Revisiting the nexus of the financial development and economic development: new international evidence using a wavelet approach

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Abstract

This study investigates Granger causality and instantaneous causality between financial development and economic development for 76 economies of four different income levels. The main novelty of the study is that it fills a gap in existing studies on the relationship between financial development and economic development by employing wavelet analysis, which enables us to study the varying timescale relationships of the variables. Among the findings is that at the scale of 4–8 years, it is more common for financial development and economic development to support each other once a country achieves at least lower-middle-income status.

Keywords Financial development · Economic development · Economic growth · Causality · Timescales · Wavelet decomposition

JEL Classifications G20 · C32 · O40

1 Introduction

The aim of this paper is to investigate Granger causality and instantaneous causality between financial development and economic development at different time horizons by using a novel approach, wavelet analysis. According to economic theory, it is impor-

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tant to consider different time horizons when studying the nexus between financial development and economic development. In the long-run, well-functioning financial markets arguably should foster economic development as is stressed in endogenous growth theory, while in the short run, an expanding financial market can be linked to credit crisis as the banking and currency literatures have found. Another strand of literature, in contrast, states that it is during the short run that higher levels of financial development benefit the real economy while the effects of financial market development disappear in the long run as the economy grows and matures. Therefore, based on theory, it is clear that empirical studies on the financial development and economic development (or growth) nexus should carefully incorporate the issue of time horizons.

In this paper, we investigate the relationship between financial depth (measured by liquid liabilities as a percentage of GDP) and real GDP per capita at various time scales. This investigation is performed for sets of countries at various levels of economic development. The traditional time-series methods for studying the relationship of the variables for the long-run and the short run, cointegration testing and error-correction models, were not very useful for our investigation since unit-root test results for financial depth were ambiguous while those for real GDP per capita were predominantly in favor of a unit-root process across all the test methods used. First differencing is often used as a remedy for turning the non-stationary variables into stationary ones, but by doing so information is lost so that only the shortest-scale relationships can be investigated. Given the data properties of the variables in the study, wavelet analysis (as discussed by Ramsey and Lampart (1998)) is used in this paper to examine the relationship between financial depth and real GDP per capita at different time horizons. Wavelet analysis has advantages in simultaneously controlling the problems of nonstationarity, autocorrelation and structural breaks (Ramsey and Lampart 1998; Schleicher 2002; Benhmad 2012 among others).

Different perspectives on the relationships between financial development and economic growth trace back to Schumpeter (1911) and Robinson (1952).[1] While Schumpeter (1911) mainly focused on the role of credit markets in financing new production technologies for entrepreneurs, thereby asserting that a well-developed financial system promotes economic growth, Robinson (1952) contended that financial development is what follows passively as a result of economic growth. These two different perspectives relate to the issue of causality between financial development and economic development. Theoretical supports for the two possible causal directions are explained by two hypotheses proposed Patrick (1966): the supply-leading and the demand-following hypothesis. The supply-leading hypothesis asserts a causal direction from financial development to economic growth since the former contributes to the latter by enabling the supply of financial services growth with deliberate creation of financial institutions. According to this view, governmental activities for establishing and promoting financial institutions in many less developed economies might reflect the belief that a greater supply of the financial services would enhance eco-

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[1] Literature included in this paragraph is focused on the role of financial intermediaries in the financial system. The functions of financial system, however, fall within a broader spectrum including those of equity markets, for instance. Theoretical and empirical studies hence stress competing or complementary roles of equity markets and banks. See Levine (2005) for a through literature review on the nexus between finance and growth.

nomic growth. Gurley and Shaw (1960), Goldsmith (1969) and Hicks (1969) are early works that argue that a financial system is crucially important in expanding the real sector (Ang 2008).[2] In contrast, the demand-following hypothesis presupposes a causal relationship from economic growth to financial development, translating passive responsiveness of the financial sector to economic growth. This means that the less developed financial systems of developing countries are simply due to the lack of demand for financial services. This view would support having policies that increase the demand for financial services, which would be attained by boosting the real economy. An early work supporting this hypothesis is Jung (1986).

