empirical studies by Demetriades and Hussein (1996), Kar, et al. (2011), Akbas (2015), and others neither support the supply-leading hypothesis nor demand-following theory,

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[1] Khan (2001) has also developed a theory for financial development based on the costs associated with the provision of external finance and concluded that financial development reduces the costs associated with the provision of external finance and increases the rate of economic growth.

or both. They use two different proxies of financial development to test whether there is any linear causality between economic growth and financial development. They conclude that the supply-leading hypothesis does not hold if there is no linear causality from financial development to economic growth. Similar tests have been used to test whether the demand-following theory holds true by testing whether there is no linear causality from economic growth to financial development.

There are two limitations to this approach. First, using a statistical test to test series of single hypothesis is not equivalent to testing those hypotheses jointly.[2] The results of using separate tests could be unreliable (Fomby et al, 2012). To circumvent the limitation, in this paper we suggest to employ the multivariate linear Granger test (Bai, et al., 2010, 2011, 2018; Chow, et al., 2018) to examine the linear causal relation between financial development and economic growth. The second problem is that a traditional linear Granger causality test may fail to detect the nonlinear causal relationship between financial development and economic growth. As Granger (1989) mentions, a real world is "almost certainly nonlinear". Nonlinear relationships between economic variables are widely reported in economic studies. For example, Hamilton (2011) and Herrera, et al. (2011) argue that the relation between GDP growth and oil prices is nonlinear and Chiou-Wei, et al. (2008) report the nonlinear relationship between economic growth and energy consumption. The debate on the direction of causality between financial development and economic growth have ignored the nonlinear behavior which could be caused by structural break. In addition to the structural break effect, non-constant marginal effect, and threshold regime effect may also make the causal relationship between financial development and economic growth become nonlinear. Studies that explicitly test for causality between financial development and real GDP (Rogalski, 1978; Smirlock and Starks, 1988; Jain and Joh, 1988, Antoniewicz, 1992) rely exclusively on traditional linear Granger causality tests. Although such tests have high power in uncovering linear causal relations, their power against nonlinear causal relations can be low (Baek and Brock, 1992 and Hiemstra and Jones, 1993). Under this situation,

[2] For example, testing whether economic growth linear causes proxies 1 and 2 of financial development separately (or proxies 1 and 2 of financial development linear cause economic growth separately) is significantly different from testing whether economic growth linear causes proxies 1 and 2 of financial development jointly (or proxies 1 and 2 of financial development linear cause economic growth jointly).

a nonlinear model may represent the proper way to model the real world that is "almost certainly nonlinear" as Granger (1989) argues. For this reason, we employ a multivariate nonlinear Granger causality test (Bai, et al., 2010, 2011, 2018; Chow, et al., 2018) to investigate the presence of nonlinear causal relations between financial development and economic growth. To test whether both demand-following supply-leading theories hold true, in this paper we also suggest the use of a cointegration technique and examine whether there is any cointegration between financial development and economic growth. If there is cointegration between financial development and economic growth, then financial development and economic growth will cause each other. We provide explanation in Section 5.1.

Using data from 14 developing countries (Brazil, Chile, China, Costa Rica, El Salvador, Guatemala, India, Malaysia, Pakistan, Peru, South Africa, Sri Lanka, Thailand and Turkey), this investigation is among the first, if not the first, to use cointegration, and both bivariate and multivariate linear and nonlinear Granger causality tests to examine the relationship between financial development and economic growth. Our findings from both the Johansen cointegration and Engle–Granger two-step cointegration tests suggest that financial development and economic growth are moving positively together in some countries but not in others, and thus, the demand-following and the supply-leading theories may hold true in some developing countries but not in others. To test whether the demand-following and the supply-leading theories hold true formally for the developing countries studied in this paper, both bivariate and multivariate linear and nonlinear causality tests are used. The results of our causality tests conclude that both demand-following and the supply-leading theories hold for most of the countries studied in our paper except Costa Rica, Guatemala, Pakistan, South Africa. Among these, the demand-following theory is only valid for both Costa Rica and South Africa, while only the supply-leading theory holds for Guatemala, and neither demand-following nor supply-leading theories hold for Pakistan. We note that the inclusion of nonlinearity in testing both the demand-following and the supply-leading hypotheses is important because if the nonlinear test had not been used, one could not find out that the supply-leading theory does hold for Turkey and the demand-following theory does hold for Brazil, India, South Africa, and Sri Lanka. It could allow us to test the overall significant of nonlinear causality between two pairs of variables. Using the multivariate tests, we find that economic growth does cause financial development, and financial development does cause economic growth which is consistent with the demand-following hypothesis and supply-leading hypothesis.

However, despite using both (multivariate) linear and nonlinear causality to study the causality relationship between financial development and economic growth, *there is still one country, Pakistan, which displays no* linear or nonlinear causality between its financial development and economic growth. One may not believe that there is no relationship between financial development and economic growth in any country. To solve this problem, we recommend scholars and practitioners use both cointegration and (multivariate) linear and nonlinear causality to study the causality relationship between financial development and economic growth. In doing so, our findings conclude that either supply-leading or demand-following hypotheses or both hold for all countries without any exception. This is a key finding never presented in any paper to date, suggesting that our paper is the first paper that find out either supply-leading or demand-following hypotheses or both hold for all countries without any exception. One could, thereafter, conclude that there is always a relationship between economic growth and financial development such that either they move together or economic growth causes financial development or financial development causes economic growth without any exception. The finding in our paper is useful for governments, politicians, and other international institutions in their decision-making processes for the development of the countries and reducing poverty.

This paper has the following structure. After a brief introduction and overview in this section, Section 2 discusses the literature of financial development and economic growth. Section 3 presents the tests used in this paper including the multivariate linear and nonlinear causality test. Section 5 presents results of the application of these techniques to data and discusses their interpretations for the developing economies. The conclusions are presented in Section 6.

2. Literature review and related theory

It is interesting to analyze the relationship between financial development and economic growth in developing countries, especially in countries with high levels of poverty. It is important to understand whether financial development will lead to economic growth or verse versa in these countries. This will help governments, politicians, and other international institutions to adopt the best polices to help the development of the country and reduce poverty. To understand the issue better, we first discuss the supply-leading and demand-following hypothesis.

2.1 Supply-leading and demand-following hypotheses

The supply-leading hypothesis hypothesizes that money related advancement is the driver of financial development. Supply leading has two functions: to transfer resources from the traditional, low-growth sectors to the modern high-growth sectors and to promote and stimulate an entrepreneurial response in these modern sectors (Patrick, 1966). This implies that the creation of financial institutions and their services occurs before there is an actual demand for them. Thus, the availability of financial services stimulates the demand for these services by the entrepreneurs in the modern, growth-inducing sectors.

On the other hand, the demand-following hypothesis hypothesizes that productive and successful utilization of economy leads to financial development. To support the demand-following hypothesis, Robinson (1952) argues that "where venture drives, finance follows" and suggests that financial development is simply a response to the greater demand for financial services as the real economy grows.

Murinde and Eng (1994) and others argue that monetary segment leads development instead of following it. They argue that the expectation in embracing money related to transforming system and the desire in acquiring cash identified with changing the framework is a win situation in the case of economies which are driven by a supply-leading approach to improved adaptation of the economy and financial institutions and to deal with enhanced adjustment of the economy and money related foundations (Murinde and Eng, 1994). It is fundamental for policy makers to be ready to inject funds into some factors that could be equipped as components of monetary strategy, as indicated by (Banerjee and Ghosh, 1998), on the grounds that national financial strategies will support a supply-driven analysis as a budgetary reconstruction is being well planned. The reactant effect of money related rebuilding in instigating financial development was affirmed by past research done in East Asia.

2.2 Financial development and economic growth

Monetary development makes cash related assets challenging for the fiscal division to provide refined implementation. Achieving economies of scale on the advancement in securing costs drew within the appraisal of firms, administrators, and the monetary circumstances upgrading resource circulation is one of the critical components of the cash related market as to adjust the risk. The financial system prompts improvement by encouraging trade, which in this manner propels interest and involuntary development (Adeyeye, et al., 2015). In light of other writings, finance if utilized productively and viably can add to development.