Financial development involves various functions of financial systems,[3] leading to a broad spectrum of measures on financial development such as size, activity, efficiency, stability of banking institutions and financial market openness and so on (Beck et al. 2000). Policy determinants on financial development such as legal and regulatory frameworks are beyond the scope of this paper, and thus we do not tackle the question of choosing the most appropriate institutional environment for healthy financial and economic development. Most measures regarding legal and regulatory frameworks are qualitative data for which numeric differences in the data are not meaningful, making wavelet analysis of such data impossible. With wavelet-filtered data on liquid liabilities as a percentage of GDP and logged real GDP per capita, we employ vector autoregressive (VAR) models. In this framework, some omitted-variable issues (such as exclusion of legal and regulatory frameworks) are handled by including lagged dependent variables as explanatory variables.

In sum, this study extends the financial development literature by providing an assessment of empirical evidence on the causal relationship between financial development and economic development at different time scales for sets of countries at different income levels. The observed data are the outcomes of mixtures of activities and expectations that occur at different scales of time, so timescale decomposition through wavelet analysis can help in finding relationships that would otherwise be hidden[4] There are various hypotheses we are investigating in this paper, associated with the affirmative to each of the following questions:

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[2] This line of thinking is dubbed as 'financial structuralist view'. In the 1970s, McKinnon (1973) and Shaw (1973) developed the early ideas of the financial structuralist view. The Mckinnon model, with an assumption of self-financed economy, emphasized the role of financial intermediaries that allow accumulating sufficient saving for investment and thus economic growth. Shaw (1973) presented a view that financial intermediation promotes economic growth. These two views suggest that an increase in output growth is caused by financial development, which can be a result of financial liberalization (Ang 2008). Therefore, the supply-leading hypothesis, overall, has an implication on financial policies regarding financial liberalization.

[3] Financial development takes place when the problems of information asymmetries and transactions costs are reduced with financial instruments, markets, and intermediaries (Levine 2005).

[4] As discussed by Ramsey and Lampart (1998), wavelet analysis is a very useful tool in investigating relationships of the variables at a scale-by-scale basis because most economic time series consist of different layers that arise from diverse time horizons being used in decision-making by market participants. As an example, long-term traders, day traders, and intraday traders all participate in trading currencies, and exchange rates are the result of aggregating these traders' activities. Thus, failing to look at the movement of the variable at disaggregate (scale) levels would mask the time-varying relationship of the relevant variables, which is also a matter of concern in the relationship between financial development and economic development.

(1) Does financial depth Granger-cause economic development? Such a finding is consistent with the supply-leading hypothesis.

(2) Does economic development Granger-cause financial depth? Such a finding is consistent with the demand-following hypothesis.

(3) Is there a positive instantaneous-causal relationship between financial depth and economic development? If so, then it is consistent with the supply leading hypothesis, the demand-following hypothesis, or both being present.

(4) Do instantaneous-causal relationships become more positive as scale increases? Such a finding would be consistent with the benefits of financial deepening taking more time to affect the economy, with perhaps more negative effects on the economy from financial deepening (say as a precursor to credit crisis) being relatively more dominating at shorter time scales.

(5) Does the strength of relationship between financial depth and economic development, in terms of Granger causality or instantaneous causality, become stronger with *higher* income levels for countries? If so, it is consistent with higher-income economies being better able to channel funds from greater financial deepening than lower-income economies due to having better-functioning economies.

(6) Does the strength of relationship between financial depth and economic development, in terms of Granger causality or instantaneous causality, become stronger with *lower* income levels for countries? If so, it is consistent with lower-income economies having more to benefit from the interaction between these two variables.

Our major findings are the following. First, at the scale of 4–8 years, it is more common for financial development and economic development to support each other once a country achieves at least lower-middle-income status. Second, at the 2–4-year scale, most countries in every country group appear to have positive interactions between financial and economic development, but at this scale, Granger causality is more frequently found from financial development to economic development than the reverse. Third, at the 2–4 year scale, bidirectional causal relationships between economic development and financial development are found only in the high-income group, and at the 4–8 year scale it is more common in the high-income group than the upper-middle-income group. Fourth, financial development appears to more frequently support economic development in lower-middle-income stage economic development than in the upper-middle-income stage at the 2–4 year scale, considering the Granger causality and median impulse response results together. Fifth, causal relationships between financial development and economic development are very often instantaneous at any of the three time scales considered, and that relationship is strongest for the high-income countries, which tend to show at all time scales strong positive contemporaneous impulse responses in both directions between economic development and financial development. Sixth, our results indicate increasingly positive relationships between financial development and economic development as timescale increases for the upper-middle- and high-income groups based on 1-lag impulse responses, but the same cannot be said for the low- and lower-middle-income groups.

The rest of the paper is organized as follows. Section 2 provides an overview of the literature on the links between financial development and economic development,

extending what has been presented already in this introduction. Section 3 presents wavelet analysis and data, which is followed by description of the estimation and testing methodologies used in the paper in Sect. 4. Empirical results are presented in Sect. 5. In Sect. 6, policy implications and some concluding remarks are offered.

2 An overview of the literature on the nexus between financial development and economic development

The volume of studies on the relationship between financial development and economic development is very large. The studies that we find most relevant to the current study, in addition to the ones discussed in the introduction, are included in this section.

2.1 Long-run and short-run relationships

There is both empirical evidence and theoretical underpinnings that the nexus of the financial development and economic growth has relevant relationships at different time scales. This subsection discusses how previous studies have contrasted these relationships at different time scales.

A well-functioning financial system mitigates market frictions caused by asymmetric information and transaction costs, which can change the incentives and constraints facing economic agents for making saving and investment decisions. By providing information to savers about possible uses of their funds, financial markets and financial intermediaries improve the allocation of saving by channeling the funds to their best uses. Financial markets not only make it possible to direct resources to investment projects but help savers avoid bearing excessive risks by having them share the risks of individual investments. Financial systems thus enhance resource allocation and eventually foster long-run economic growth. The endogenous growth literature that emerged in the early 1990s stressed the role of financial markets in affecting long-run economic growth. This line of research has included the role of financial intermediaries, information collection and risk in the models for analysis and has suggested that there is a positive relationship between financial development and total factor productivity (Obstfeld 1994; Bencivenga et al. 1995; Greenwood and Smith 1997).

In contrast to the theoretical positive long-run effects of financial development on economic growth, the relationship can be negative in the short run according to the literature on banking and currency crisis. Various papers in the banking and currency literature have found rapid growth of domestic credit signals the onset of financial crisis and economic downturn (Demirguc-Kunt and Degatriache 1998; Gourinchas et al. 2001; Kaminsky and Reinhart 1999 among others). Loayza and Ranciere (2006) considered the competing long-run and short-run effects of financial development on economic activity and documented a positive association between financial development and economic growth, except for a set of countries in Latin America that have experienced severe and repeated banking crises.

Darrat (1999), however, proposed that it is during the short run that higher levels of financial development benefit the real economy, but those benefits disappear in

the long run as the economy grows and matures. The empirical results of the study generally support the view that financial deepening causes economic growth, yet with varying degrees of strength both across countries and across different proxy-measures of financial deepening.

2.2 More empirics in the literature

Although numerous studies have been done on the relationship between financial development and economic growth, it is hard to draw conclusions on general findings. Not only theoretical frameworks but also empirical results diverge regarding the causal directions and signs of the relationships.

In a study including both developed and developing countries, King and Levine (1993) investigated the relationship between economic growth and financial development, the latter of which was captured by different indicators such as the ratio of liquid liabilities of the financial system to GDP, private sector credit, and the ratio of claims on the non-financial private sector to GDP. They concluded that all the measures of financial development included in their study have a statistically significant and positive effect on indicators showing economic performance.

Demetriades and Hussein (1996) focused on the causal relationship between the financial development and economic growth rather than on the sign of the association between these variables. They selected 16 developed countries in the 1960s that satisfied data-availability requirements and used two proxies for financial development: the ratio of bank deposit liabilities to nominal GDP and the ratio of bank claims on the private sector to nominal GDP. Their results did not show support for the supply-leading hypothesis. Instead, they found considerable evidence of bidirectionality with some evidence of demand-following hypothesis. However, Levine et al. (2000) found that financial market development (measured by liquid liabilities and private credit) has a statistically significant and positive effect on economic growth based on panel results for 74 developed and developing countries and on cross-sectional results for 71 developed and developing countries. The findings of the Kemal et al. (2007) instead reported that there was no causal relationship between financial development and economic growth based on data for 19 highly developed economies.