The evidence in the literature supports the supply-leading hypothesis only when broad monetary aggregates and a monetization variable are used as surrogates for financial development. Murinde and Eng (1994) conclude that there is a plausible case for those economies which intend to adopt a financial restructuring strategy driven by a supply-leading policy stance that involves enhanced monetization of the economy and bank intermediation.

On the other hand, Uddin et al. (2013) investigate the relationship between financial development and economic growth in Kenya and find that the development of the financial sector had a positive impact on economic growth in the long run. Analyzing the role of stock market development on economic growth in Africa, Ngare et al. (2014) find that countries with stock markets tend to grow faster compared to countries without stock markets, inferring that stock market development has a positive effect on economic growth.

Moreover, analyzing 109 developing and industrial countries from 1960 to 1994, Calderón and Liu (2003) find that financial development generally leads to economic growth. They also find that Granger causality from financial development to economic growth and the Granger causality from economic growth to financial development coexist. They argue that financial deepening contributes more to the causal relationships in developing countries than in industrial countries. Investigating the relationship between financial development and economic growth from 30 developing countries for the period 1970–1999, Al-Yousif (2012) finds strong bidirectional causality between financial development and economic growth. Examining 52 middle-income countries over the 1980–2008 period, Samargandi et al. (2015) find that there is an inverted U-shaped relationship between finance and growth in the long run but no significant relationship in the short term. Using a bootstrap panel causality test to analyze the causality relationship between financial development and economic growth in emerging market countries, Akbas (2015) finds a weak causal relationship between economic growth and financial development, with the exception of Turkey. Zhang et al. (2012) find a positive and statistically significant monotonic relationship between economic and financial development in China and Hassan et al. (2011) find a positive relationship between financial development and economic growth in developing countries but only on a long-term basis. Deltuvaitė and Sinevičienė (2014) analyze 73 different economies between 1975–2011 and find a positive and statistically significant monotonic relationship between economic and financial development. However, Kar et al. (2011) and Menyah et al. (2014) conclude that there is no clear consensus on the direction of causality between financial development and economic growth.

Gregorio and Guidotti (1995) describe that the main channel of transmission from financial development to growth is the efficiency, rather than the volume, of investment. Hsueh et al. (2013) find that the direction of causality between financial development and economic growth is sensitive to the financial development variables used. Herwartz and Walle (2014) argue that the impact of finance on economic development is generally stronger in high-income than low-income economies. Base on 67 studies that investigate the effect of financial development on economic growth, Valickova et al. (2015) conclude that studies which do not address endogeneity tend to overstate the effect of finance on growth.

Fan, et al. (2018) find a significant bidirectional relationship between financial development and trade openness in China, inferring the existence of both ‘demand-following’ and ‘supply-leading’ hypotheses, concluding that Chinese policymakers should further increase financial reform to promote trade development.

3. Data and Methodology

3.1 Data

Our data include information from 14 developing countries: Brazil, Chile, China, Costa Rica, El Salvador, Guatemala, India, Malaysia, Pakistan, Peru, South Africa, Sri Lanka, Thailand, and Turkey from 1950 to 2014 obtained from the International Financial Statistics, the database of International Monetary Fund. Our criteria for including a country in our study is that the developing country has a population exceeding one million in 2017 and the database has enough data in all the variables.

It is difficult to directly measure both financial development and economic growth. Economic growth is commonly measured using real GDP per capita, see for example Gelb (1989), Roubini and Sala-i-Martin (1992), King and Levine (1993), and Demetriades and Hussein (1996). Similar to these studies, a logarithm of real GDP per capita is used to proxy economic growth and has been denoted as Y.

A common practice to measure financial development (Gelb, 1989 and King and Levine, 1993) is to use a ratio of some broad measures of the money stock to the level of nominal GDP. However, Demetriades and Hussein (1996) argue that this type of ratio may reflect more extensive use of currency rather than an increase in the volume of bank deposits. To circumvent the limitation, they recommend excluding currency in circulation from the broad money stock. In this paper we follow their recommendation and use the logarithm of the ratio of bank deposit liabilities to nominal GDP as the first proxy for financial development and represented as M.

In addition, academics (Demetriades and Hussein, 1996) suggest using the ratio of bank claims on the private sector to nominal GDP to measure the financial development in a country. According to Demetriades and Hussein (1996), this ratio provides more direct information on the extension of financial intermediation and yield additional insights pertaining to the hypothesis. Thus, in this paper we also follow their recommendation and use the logarithm of the ratio of claims on private sector to nominal GDP as the second proxy for financial development and designate it as *D*.

3.2 Methodology

In the literature on the subject of the relationship between financial development and economic growth, academics, such as Horng, et al. (2012) are interested in testing the following two hypotheses:

H_0^1: financial development does not cause economic growth, and

H_0^2: economic growth does not cause financial development.

Academics and practitioners, such as Horng, et al. (2012) and Fan, et al. (2018) employ linear causality to study whether there is any unidirectional or bidirectional causality between financial development and economic growth. Thus, they set

$H_0^{1\prime}$: financial development does not cause economic growth if there is no linear causality from financial development to economic growth.

However, in this paper, we set

H_0^1: financial development does not cause economic growth if there is no linear and no nonlinear causality from financial development to economic growth. Similarly, definitions are set for $H_0^{2\prime}$ and H_0^2.

To our knowledge, this is the first paper to employ (multivariate) linear causality to study whether there is any unidirectional or bidirectional causality between financial development and economic growth, and also employ (multivariate) nonlinear causality to study whether there is any unidirectional or bidirectional nonlinear causality between financial development and economic growth and whether there is any multivariate linear and nonlinear causality between financial development and economic growth. Ascertaining whether financial development and economic growth are cointegrated is an important piece of information. If financial development and economic growth are cointegrated, we conjecture that both demand-following and supply-leading theories hold so that financial development and economic growth move positively together. Thus, in this paper, we examine the following hypothesis:

H_0^3: financial development and economic growth are not positively cointegrated.

There are certain studies which have used cointegration in some related work. For example, Samargandi, et al. (2015) use pooled mean group estimations in a dynamic heterogeneous panel setting and demonstrate that there is an inverted U-shaped relationship between finance and growth in the long run. However, as far as we know, no paper has used the same variable settings in the cointegration relationship we are analyzing in this paper. Thus, we believe our paper is the first paper to use cointegration to examine the relationship between financial development and economic growth, which, in turn could lead to conclude whether demand-following and supply-leading theories hold. In this paper we only conjecture that if financial development and economic growth are cointegrated positively, then both demand-following and supply-leading theories hold for the countries. However, if financial development and economic growth are indeed cointegrated, does it lead to conclude that both demand-following and supply-leading theories hold for the countries? Further development in economic theory is needed to support this argument.

In the following subsections, we will discuss cointegration and linear and nonlinear causality tests to analyze the relationship between financial development and economic growth in developing countries. We first discuss the cointegration approach in next subsection.