Al-Yousif (2002) examined the direction of the relationship between financial development and economic growth using both time-series and panel data from 30 developing countries for the period 1970–1999. The empirical results indicated strong evidence for bidirectional causality although some evidence for the other views (supply-leading, demand-leading, and no relationship) was detected in some cases. The evidence for the other views, however, was not as strong as that for the bidirectional causality.

Fase (2001) focused on the Dutch economy between 1900 and 2000. By dividing the sample periods into the first four decenniums of the twentieth century and the post-World War periods, Fase found that the level of financial development has a positive influence on economic growth, which nonetheless applies only to the early half of the twentieth century. In Fase and Abma (2003), the research focus turned to the relationship between financial development and economic growth for nine emerging Asian economies. Their findings show that causality runs from financial development

(measured by balance-sheet totals of the banking sector) to growth. This result bears the policy implication that improvement in the financial structure in developing economics may benefit economic development.

Relatively more recent studies offer some evidence that the financial system leads to economic growth in Asian emerging economies as well. However, the causal relationships are still unclear and conflicting in some cases. For example, Habibullah and Eng (2006) examined the causal relationship between financial development and economic growth of the Asian developing countries in a panel study. Their results support Patrick's 'supply-leading' hypothesis. Hassan et al. (2011) found a positive relationship between financial development and economic growth in developing countries of different regions in the world, while their causality tests show mixed results: bidirectional causality for most countries while one-way causality was found for the two poorest regions. Hsueh et al. (2013) focused on ten Asian economies, finding support for the supply-leading hypothesis. More recent studies in this area have also concentrated on African countries. Nyamongo et al. (2012) investigated the role of financial development (and remittances) on economic growth in a panel of 36 African countries over the period 1980 and 2009. Their evidence indicated that the role of financial development in enhancing economic performance appears weak, based on estimates of various panel data models. Rousseau and Wachtel (2011), however, reported that the weaker the relationship between the financial development and economic growth was, the more economies developed during the period of 1960–1990.[5]

3 Data description and Wavelet analysis

3.1 Data description

The sample for the current study consists of annual data on 76 economies during the period 1976–2007, which was obtained from the World Bank database. Although the database starts from the year 1960, the sample period was chosen for these 32 years to take into account constraints in the wavelet method (more specifically for the discrete wavelet transform, as described in Sect. 3.3) used in the study, and to exclude the period of the financial crisis period that hit most of the economies in the world starting in 2008. There are 213 economies listed in the World Bank database, yet many countries were not included in the empirical analysis to avoid series with missing values over the years of consideration (e.g., St. Lucia and Tanzania, Austria, Belgium, Canada) and to avoid countries with certain special circumstances, in particular, conflict-ridden countries (e.g. Syria, Afghanistan), resource-dependent countries (e.g. Oman, Saudi Arabia) and tourism-dependent economies (e.g., Antigua & Barbuda, Bahamas, Barbados, Belize). The full list of the economics included in the study is found in Appendix 1. For each country in the study, two variables have been collected: financial depth as measured by of liquid liabilities as a percentage of GDP, from the *Financial Devel-*

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[5] The previous empirical studies above take a macro perspective of financial development by looking at the size of the financial system. It is however also noted by some studies that the financial system's capacity of fulling various functions matter more than the size of the system itself (Hassan et al. 2011; Gimet and Lagorarde-Segor 2011, 2012; Lagorarde-Segor 2013).

opment and Structure Database of the World Bank[6]; and real GDP per capita, from *World Bank Development Indicators*.[7] In this study, we focus on the natural log of real GDP per capita to take advantage that changes in this variable are approximately the growth rate in real GDP per capita. Liquid liabilities as a percentage of GDP is a traditional indicator of financial depth, and is the broadest available indicator of financial intermediation since it includes interest-bearing liabilities of banks and other financial intermediaries (bank-like and non-bank financial institutions) in its construction (Beck et al. 2000). King and Levine (1993) and Levine et al. (2000) interpreted a positive effect of liquid liabilities on per capita GDP growth as the growth-enhancing effect of financial development.