3.2.1 Cointegration

As mentioned in Section 3.1 M, D, and Y have been designated to be the logarithms of the ratio of bank deposit liabilities to nominal GDP (M), the ratio of claims on private sector to nominal GDP, and real GDP per capita, respectively. If all the variables (M, D, and Y) are integrated in degree one, academics and practitioners will be interested in examining whether there is any cointegration relationship among the variables. To analyse the issue, we employ the Johansen cointegration test proposed by Johansen (1988), Johansen and Juselius (1990) and Johansen (1991) as some studies, for example, Gonzalo (1994), confirm that the Johansen cointegration test performs better than the other cointegration tests, namely the ADF test (Engle and Granger, 1987). In addition, when GARCH errors exist in the model, Lee and Tse (1996) conclude that the bias is not too serious when using Johansen's cointegration test if we compare its performance with other cointegration tests

Johansen and Juselius (1990) and Johansen (1991) develop a multivariate maximum likelihood (ML) procedure for the estimation of the cointegrating vectors. According to Johansen's procedure, the p-dimensional unrestricted Vector Autoregression (VAR) model should be first specified with k lags:

$$\boldsymbol{Z_t} = \sum_{i=1}^{k} \boldsymbol{A_i Z_{t-i}} + \Psi \boldsymbol{D_t} + U_t \qquad (1)$$

where $\boldsymbol{Z_t} = [M_t, D_t, Y_t\,]'$ is a 3×1vector of stochastic variables and M_t, D_t, and Y_t are to be the logarithms of the ratio of bank deposit liabilities to nominal GDP, the ratio of claims on private sector to nominal GDP, and real GDP per capita in period t, respectively. $\boldsymbol{D_t}$ is a vector of dummies and $\boldsymbol{A_i}$ is a vector of parameters. This VAR could be rewritten as:

$$\Delta \boldsymbol{Z_t} = \sum_{i=1}^{k-1} \Phi_i \Delta \boldsymbol{Z_{t-i}} + \boldsymbol{\Pi Z_{t-i}} + \Psi \boldsymbol{D_t} + U_t\ . \qquad (2)$$

The hypothesis of cointegration is formulated as a reduced rank of the $\boldsymbol{\Pi}$ matrix where $\boldsymbol{\Pi} = \boldsymbol{\alpha\beta'}$ such that $\boldsymbol{\alpha}$ is the vector or matrix of the adjustment parameter and $\boldsymbol{\beta}$ is the vector or matrix of the cointegrating vectors. According to Engle and Granger (1987), if the rank of $\boldsymbol{\Pi}$ (r) is not equal to zero, then r cointegrating vectors exist. The number of cointegrating vectors is less than or equal to the number of variables, which is 3 in our case. The likelihood ratio (LR) reduced the rank test for the null hypothesis of at most r cointegrating vectors is given by the following Trace statistic, and for the null hypothesis of r against the alternative of r+1 cointegrating vectors is known as the maximal eigenvalue statistic

$$3\lambda_{trace} = -\mathrm{T}\sum_{i=r}^{m}\ln(1-\lambda_{i+1}) \quad , \qquad \lambda_{max} = -\mathrm{T}\ln(1-\lambda_{r+1}) \qquad (3)$$

where m is the maximum number of possible cointegrating vectors which is 3 in our case, in this paper, $r = 0, 1, 2$ and $\lambda_1 > \lambda_2 > \lambda_3$ denote eigenvalues of their corresponding eigenvectors $\mathrm{v} = (v_1, v_2, v_3)$.If the null hypothesis of r cointegrating vectors is accepted, then the rank of the $\mathbf{\Pi}$ matrix equal to r and there is exactly r cointegrating vector.

3.2.2 Granger Causality

Since our analysis presented in next section confirms that all the variables $M_t, D_t,$ and Y_t are $\mathrm{I}(1)$, academics and practitioners are interested in testing whether there is any causality relationship among the differences of the variables $M_t, D_t,$ and Y_t. We let $m_t = \Delta M_t$, $d_t = \Delta D_t$, and $y_t = \Delta Y_t$. This means that academics and practitioners are interested in testing whether there is any causality relationship among m_t, d_t, and y_t. Thus, in this paper we will test whether there is any linear Granger causality and thereafter examine whether there is any nonlinear Granger causality among the variables m_t, d_t, and y_t.

3.2.2.1 Linear Granger Causality

To test the linear causality relationship between two vectors of stationary time series, we set $x_t = (x_{1,t}, \dots, x_{n_1,t})'$ and $y_t = (y_{1,t}, \dots, y_{n_2,t})'$ say $x_t = (m_t, d_t)'$ and $y_t = (y_t)'$, where there are 3 series in total. Under this setting, one could construct the following vector autoregressive regression (VAR) model:

$$\begin{pmatrix} x_t \\ y_t \end{pmatrix} = \begin{pmatrix} A_{x[2\times1]} \\ A_{y[1\times1]} \end{pmatrix} + \begin{pmatrix} A_{xx}(L)_{[2\times2]} & A_{xy}(L)_{[2\times1]} \\ A_{yx}(L)_{[1\times2]} & A_{yy}(L)_{[1\times1]} \end{pmatrix} \begin{pmatrix} x_{t-1} \\ y_{t-1} \end{pmatrix} + \begin{pmatrix} e_{x,t} \\ e_{y,t} \end{pmatrix} \qquad (4)$$

where $A_{x[2\times1]}$ and $A_{y[1\times1]}$ are two vectors of intercept terms, $A_{xx}(L)_{[2\times2]}$, $A_{xy}(L)_{[2\times1]}$, $A_{yx}(L)_{[2\times1]}$, and $A_{yy}(L)_{[1\times1]}$ are matrices of lag polynomials, $e_{x,t}$ and $e_{y,t}$ are the corresponding error terms.

Testing the following null hypotheses: $H_0^1: A_{xy}(L) = 0$ and $H_0^2: A_{yx}(L) = 0$ is equivalent to testing the linear causality relationship between x_t and y_t.There are four different situations for the causality relationships between x_t and y_t in (1): (a) rejecting H_0^1 but not rejecting H_0^2 implies a unidirectional causality from y_t to x_t, (b) rejecting H_0^2 but not rejecting H_0^1 implies a unidirectional causality from x_t to y_t, (c) rejecting both H_0^1 and H_0^2 implies the existence of feedback relations, and (d) not rejecting both H_0^1 and H_0^2 implies that x_t and y_t are not rejected to be independent. Readers may refer to Bai, et al. (2010) for the details of testing H_0^1 and/or H_0^2.

If the time series are cointegrated, one should impose the error-correction mechanism (ECM) on the VAR to construct a vector error correction model (VECM) in order to test Granger causality between the variables of interest. In particular, when testing the causality relationship between two vectors of non-stationary time series, we let $\Delta x_t = (\Delta M_t, \Delta D_t)'$ and $\Delta y_t = (\Delta Y_t)'$ be the corresponding stationary differencing series such that there are 3 series in total. If x_t and y_t are cointegrated, then instead of using the VAR in (1), one should adopt the following VECM model:

$$\begin{pmatrix}\Delta x_t \\ \Delta y_t\end{pmatrix} = \begin{pmatrix}A_{x[2\times1]} \\ A_{y[1\times1]}\end{pmatrix} + \begin{pmatrix}A_{xx}(L)_{[2\times2]} & A_{xy}(L)_{[2\times1]} \\ A_{yx}(L)_{[1\times2]} & A_{yy}(L)_{[1\times1]}\end{pmatrix}\begin{pmatrix}\Delta x_{t-1} \\ \Delta y_{t-1}\end{pmatrix} + \begin{pmatrix}\alpha_{x[2\times1]} \\ \alpha_{y[1\times1]}\end{pmatrix} \cdot ecm_{t-1} + \begin{pmatrix}e_{x,t} \\ e_{y,t}\end{pmatrix} \quad (5)$$

where ecm_{t-1} is lag one of the error correction term, and $\alpha_{x[2\times1]}$ and $\alpha_{y[1\times1]}$ are the coefficient vectors for the error correction term ecm_{t-1}. There are now two sources of causation of $y_t(x_t)$ by $x_t(y_t)$, either through the lagged dynamic terms $\Delta x_{t-1}(\Delta y_{t-1})$, or through the error correction term ecm_{t-1}. Thereafter, one could test the null hypothesis $H_0 : A_{xy}(L) = 0\big(H_0 : A_{yx}(L) = 0\big)$ and/or $H_0 : \alpha_x = 0\big(H_0 : \alpha_y = 0\big)$ to identify Granger causality relation using the LR test.