Table 1 reports the descriptive statistics of the variables used in the study. The countries included in the study are divided into the four income groupings (Low income, Lower middle income, Upper middle income, and High income) which are defined by the World Bank based on gross national income (GNI) per capita (World bank classification by income level 2017).[8] It is clearly shown that the mean values of both variables, liquid liabilities as a percentage of GDP ratio and the logged real GDP per capita, are higher as the income levels go up.

The same pattern is also found in Fig. 1 although logged real per capita GDP levels for the Low-income countries are on average slightly higher than those of the Lower-middle-income countries until the late 1980s, indicating some of the latter group had development that moved them out of the Low-income category. In general, the mean of the variables show an upward trend for the Lower-middle-, Upper-middle-, and High-income categories. For the Low-income countries such a trend is not obvious, although starting in the late 1990s liquid liabilities as percentage of GDP appears to be increasing for these countries.

3.2 Preliminaries before applying the wavelet approach

Before moving to the wavelet analysis, the time series characteristics of the variables in the study were examined. Results of the panel unit root tests by income groups are reported in Table 3. The tests are those proposed by Levin et al. (2002), Breitung (2000), and Im et al. (2003), and the Fisher-types proposed by Maddala and Wu (1999) and by Choi (2001). Each of the five tests was performed with an individual intercept and trend included. The first two tests assume that there is a common unit-root process of all the series while the latter three tests assume both heterogeneity (i.e. individual

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[6] As a robustness check, we performed the empirical analysis for Granger causality by using another measure, bank credit as a percentage of bank deposits, as an alternative measure of financial depth. The results from that robustness check are discussed at the beginning of the *Empirical findings* section. Otherwise, the results presented in this paper are based on using liquid liabilities as a percentage of GDP.

[7] Further details on financial development data are available at http://econ.worldbank.org/programs/finance.
GDP per capita is measured by dividing gross domestic product by midyear population, the data for which were retrieved from http://databank.worldbank.org/data/reports.aspx?source=2&series=NY.GDP.PCAP.KD&country=#.

[8] In detail description of the categorization is found from https://datahelpdesk.worldbank.org/knowledgebase/articles/378834-how-does-the-world-bank-classify-countries. In short, income is measured using gross national income (GNI) per capita, in U.S. dollars, which was converted from local currency. The size of the population is estimated by World Bank demographers from a variety of sources.

Table 1 Descriptive statistics

Income* Group	Variables**	Mean	S.D.	Min	Max	Obs.
Low	Liquid liabilities as % of GDP					
	Overall	21.15	7.53	6.91	55.69	$N = 416$
	Between		5.50	14.22	33.73	$n = 13$
	Within		5.15	1.30	43.12	$T = 32$
	Ln (real GDP per capita)					
	Overall	6.11	0.31	5.31	6.92	
	Between		0.29	5.57	6.79	
	Within		0.14	5.52	6.46	
Lower middle	Liquid liabilities as % of GDP					
	Overall	33.05	15.73	4.46	92.56	$N = 672$
	Between		13.18	18.06	74.85	$n = 21$
	Within		9.04	2.07	69.46	$T = 32$
	Ln (real GDP per capita)					
	Overall	7.14	0.55	5.17	8.20	
	Between		0.53	5.58	7.88	
	Within		0.21	6.58	8.16	
Upper-middle	Liquid liabilities as % of GDP					
	Overall	41.69	28.38	6.80	145.86	$N = 672$
	Between		24.12	17.35	102.43	$n = 21$
	Within		15.83	-16.54	111.12	$T = 32$
	Ln (real GDP per capita)					
	Overall	8.40	0.66	5.57	9.88	
	Between		0.62	6.80	9.45	
	Within		0.27	7.18	9.76	
High	Liquid liabilities as % of GDP					
	Overall	68.76	38.99	6.87	231.62	$N = 672$
	Between		35.59	31.05	179.96	$n = 21$
	Within		17.59	13.44	149.41	$T = 32$
	Ln (Real GDP per capita)					
	Overall	10.14	0.58	8.06	11.43	
	Between		0.52	8.83	11.07	
	Within		0.28	9.12	10.98	