3.2.2.2 Nonlinear Granger Causality

Bai, et al. (2010, 2011, 2018) and Chow, et al. (2018) extend the nonlinear causality test developed by Hiemstra and Jones (1994) and others to the multivariate setting. To identify any nonlinear Granger causality relationship from any two series, say $\{x_t\}$ and $\{y_t\}$ in the bivariate setting, one has to first apply the linear model to $\{x_t\}$ and $\{y_t\}$ to identify their linear causal relationships and obtain the corresponding residuals, $\{\hat{\varepsilon}_{1t}\}$ and $\{\hat{\varepsilon}_{2t}\}$. Thereafter, one has to apply a nonlinear Granger causality test to the residual series, $\{\hat{\varepsilon}_{1t}\}$ and $\{\hat{\varepsilon}_{2t}\}$, of the two variables being examined to identify the remaining nonlinear causal relationships between their residuals. This is also true if one would like to identify the existence of any nonlinear Granger causality relation between two vectors of time series, say $x_t = (x_{1,t}, \dots, x_{n1,t})'$ and $y_t = (y_{1,t}, \dots, y_{n2,t})'$ in the multivariate setting. One has to apply the VAR model or the VECM model to the series to identify their linear causal relationships and obtain their corresponding residuals. Thereafter, one has to apply a nonlinear Granger causality test to the residual series. For simplicity, in this section we denote $X_t = (X_{1,t}, \dots, X_{n1,t})'$ and $Y_t = (Y_{1,t}, \dots, Y_{n2,t})'$ to be the corresponding residuals of any two vectors of variables being examined. We first define the lead vector and lag vector of a time series, say $X_{i,t}$, as follows: for

$X_{i,t}$, i $= 1,2$, the m_{x_i}-length lead vector and the L_{x_i}-length lag vector of $X_{i,t}$ are:

$$X_{i,t}^{m_{x_i}} \equiv \left(X_{i,t}, X_{i,t+1}, \dots, X_{i,t+m_{x_i}-1}\right), m_{x_i} = 1,2, \dots, t = 1, 2, \dots,$$

$$X_{i,t-L_{x_i}}^{L_{x_i}} \equiv \left(X_{i,t-L_{x_i}}, X_{i,t-L_{x_i}+1}, \dots, X_{i,t-1}\right), L_{x_i} = 1, 2, \dots, \mathrm{t} = L_{x_i} + 1, L_{x_i} + 2, \dots,$$

respectively. We denote $M_x = \left(m_{x1}, \dots, m_{x_{n_1}}\right)$, $L_x = \left(L_{x1}, \dots, L_{x_{n_1}}\right)$, $m_x = \max\left(m_{x1}, \dots, m_{n_1}\right)$, and $l_x = \max\left(L_{x1}, \dots, L_{x_{n_1}}\right)$. The m_{y_i}-length lead vector, $Y_{i,t}^{m_{y_i}}$, the L_{y_i}-length lag vector, $Y_{i,t-L_{y_i}}^{L_{y_i}}$, of $Y_{i,t}$, and M_y, L_y, m_y, and l_y can be defined similarly.

Given m_x, m_y, L_x, L_y, and $e > 0$, we define the following four events:

$$\{\|X_t^{M_x} - X_s^{M_x}\| < e\} \equiv \left\{\left\|X_{i,t}^{M_{x_i}} - X_{i,s}^{m_{x_i}}\right\| < e, \text{for any } i = 1, \dots, n_1\right\};$$

$$\{\|X_{t-L_x}^{L_x} - X_{s-L_x}^{L_x}\| < e\} \equiv \left\{\left\|X_{i,t-L_{x_i}}^{L_{x_i}} - X_{i,s-L_{x_i}}^{L_{x_i}}\right\| < e, \text{for any } i = 1, \dots, n_1\right\};$$

$$\left\{\left\|Y_t^{M_y} - Y_s^{M_y}\right\| < e\right\} \equiv \left\{\left\|Y_{i,t}^{m_{y_i}} - Y_{i,s}^{m_{y_i}}\right\| < e, \text{for any } i = 1, \dots, n_2\right\}; and$$

$$\left\{\left\|Y_{t-L_y}^{L_y} - Y_{s-L_y}^{L_y}\right\| < e\right\} \equiv \left\{\left\|Y_{i,t-L_{y_i}}^{L_{y_i}} - Y_{i,s-L_{y_i}}^{L_{y_i}}\right\| < e, \text{for any } i = 1, \dots, n_2\right\};$$

where $\|\cdot\|$ denotes the maximum norm which is defined as $\|X - Y\| = \max(|x_1 - y_1|, |x_2 - y_2|, \dots, |x_n - y_n|)$ for any two vectors $X = (x_1, \dots, x_n)$ and $Y = (y_1, \dots, y_n)$. The vector series $\{Y_t\}$ is said not to strictly Granger cause another vector series $\{X_t\}$ if

$$Pr\left(\|X_t^{M_x} - X_s^{M_x}\| < e \middle| \|X_{t-L_x}^{L_x} - X_{s-L_x}^{L_x}\| < e, \left\|Y_{t-L_y}^{L_y} - Y_{s-L_y}^{L_y}\right\| < e,\right)$$

$$= Pr\left(\|X_t^{M_x} - X_s^{M_x}\| < e \middle| \|X_{t-L_x}^{L_x} - X_{s-L_x}^{L_x}\| < e\right) \quad (6)$$

where $\Pr(\cdot \mid \cdot)$ denotes conditional probability. Applying (6), one has to use the following test statistic to test for the nonlinear Granger causality:

$$\sqrt{n}\left(\frac{C_1(M_x+L_x,L_y,e,n)}{C_2(L_x,L_y,e,n)} - \frac{C_3(M_x+L_x,e,n)}{C_4(L_x,e,n)}\right) \quad (7)$$

Readers may refer to Bai, et al. (2010, 2011, 2018) and Chow, et al. (2018) for the details of the equation (7). Under this setting, Bai, et al. (2010, 2011) prove that to test the null hypothesis, H_0, that $\{Y_{1,t}, \dots, Y_{n2,t}\}$ does not strictly Granger cause $\{X_{1,t}, \dots, X_{n1,t}\}$, under the assumptions that the time series $\{X_{1,t}, \dots, X_{n1,t}\}$ and $\{Y_{1,t}, \dots, Y_{n2,t}\}$ are strictly stationary, weakly dependent, and satisfy the mixing conditions stated in Denker and Keller (1983), if the null hypothesis, H_0, is true, the test statistic defined in (7) is distributed as $N\left(0, \sigma^2(M_x, L_x, L_y, e)\right)$. When the test statistic in (7) is too far away from zero, we reject the null hypothesis. Readers may refer to Bai, et al. (2010, 2011, 2018) and Chow, et al. (2018) for the details of the consistent estimator of the covariance matrix.

The nonlinear causality test has the ability to detect a nonlinear deterministic process which originally "looks" random. The nonlinear causality test is a complementary test for the linear causality test as linear causality tests could not detect nonlinear causal relationship while the nonparametric approach adopted in this paper can capture the nonlinear nature of the relationship among variables.

From literature we note an interest in analyzing the cross-correlation relationship. For example, Podobnik and Stanley (2008) propose a detrended cross-correlation analysis (DXA) to investigate power-law cross-correlations between different simultaneously-recorded time series in the presence of non-stationarity. Podobnik, et al. (2009) introduce a joint stochastic process to model cross-correlations. In addition, using stock market returns from two stock exchanges in China, Ruan, et al. (2018) employ the MF-DCCA to investigate the non-linear cross-correlation between individual investor sentiment and Chinese stock market return. Zhang, et al. (2018) study the cross-correlations between Chinese stock markets and the other three stock markets. Xiong, et al. (2018) use a new policy uncertainty index to investigate the time-varying correlation between economic policy uncertainty and Chinese stock market returns. On the other hand, Wan and Wong (2001) develop a model to study the contagion effect. Cerqueti, et al. (2018) develop a model based on Mixed Poisson Processes to deal with the theme of contagion in financial markets. Wang, et al. (2018) propose a non-Markovian social contagion model in multiplex networks with inter-layer degree correlations to delineate the behavior of spreading, and develop an edge-based compartmental theory to describe the model. The nonlinear causality used in this paper could also be used to measure nonlinear cross-correlation to handle the nonlinear contagion effect. One could easily use or modify Equation (6) to deal with the nonlinear cross-correlation and the nonlinear contagion effect.

4. Empirical Analysis

In this section, we apply the econometrics tools described in Section 3 to the economic models stated in Section 2 on real data and test whether these models are valid with the data from developing countries. We first exhibit the summary statistics of M_t, D_t, Y_t where M, D, and Y are the logarithms of the ratio of bank deposit liabilities to nominal GDP (*M*), the ratio of claims on private sector to nominal GDP, and real GDP per capita, respectively, for each country. We notice from the summary statistics[3] that the means of the first financial development proxy (M) and the second financial development proxy (D) of different countries fall within relatively large ranges of [-3.308, 22.591] and [-1.983, 23.659] with an average of 0.449 and 1.729, respectively, while the economic growth proxy (Y) of different countries fall within a relatively small range of [-17.321, -8.210], with an average of -12.669. The summary statistics also demonstrate that all of the variables in most countries have a smaller variance than a standard normal distribution (12 out of 14 for both variables M and D, and all for variable Y). It is interesting to notice that slightly more than half of the first financial development proxy series are skewed to the right (8 out of 14), as are most of the second financial development proxy series (10 out of 14) while most of the economic growth proxy series are skewed to the left (10 out of 14).

4.1 Augmented Dickey-Fuller unit root test

Before the cointegration and causality analysis is conducted, we employ the most commonly used unit root test -- augmented Dickey-Fuller unit root test -- to test whether the variables, $M_t, D_t,$ and Y_t, used in this paper contain a unit root. The results are exhibited in Table 2, reader may refer to Chow, Vieito, and Wong (2018) for Table 2. From the table, the hypothesis of having a unit root in the original (level) series of the first financial development proxy (*M*), the second financial development proxy (*D*) and the economic growth proxy (*Y*) are not rejected for all countries. On the other hand, the hypothesis of having a unit root for the first differences of the first financial development proxy (*M*), the second financial development proxy (*D*) and the economic growth proxy (*Y*) are rejected for all countries. Thus, without exception, the

[3] To save space, we do not report the table but the results are available on request.

augmented Dickey-Fuller unit root test leads us to conclude that all three variables (*M*, *D,* and *Y*) are I (1) for all countries.

4.2 Johansen cointegration test

The cointegration and causality analysis cannot be carried out without first applying the Johansen cointegration test for the variables, $M_t, D_t,$ and Y_t, to examine whether there is any cointegration relationship among the variables, $M_t, D_t,$ and Y_t, for each country and the results are displayed in Table 2. The number of lags to introduce in the Johansen cointegration test is a key decision, and various informational criteria could recommend different lag lengths for the explanatory variable and different criteria could lead to conflicting results. To circumvent the limitation, we use lag one to lag four in applying the Johansen cointegration test for each country. From the table, the null hypothesis of no cointegration among the first financial development proxy (M), the second financial development proxy (D) and the economic growth proxy (Y) is rejected by at least half of the test statistics at ten percent significant level in all countries except Brazil, El Salvador, Guatemala, India, Malaysia, Peru, and Sri Lanka. For Brazil, El Salvador, Guatemala, India, Malaysia, Peru, and Sri Lanka, more than half of the test statistics suggest that the null hypothesis of no cointegration is not rejected. In particular, eight out of eight test statistics suggest that the null hypothesis of no cointegration is not rejected in Malaysia. Thus, the Johansen cointegration test leads us to conclude that M, D, and Y are conintegrated in some countries but not in other countries. In particular, we conclude that for Chile, China, Costa Rica, Pakistan, South Africa, Thailand, and Turkey, M, D, and Y are cointegrated. However, for Brazil, El Salvador, Guatemala, India, Malaysia, Peru, and Sri Lanka, M, D, and Y are not cointegrated.

4.3 Engle–Granger based cointegration test

We next conduct the Engle–Granger two-step cointegration test as a complementary analysis of the Johansen cointegration test and report the results in Tables 3 and 4 for each of the countries for different pairs of variables. Table 3 (reader may refer to Chow, Vieito, and Wong (2018) for

Table 3) suggests that a cointegration relationship between the first financial development proxy (M) and the economic growth proxy (Y) exists for Chile, China, South Africa, and Sri Lanka while Table 4 (reader may refer to Chow, Vieito, and Wong (2018) for Table 4) suggests that a cointegration relationship between the second financial development proxy (D) and the economic growth proxy (Y) exists for Pakistan, South Africa, and Turkey at ten percent significant level. The results are consistent with those from the Johansen cointegration test.

To obtain more details, results from Tables 3 and 4 are further analyzed: a cointegration relationship between the first financial development proxy (M) and the economic growth proxy (Y) and between the second financial development proxy (D) and Y is only found for South Africa. There is also a cointegration relationship only between M and Y for Chile, China, and Sri Lanka and finally a cointegration relationship only between D and Y is found for Pakistan, South Africa, and Turkey at ten percent significant level. In addition, there is no cointegration relationship between M and Y and between D and Y for Brazil, Costa Rica, El Salvador, Guatemala, India, Malaysia, Peru, and Thailand.

4.4. Multivariate linear Granger Causality

As some pairs of variables are cointegrated while others are not, we employ both VAR and VECM models to the multivariate linear Granger causality for the corresponding countries' data. More specifically, Brazil, El Salvador, Guatemala, India, Malaysia, Peru and Sri Lanka are modeled by the VAR model and Chile, China, Costa Rica, Pakistan, South Africa, Thailand and Turkey are modeled by the VECM. The multivariate linear Granger causality test is applied to test the following two hypotheses: 1) (both first and second proxies of) financial development does not linearly Granger cause economic growth ($H_0: M, D \nRightarrow Y$); 2) economic growth does not linearly Granger cause (both first and second proxies of) financial development ($H_0: Y \nRightarrow M, D$). The results are showed in Table 5 (reader may refer to Chow, Vieito, and Wong (2018) for Table 5).

As the number of lags to introduce is an important issue in the test and various informational criteria could lead to conflicting results, we apply the null hypothesis of no linear Granger causality test in all of the countries' data from lag one to lag four. Since we are dealing with annual data, this implies that we account for lead-lag effects up to four years.

The results displayed in Table 5 demonstrate that 13 out of 14 countries appear to have linear Granger causal relationship between (both first and second proxies of) financial development and economic growth. The hypothesis of no linear Granger causality from (both first and second proxies of) financial development to economic growth is rejected in the case of Brazil, Chile, El Salvador, Guatemala, India, Malaysia, Peru, and Sri Lanka at ten percent significant level. The rejection results are strong in all nine countries in a sense that null hypothesis is rejected in at least two out of four different lags. As for the opposite direction, there are five countries for which the test statistics suggest that there is linear Granger causality from economic growth to (both first and second proxies of) financial development, namely Chile, China, Malaysia, Thailand and Turkey. These results are also strong in the same manner, inferring that economic growth linear Granger cause (both first and second proxies of) financial development at ten percent significant level. The results infer that in most (all except 2) of the countries under analysis (both first and second proxies of) financial development linear Granger cause economic growth. On the other hand, in only one third of countries under analysis, economic growth linear Granger causes (both first and second proxies of) financial development.

4.5 Bivariate Linear Granger Causality

As a complementary analysis of the Multivariate linear Granger causality tests for all 14 countries, Tables 6 and 7 show the results of bivariate linear Granger causality tests for each of the countries for different pairs of variables. The results in Table 6 (reader may refer to Chow, Vieito, and Wong (2018) for Table 6) suggest that there is a linear Granger causality relationship from the first financial development proxy to economic growth proxy for 5 countries (Chile, India, Malaysia, Peru, and Turkey), while the inverse (a causality relationship from the economic growth proxy to the first financial development proxy) only holds true for 2 countries (Chile and China). On the other hand, Table 7 (reader may refer to Chow, Vieito, and Wong (2018) for Table 7) suggests that there is a linear Granger causality relationship from the second financial development proxy to economic growth proxy for only Turkey, while a causality relationship from economic growth proxy to the second financial development proxy exists for 4 countries (India, Malaysia, Peru, and Thailand).