n is the number of countries, T is the number of years and $N = nT$
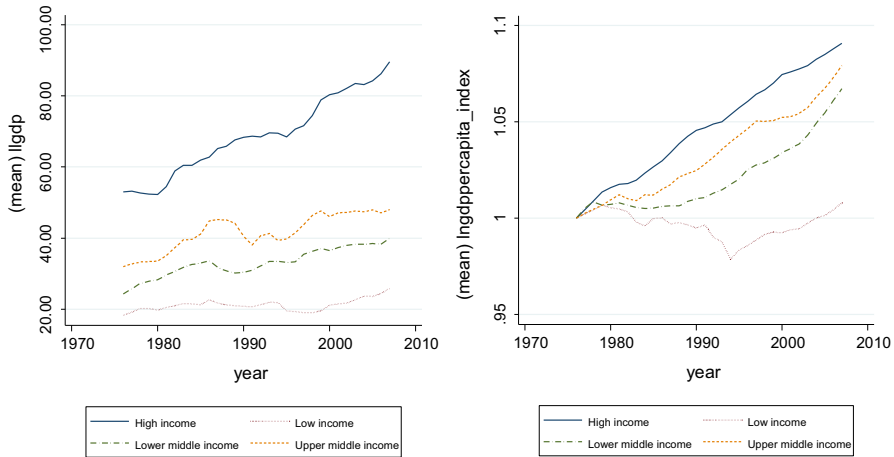
Fig. 1 Time plots of the means of the variables by each income group and year. *llgdp* refers to liquid liabilities as a % of GDP and *lngdppercapita_index*$_{(1976=1)}$ is the natural log of real GDP per capita

unit root process) and that under the null hypothesis all the cross-sectional units in each panel contain a unit root.

It is predominantly shown in Table 2 that the logarithm of real GDP per capita includes a unit root process for all the income groups, but results on the unit-root tests for the liquid liabilities as a percentage of GDP are conflicting across all income groups. Performing these unit-root tests on the first difference of these series shows instead consensus across the five tests that the first-differenced series are stationary.

The ambiguous unit-root test results regarding liquid liabilities as a percentage of GDP leaves us in a grey area regarding how to advance to the next stages of performing empirical study. Investigating relationships between the first-differenced data, which are stationary, is a common and legitimate next step according to the traditional time-series approach. This approach misses, however, the aspect of investigating the relationships at different time horizons [see discussion in Ramsey and Lampart (1998) for example regarding this issue]. We also performed panel cointegration tests for these variables, despite the ambiguous results on unit roots, but the results of these tests were also ambiguous as shown in Appendix 2.

3.3 Wavelet analysis

Due to the importance of time scale regarding the nexus between financial development and economic development, a time series methodology that can be used to consider the movements of the variables of interest at various scales, as in wavelet analysis, is clearly desirable. Wavelet analysis has increased in popularity for analysis of economic time series since it has an advantage in being able to decompose a time series into various time scales. The term "wavelets" refers to small waves that can take on a variety of function-determined shapes that have the ability to be either 'squeezed' or 'stretched' for local approximation of variables locally in space or time since they can

Table 2 *P* values for panel unit-root tests

Income groups	Variables	Levels					1st differences
		LLC	Breitung	IPS	Fisher-ADF	Fisher-PP	All
Low	liquid liabilities as % of GDP	0.16	**0.03****	**0.01****	**0.00*****	**0.34**	**0.00*****
	Ln (real GDP per capita)	0.26	0.40	0.73	0.83	0.82	**0.00*****
Lower-middle	Liquid liabilities as % of GDP	0.15	0.25	**0.01****	**0.00*****	0.91	**0.00*****
	Ln (real GDP per capita)	0.40	0.99	0.67	**0.09***	0.99	**0.00*****
Upper-middle	Liquid liabilities as % of GDP	0.29	0.74	**0.00*****	**0.01****	0.89	**0.00*****
	Ln (real GDP per capita)	0.73	0.25	0.58	0.14	0.85	**0.00*****
High	Liquid liabilities as % of GDP	0.29	0.74	**0.00*****	**0.01****	0.89	**0.00*****
	Ln (real GDP per capita)	0.73	0.25	0.58	0.14	0.85	**0.00*****

The number of lags was selected using the AIC criteria. Boldface values denote sampling evidence against unit root