Based on results, the following is a detailed summary of information obtained for the first financial development proxy: There is a strong bidirectional linear Granger relationship between economic growth and the first financial development proxy for Chile, Peru, and China. The first financial development proxy strongly linear Granger causes economic growth, but economic growth weakly linear Granger causes the first financial development proxy for Turkey. There is a strong unidirectional linear Granger relationship from the first financial development proxy to economic growth for India, Malaysia, El Salvador, and Thailand. Guatemala, on the other hand presents a weak unidirectional linear Granger relationship from the first financial development proxy to economic growth. There is a weak unidirectional linear Granger relationship from economic growth to the first financial development for Sri Lanka. And lastly, there is no linear Granger relationship between economic growth and the first financial development proxy for Brazil, Costa Rica, Pakistan, and South Africa.

The summary of detailed information obtained for the second financial development proxy is as follows: No bidirectional linear Granger relationship between economic growth and the second financial development proxy is found for any country. There is however a strong unidirectional linear Granger relationship from the second financial development proxy to economic growth for Turkey. We notice that there are more linear causalities from the first financial development proxy than from the second financial development proxy to economic growth and the number of linear causality from economic growth to the first financial development is about the same as those to the second financial development proxy. However, the causality could be completely different. For example, economic growth strongly linear Granger causes the first financial development proxy but does not linear cause the second financial development proxy for Chile. Economic growth strongly linear Granger causes the second financial development proxy but does not linear cause the first financial development proxy for Thailand. Economic growth strongly linearly Granger causes second financial development proxy but second financial development proxy not linearly Granger causes economic growth for India, Malaysia, Peru, and Thailand. Second financial development proxy weakly linearly Granger causes economic growth but economic growth proxy not linearly Granger causes financial development for El Salvador and South Africa. Economic growth weakly linearly

Granger causes second financial development proxy but second financial development proxy not linearly Granger causes economic growth for China. Second financial development proxy does not linearly Granger cause economic growth and economic growth does not linearly Granger cause second financial development proxy for Brazil, Chile, Costa Rica, Guatemala, Pakistan and Sri Lanka.

4.6 Multivariate Nonlinear Granger causality test

Many studies, among which Chiang, et al. (2009), Qiao, et al. (2008, 2009), and Owyong, et al. (2015), have found that linear causality and nonlinear causality are independent from one another in the sense that certain variables may present a linear causality while others a nonlinear causality. It is thus advisable to test for nonlinear causality following the testing for linear causality.. Thus, examination of nonlinear causality is important after examination of linear causality among some variables. We note that before examining whether there is any nonlinear causality among the variables, it is good to examine whether there is any nonlinearity in the residuals of fitting linear causality. In this paper, we have employed the latest powerful nonlinearity test (Hui, et al., 2017) in the residuals of fitting linear causality. We omit reporting the results for simplicity.

We apply the multivariate nonlinear Granger causality test to the residuals obtained from using either VAR or VECM to the logarithm of the ratio of bank deposit liabilities to nominal GDP (M) and the logarithm of the ratio of claims on private sector to nominal GDP (D) and the logarithm of real GDP per capita (Y) and exhibit the results in Table 3. In the table, lags denote the number of lags on the residuals series used in the test. The results shows that 12 out of 14 countries appear to have nonlinear Granger causal relationship between (both first and second proxies of) financial development and economic growth. There are eight countries for which at least half of the test statistics suggest that (both first and second proxies of) financial development nonlinearly causes economic growth, namely *Brazil, Chile, Guatemala, Malaysia, Peru, Sri Lanka, and Turkey*. The results again are strong in all eight countries in a sense that null hypothesis is rejected in at least two out of four different lags. On the other hand, there are nine countries for which the test statistics suggest that economic growth nonlinearly causes (both first and second proxies of) financial development, namely *Brazil, Chile, China, India, Peru, South*

Africa, Sri Lanka, and Thailand. However, strong results only appear in *Brazil, India, Peru, and South America*.

We now present more detailed information on the relationship as follows: A bi-directional nonlinear Granger causal relationship is present in a strong sense for Brazil and Peru. Financial development strongly Granger causes economic growth nonlinearly but economic growth weakly Granger causes financial development nonlinearly for both Chile and Sri Lanka. Economic growth strongly Granger causes financial development nonlinearly but financial development weakly Granger causes economic growth nonlinearly for India. Financial development strongly Granger causes economic growth nonlinearly but economic growth does not nonlinearly Granger cause financial development for Guatemala, Malaysia, and Turkey. Economic growth strongly Granger causes financial development nonlinearly but financial development does not Granger cause economic growth nonlinearly for South Africa. Economic growth weakly Granger causes financial development nonlinearly but financial development does not Granger cause economic growth nonlinearly for both China and Thailand. There is no nonlinear causality between financial development and economic growth for Costa Rica, El Salvador, and Pakistan.

4.7 Bivariate Non-Linear Granger Causality

Again, and as a complementary analysis of the multivariate nonlinear Granger causality tests in our analysis, Tables 9 and 10 exhibit the results of the individual nonlinear Granger causality tests for each of the countries for different pairs of variables. Table 9 suggests that a nonlinear Granger causality relationship exists from the first financial development proxy to economic growth proxy for Brazil, Chile, and Peru, while there is causality relationship from economic growth proxy to the first financial development proxy for Chile, Guatemala, and Thailand. On the other hand, Table 10 (reader may refer to Chow, Vieito, and Wong (2018) for Table 10) suggests that a nonlinear Granger causality relationship exists from the second financial development proxy to economic growth proxy for Guatemala, Malaysia, and Turkey, and there is causality relationship from economic growth proxy to the second financial development proxy for Chile, India, Pakistan, Peru, and South Africa.

We now present more detailed information on nonlinear causality for the first financial development proxy as follows: There is strong evidence of a bidirectional nonlinearly Granger relationship between economic growth and the first financial development proxy for Chile. The first financial development proxy strongly Granger causes economic growth nonlinearly but economic growth weakly Granger causes the first financial development proxy nonlinearly for both Brazil and Peru. Economic growth strongly Granger causes the first financial development proxy nonlinearly but the first financial development proxy does not Granger cause economic growth nonlinearly for both Guatemala and Thailand. The first financial development proxy weakly Granger causes economic growth nonlinearly but the economic growth proxy does not Granger cause financial development nonlinearly for Costa Rica, Pakistan, and Sri Lanka. Economic growth weakly Granger causes the first financial development proxy nonlinearly but the first financial development proxy does not nonlinearly Granger cause economic growth nonlinearly for China, Malaysia, and South Africa. There is no nonlinear causality between the first financial development and economic growth for El Salvador, India, and Turkey.

We turn to present more detailed information in nonlinear causality for the second financial development proxy as follows. The second financial development proxy strongly Granger causes economic growth nonlinearly but economic growth weakly Granger causes the second financial development proxy nonlinearly for Malaysia. Economic growth strongly Granger causes the second financial development proxy nonlinearly but the second financial development proxy weakly Granger causes economic growth nonlinearly for Chile, Pakistan, Peru, and South Africa. The second financial development proxy strongly Granger causes economic growth nonlinearly but economic growth does not Granger cause the second financial development proxy nonlinearly for both Guatemala and Turkey. Economic growth strongly Granger causes the second financial development proxy nonlinearly but the second financial development proxy does not Granger causes economic growth nonlinearly for India. The second financial development proxy weakly Granger causes economic growth nonlinearly but the economic growth proxy does not Granger cause financial development nonlinearly for Brazil, Sri Lanka, and Thailand. There is no nonlinearly Granger relationship between economic growth and the second financial development proxy for China, Costa Rica, and El Salvador.

We summarize the results of our bivariate linear and nonlinear causality tests in Table 11, reader may refer to Chow, Vieito, and Wong (2018) for Table 11.

From the table, we conclude that there are bidirectional (linear or nonlinear) relationships between financial development and economic growth for most of the countries studied in our paper, economic growth leads to financial development in both Costa Rica and South Africa, financial development has a positive effect on economic growth for Guatemala, and no causality between financial development and economic growth in Pakistan.

5. Inference

In this paper, we draw inference on cointegration and causality. We first draw inference on cointegration.

5.1 Cointegration

We first find that financial development and economic growth are cointegrated in some countries but not in others. From Tables 3 and 4, we find that cointegration relationships are present between both M and Y and between D and Y only in South Africa. There is a cointegration relationship only between M and Y for Chile, China, and Sri Lanka and a cointegration relationship only between D and Y for Pakistan, South Africa, and Turkey at ten percent significant level. In addition, no cointegration relationship is found between M and Y and between D and Y for Brazil, Costa Rica, El Salvador, Guatemala, India, Malaysia, Peru, and Thailand.

Readers may ask the following questions: (1) could the cointegration between financial development and economic growth in a country imply that both demand-following and supply-leading theories hold for the country? and (2) why are financial development and economic growth cointegrated in some countries but not in other countries?

To answer these, the following hypothesis are tested:

H_0^3: financial development and economic growth are not positively cointegrated.

versus

H_1^3: financial development and economic growth are positively cointegrated.

Rejection of H_0^3 or acceptance of H_1^3 implies that financial development and economic growth are positively cointegrated. We suggest that there is either a cointegration relationship between the first financial development proxy (M) and the economic growth proxy (Y) or between the second financial development proxy (D) and Y, and conclude that there is a cointegration relationship between financial development and economic growth. In this paper we make the following conjecture:

Conjecture 1: *If there is a positive cointegration relationship between financial development and economic growth in a country, then both demand-following and supply-leading theories hold for that country.*

The reasoning behind Conjecture 1 is that since financial development and economic growth are cointegrated, financial development and economic growth move positively together. If a Government could boost its economic growth, then its financial development would also expand, implying that the supply-leading hypothesis holds. On the other hand, if a Government could expand its financial development, then its economic growth would also boom, implying that the demand-following hypothesis holds. We note that if financial development and economic growth are not cointegrated positively in a country, then one cannot conclude that both demand-following and supply-leading theories do not hold for the country. To make such a strong conclusion, we need to examine their (linear and nonlinear) causality as well. We will discuss this issue later on. In addition, we conclude that financial development and economic growth move together positively if there is any positive cointegration from any of the proxies of financial development, including the first financial development proxy (M) and the second financial development proxy (D), and any proxy of economic growth, which for the purpose of this analysis, only the economic growth proxy (Y) is used where M, D, and Y are the logarithms of the ratio of bank deposit liabilities to nominal GDP (*M*), the ratio of claims on private sector to nominal GDP, and real GDP per capita, respectively, for each country. We also note that the proxies of financial development and economic growth are not limited to M, D, and Y, but could also include any new proxy of financial development or economic growth that economists may encounter in the future. However, as far as we know, to date only M, D, and Y are being used as proxies of financial development and economic growth, respectively. Thus, from Tables 3 and 4 (or from Table 11), we can reject H_0^3 and conclude that *financial development and economic growth move positively together and both demand-following and supply-leading theories work for Chile, China, Pakistan, South Africa, Sri Lanka, and Turkey.*

As far as the second question of why financial development and economic growth are cointegrated in some countries but not in others, this analysis is unable to provide an answer to the second question as this is an applied econometric study and not a theoretical economic research paper. Nonetheless, we believe that there could be some factors, say, Fi, i=1,...,p in financial development and some factors, say, Ej, j=1,...,q in economic growth that could be related to one another. It could be an interesting topic for further research, to investigate whether there are some pairs (Fi, Ej) which are cointegrated while others (Fi, Ej) are not. Financial development and economic growth could be cointegrated in a specific country, say, Country A, due to the existence of cointegrated factors (Fi, Ej) in Country A, while in another country, say, Country B, financial development and economic growth may not be cointegrated because there is no cointegrated factors (Fi, Ej) in Country B. Instead, which not be cointegrated. Country B obtain all (Fi, Ej)'s that are not cointegrated.

5.2 Causality

As discussed in Section 3.2, the following two hypotheses are tested:

H_0^1: financial development does not cause economic growth, and

H_0^2: economic growth does not cause financial development.

Unlike other approaches employed by other researchers such as Horng, et al. (2012) and Fan, et al. (2018) who employ linear causality to study whether there is any unidirectional or bidirectional causality between financial development and economic growth, in this paper we set the following hypotheses:

H_0^1: financial development does not cause economic growth if there is no linear and no nonlinear causality from financial development to economic growth. Similar hypothesis are set for H_0^2,

and set H_1^1 that the financial development causes economic growth if there is any linear and/or nonlinear causality from financial development to economic growth. In addition, we conclude that financial development causes economic growth if there is any linear and/or nonlinear causality from any of the proxies of financial development, including the first financial development proxy (M) and the second financial development proxy (D), to any proxy of economic growth, which, for the purpose of this analysis, only the economic growth proxy (Y) is was used. We also note that the proxies of financial development and economic growth are not limited to M, D, and Y, but may include any other existing proxy or any new proxy of financial development or economic growth that economists may find in the future.

Based on the results displayed in Tables 6, 7, 9, and 10 (or from Table 11), H_0^1 is rejected and we conclude that financial development does cause economic growth and consequently the supply-leading hypothesis holds true; in other words, either M or D or both cause Y, for Brazil, Chile, China, El Salvador, Guatemala, India, Malaysia, Peru, Sri Lanka, and Turkey. However, H_0^1 may be valid and we may conclude that financial development does not cause economic growth and consequently the supply-leading hypothesis does not hold true; in other words that both M or D do not cause Y, for Costa Rica, Pakistan, South Africa, and Thailand if both linear and nonlinear causality tests are employed. If one adopts the traditional approach to include only linear causality, then one could accept H_0^1 and conclude that *financial development does not cause economic growth and consequently the supply-leading hypothesis does not hold for Costa Rica, Pakistan, South Africa, Thailand, and Turkey. This implies that if one adopts the approach we proposed to include both linear and nonlinear causality to determine whether the supply-leading hypothesis holds true, then one more country (Turkey) is included.*

H_0^2 is rejected and we conclude that economic growth does cause financial development consequently validating the demand-following hypothesis. In other words, Y causes either M or D or both for Brazil, Chile, China, Costa Rica, El Salvador, India, Malaysia, Peru, South Africa, Sri Lanka, Thailand, and Turkey. However, only in the case of Guatemala and Pakistan, we do not reject H_0^2 and conclude that economic growth does not cause financial development consequently denying the demand-following hypothesis. If one adopts the traditional approach to include only linear causality, then one can accept H_0^2 and conclude the demand-following hypothesis does not hold true for *Brazil*, Guatemala, *India*, Pakistan, *South Africa*, and *Sri Lanka*. If, however, the approach proposed to include *both linear and nonlinear causality is used, then the demand-following hypothesis holds true for four more countries: Brazil, India, South Africa, and Sri Lanka.*

Thus, if one adopts the proposed approach to include both linear and nonlinear causality to determine if the supply-leading and demand-following hypotheses hold true, then only *Pakistan* is rejected and both hypotheses are true for five more countries: *Turkey, Brazil*, *India*, *South Africa*, and *Sri Lanka*. In addition, if the approach we proposed to include both cointegration as well as linear and nonlinear causality is adopted to determine whether the supply-leading and demand-following hypotheses hold true, then six more countries would be included: *Pakistan, Turkey, Brazil*, *India*, *South Africa*, and *Sri Lanka* and we could conclude that either supply-leading or demand-following hypotheses or both hold for all countries without exception. This is a very strong finding that we believe has not been reported to date by any other study. This leads us to further *conclude that somehow there will be some relationships between economic growth and financial development for any country such that either they move together or economic growth causes financial development or financial development causes economic growth without any exception.*

One may ask *why both demand-following and supply-leading theories hold for most of the countries studied in their paper, with the former theory holding true for both Costa Rica and South Africa, and the latter for Guatemala, and neither for Pakistan. Our answer is similar to the one provided in cointegration, more specifically* since our paper is an applied econometric paper and not a theoretical economic paper, we are unable to provide an answer to this question. However, we believe that there may be some factors, say, Fi, i=1,...,p in financial development and some factors, say, Ej, j=1,...,q in economic growth which could cause one another. It could be an interesting topic in the extension to study whether there are some pairs (Fi, Ej) that (a) Fi and Ej cause each other (linearly or nonlinearly), (b) Fi causes Ej (linearly or nonlinearly), (c) some other pairs (Fi, Ej) that Ej causes Fi (linearly or nonlinearly), and (d) the rest of pairs (Fi, Ej) such that Ej and Fi do not cause each other. Thus, if any country, say, Country A, in which both demand-following and supply-leading theories hold true, this means that there should have at least one pair of (Fi, Ej) that belongs to (a), if only the supply-leading hypothesis holds true for another country, say Country B, this means that there is no pair of (Fi, Ej) that belongs to (a) and (c) while there is at least one pair of (Fi, Ej) that belongs to (b), similarly, if only the *demand-following theory holds* for a country, say Country C, this means that there is no pair of (Fi, Ej) that belongs to (a) and (b) while there is at least one pair of (Fi, Ej) that belongs to (c). Lastly, if none of the *demand-following and supply-leading theories hold* for a given country, say Country D, this means that there is no pair of (Fi, Ej) that belongs to (a), (b) and (c) and all pairs of (Fi, Ej) for Country D belong to (d).