***, **, *Signify rejection of the unit root hypothesis at the 1%, 5% and 10% levels, respectively. LLC, Breitung, IPS, refer to the tests proposed respectively in Levin et al. (2002), Breitung (2000) and Im et al. (2003) Fisher-ADF and Fisher-PP refer to the Fisher-type tests proposed respectively in Maddala and Wu (1999) and by Choi (2001)

be manipulated to imitate a series (Crowley 2007). The current paper's use of wavelets is to decompose our time-series variables into various different-scale sequences that are orthogonal to each other, and with those sequences consider Granger causality and instantaneous causality. Ramsey and Lampart (1998) used this method to investigate causal relationships between money and output at various times scales. This section is intended to introduce wavelets in a way that is informal and non-technical.

Having a series of observations decomposed through a wavelet transform provides a multi-scale analysis that is often compared to the camera-lens activity that results in a wide landscape when zoomed-out, while it also allows us to zoom-into observe details that are not perceptible in the landscape portrait. More explicitly, "wavelets are local orthonormal bases consisting of small waves that dissect a function into layers of different scale" (Schleicher 2002, p. 1). Time scales in wavelet analysis vary on a dyadic basis, i.e. 2^j signifies a 2^{j-1} to 2^j period scale. That means for annual data, as

used in this paper, scale level 1 ($j = 1$) refers to a time scale of 1–2 years, and the scale levels 2 and 3 refers to time scales of 2–4 years and 4–8 years, respectively. In this paper we decompose various series according to the discrete wavelet transform, DWT. This method utilizes averages of the data and averages of averages, in which the average over a particular series does not reuse any of that series' values (i.e. it does not utilize moving averages in producing its wavelet and scaling coefficients, to be discussed shortly). The DWT has observation sizes that are limited to an element of the dyadic series ($N = 2^J$ for some integer J). It also suffers from having fewer distinct values from the averages as the scale increases since a value from the original series can be used only once for the average calculations at a particular scale. Another option available is the maximum-overlap discrete wavelet transform, MODWT, where one uses moving averages and differences based on this process. However, the DWT is preferred in this study since we combine wavelet analysis with VAR models and the reuse of data is not optimal when estimating autoregressive models. We use a multiresolution analysis, MRA, version of the DWT, which is discussed more below. This methodological choice of VAR models and wavelet technique (an MRA version of the DWT) was adopted in the well-established and pioneering works by Ramsey and Lampart (1998) and described in Gençay et al. (2002).

When using MRA for DWT for decomposition of an original series, $\mathbf{y}$, we get at every scale level j, from $j = 1$ to maximum scale level J, a smooth series (s_j), and detail series ($\mathbf{d}_j$). The smooth series consists of weighted averages at that scale, in which the averages are over values in the next-lower scale level's smooth series. The smooth series at the scale level J, $\mathbf{s}_J$, captures the original series' long-term trend and includes any existing non-stationary components of the original series. MRA for DWT is an orthogonal transformation such that all of the detail series are orthogonal to each other. The detail series at scale 1 is the difference of the original series from the smooth series at scale level 1, and the detail series for scale level j with $j > 1$ is found by subtracting the smooth series for the current scale level from the next-lower-level smooth series:

$$\mathbf{d}_j = \begin{cases} \mathbf{y} - \mathbf{s}_j & \text{if } j = 1 \\ \mathbf{s}_{j-1} - \mathbf{s}_j & \text{if } j > 1 \end{cases} \tag{1}$$

Equivalently, the detail series at scale j is the original series minus the sum of the smooth series at that scale and all of the detail series at the lower scales, i.e. letting $\mathbf{d}_0 = 1$,

$$\mathbf{d}_j = \mathbf{y} - \left(\mathbf{s}_j + \sum_{i=1}^{j} \mathbf{d}_{i-1} \right) \tag{2}$$

Since the multiresolution analysis is an additive decomposition we get the original series $\mathbf{y}$ by adding together the scale-J smooth series and all of the detail series from level 1 to level J:

$$\mathbf{y} = \mathbf{s}_J + \sum_{j=1}^{J} \mathbf{d}_j \tag{3}$$

The detail series and smooth series are themselves built using what are referred to as *wavelet coefficients* and *scaling coefficients*, which are themselves weighted averages of nearby observations of the original data and weighted averages of these weighted averages. The number of original observations or weighted averages used to calculate the weighted averages at the next higher-scale level is referred to as the *filter length*. The weights used for the weighted averages depend on what wavelet transform filter is used. We choose a common one, the least asymmetric (LA) transform filter with a filter length of eight. Exact values for these weights may be found in Gençay et al. (2002).