One may wonder why some countries have causality, but no cointegration, while others have cointegration but no causality, and the rest have both causality and cointegration. Our answer is similar to our answer provided above: since our paper is an applied econometric paper, not a theoretical economic paper, our paper is not be able to provide an answer to this question. However, we believe that for each class (a) to (d) in the above, we can further partition each, say Class (a) into two parts – one part is (a1) in which all pairs (Fi, Ej) are cointegrated with each other while in another part (a2) all pairs (Fi, Ej) are not cointegrated with each other. Then, if a country, say Country E, in which all pairs (Fi, Ej) belong to (a1), then Fi and Ej in Country E are cointegrated as well as cause each other (linearly or nonlinearly). However, if a country, say Country F, in which all pairs (Fi, Ej) belong to (a2), then Fi and Ej in Country F are not cointegrated but cause each other (linearly or nonlinearly). Similar arguments can be made to partituion (b), (c), and (d) into (b1), (c1), and (d1) and (b2), (c2), and (d2). This could also explain why the (cointegratin and/or causality) results hold in some countries and not in others. This may also explain why there is a bidirectional relationship in some countries and only a unidirectional relationship in others and no relationship in yet other countries.

One may question why including a nonlinear test allow us to detect causality in five more countries. In the above, we can further partition each class, say (a) into two other groups (ai) and (aii) such that Fi and Ej cause each other linearly when (Fi, Ej) belongs to (ai) and Fi and Ej cause each other nonlinearly when (Fi, Ej) belongs to (aii) and for some countries, for example, for *Turkey, Brazil*, *India*, *South Africa*, and *Sri Lanka*, there are only nonlinear causality relationships for their *economic growth and financial development but there is no linear causality for either from economic growth to financial development or from financial development to economic growth. Thus, when we include nonlinearity to measure their causality relationship, we have 5 more counts.*

6. Conclusion

Since financial sectors have witnessed a strong growth trend for many countries in the last few decades, it is important to examine the relationship between financial development and economic growth and test whether economic growth causes financial development or financial development causes economic growth. The relationship can be explained by both demand-following and supply-leading theories. The demand-following theory suggests that financial development will lead to economic growth while the supply-leading theory suggests that financial development has a positive effect on economic growth. The findings of whether economic growth causes financial development or financial development causes economic growth is important as the results could help governments, politicians, and other international institutions to determine the best polices to help the development of the countries and reduce poverty.

Other studies which have examined whether economic growth causes financial development or financial development causes economic growth have employed linear causality tests. However, the limitations of this approach in the literature is that this test alone does not take into consideration the dependent, joint, and nonlinear effects among the variables. To circumvent the limitation, in this paper we employ the (multivariate) linear and nonlinear causality tests to conclude that there are either linear and nonlinear causal relations between financial development and economic growth in the 13 developing countries including Brazil, Chile, China, Costa Rica, El Salvador, Guatemala, India, Malaysia, Pakistan, Peru, South Africa, Sri Lanka, Thailand, and Turkey. The multivariate nonlinear causality tests not only consider both dependent and joint effects among the variables, but is also able to detect whether this is any nonlinear causal relationship among the variables. In addition, we suggest using cointegration to examine whether there is any co-movement between financial development and economic growth and use all the proxies of financial development and economic growth to study the relationship between financial development and economic growth.

Our findings from both the Johansen cointegration and Engle–Granger two-step cointegration tests lead us to conclude that financial development and economic growth are conintegrated positively in some countries but not in others. This suggests that financial development and economic growth could move together positively in some countries but not in others and thus, the demand-following and the supply-leading theories may hold in some countries but not in other countries. To test whether the demand-following and the supply-leading hypotheses are not rejected, we recommend to use both bivariate and multivariate linear and nonlinear causality tests. The results of our multivariate linear and nonlinear causality tests are consistent with that of our bivariate linear and nonlinear causality tests. The results of our bivariate linear and nonlinear causality tests conclude that both demand-following and the supply-leading theories hold for most of the countries studied in our paper except for Costa Rica, Guatemala, Pakistan, South Africa in which only the demand-following theory holds true for both Costa Rica and South Africa, and only the supply-leading theory holds for Guatemala, and neither demand-following nor supply-leading theories hold for Pakistan.

Based on the obtained results we recommend that further studies include nonlinear tests to study the relationship between financial development and economic growth. Without nonlinear tests, one would conclude that the supply-leading theory does not hold for Turkey and the demand-following theory does not hold for Brazil, India, South Africa, and Sri Lanka; but, this is not true if nonlinear tests are used and included in the analysis. The inclusion of nonlinearity in testing both the demand-following and the supply-leading hypotheses is important. Thus, we recommend that future studies apply not only bivariate linear and nonlinear causality but also multivariate linear and nonlinear causality in their analysis to account for both dependent and joint effects among variables. More importantly, if nonlinearity and regime changes occur in the data among the variables of concern, one must rely on nonlinear tests instead of linear test. Therefore, by using both linear and nonlinear bivariate and multivariate causality tests, one is able to obtain further evidence on whether economic growth predicts financial development and financial development predicts economic growth. It is very important to understand if it is the financial development which will lead to economic growth in these countries, the inverse situation, or if the causality is a bi-directional relationship. This could help governments, politicians, and other international institutions to adopt the best practices in their decision-making to help in the development of the countries and reduce poverty.

However, despite adopting the approach to include both linear and nonlinear causality to determine if the supply-leading and demand-following hypotheses hold true, these hypothesis are still rejected for one country – Pakistan..

It is implausible to consider that there is no relationship between financial development and economic growth in any country. To solve this problem, we recommend that, in addition to using both (multivariate) linear and nonlinear causality to study the causality relationship, cointegration should also be used to study the relationship between financial development and economic growth. If this approach is adopted, results demonstrate that either supply-leading or demand-following hypotheses or both hold true for all countries without any exception. This is a very strong finding which we believe has not been presented in literature *The findings demonstrate that there will always be some types of relationships between economic growth and financial development such that either they move together or economic growth causes financial development or financial development causes economic growth without any exception.*

There are many applications for our findings and the government and/or politicians could benefit from the results. *F*or example, if a country, say Country A, finds that in their country financial development and economic growth are cointegrated or there is a bidirectional relationship between financial development and economic growth, then they can either boost financial development or economic growth or both. However, if in another country, say Country B, they find that their financial development and economic growth are not cointegrated and there is only an unidirectional relation from, say, financial development to economic growth, then they can concentrate on boosting their financial development which, in turn, will increase their economic growth.

One may question whether the supply-leading or demand-following theories are correct or not and whether the employed proxies are sufficient to reflect the hidden causality. The supply-leading or demand-following theories have been used since Robinson (1952) and others have used the theory and, many authors have used the same proxies of financial development and economic growth since Demetriades and Hussein (1996). To our knowledge, neither the theory nor the proxies have been rejected However, it is a good idea to doubt whether the theory works and improve the theory and doubt whether the proxies are good enough and propose better proxies. This is a good extension to the study but it is beyond the scope of our paper.

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