4 Estimation and testing methodologies

This section discusses how we will investigate various forms of causal relationships for two variables: *findep*, financial depth, which is measured by liquid liabilities as percentage of GDP; and *ecdev*, the economic development level which is measured by the natural log of real GDP per capita. At each wavelet scale for each country pair, we estimate a VAR model for a vector of filtered data series *findep* and *ecdev* and investigate potential causal relationships (Granger causality and instantaneous causality) between same-type filtered series for these two variables. The types of filtered series are the first difference between two consecutive years, and the wavelet detail series $d1$, $d2$, and $d3$. Let φ_t^{findep} be the filtered series of a particular type for *findep* at time t and let φ_t^{ecdev} be the filtered series of the same type for *ecdev* at time t. For investigating causal relationships we estimate a vector autoregressive model of order K, VAR(K), for the filtered series as shown below:

$$\begin{bmatrix} \varphi_t^{findep} \\ \varphi_t^{ecdev} \end{bmatrix} = \begin{bmatrix} \beta_{01} \\ \beta_{02} \end{bmatrix} + \sum_{i=k}^{K} \begin{bmatrix} \beta_{11}^{(k)} & \beta_{12}^{(k)} \\ \beta_{21}^{(k)} & \beta_{22}^{(k)} \end{bmatrix} \begin{bmatrix} \varphi_{t-k}^{findep} \\ \varphi_{t-k}^{ecdev} \end{bmatrix} + \begin{bmatrix} u_{1t} \\ u_{2t} \end{bmatrix} \tag{4}$$

where each of β parameters is constant and $[u_{1t}\ u_{2t}]'$ is the time-t error vector, which is assumed to be a white-noise sequence drawn independently across time from a bivariate distribution that has zero expected values for each of the error terms and that has the constant covariance matrix

$$\Omega \equiv \begin{bmatrix} \Omega_{11} & \Omega_{12} \\ \Omega_{12} & \Omega_{22} \end{bmatrix} \equiv E\left[\begin{bmatrix} u_{1t} \\ u_{2t} \end{bmatrix} \begin{bmatrix} u_{1t} & u_{2t} \end{bmatrix} \right]. \tag{5}$$

Granger causality (as in Granger and Newbold 1986) between filtered series of the same type from *findep* to *ecdev* is indicated if the hypothesis that $\beta_{21}^{(k)} = 0$ for all $k \in \{1, \ldots, K\}$ can be statistically rejected. Granger causality between the filtered series

of the same type from *ecdev* to *findep* is indicated if the hypothesis that $\beta_{12}^{(k)} = 0$ for all $k \in \{1, \dots, K\}$ can be statistically rejected. Instantaneous causality in the filtered series of the same type is indicated for *findep* and *ecdev* if the hypothesis that $\Omega_{12} = 0$ can be statistically rejected (see Lütkepohl 2006, pp. 104–105).

For the estimated VAR models, we use the Schwarz (1978) information criteria (SIC) to determine the number of lags, K. F tests are implemented for testing Granger causality and Wald tests are used for testing instantaneous causality.[9]

5 Empirical findings

In this section, we consider the relationship between financial development and economic development based on the results of Granger causality and instantaneous causality tests for first-differenced and same-scale wavelet detail series *for findep and ecdev*. Given the sample-size limitations, the analysis for wavelet details is performed for those at scale levels 1–3. As a robustness check, we also used bank credit as a percentage of bank deposits as an alternative measure to financial development and replicated the Granger causality results presented in this section using that measure instead as a measure of financial depth. The results from those alternative Granger causality tests are qualitatively the same as the ones presented here (those results are available from the authors upon request).

Table 3 presents the results on causality tests based on estimates of Eq. (4) and the associated covariance matrix in (5) for different economies with different development stages. The notations $d1$, $d2$ and $d3$ that are shown in Table 3 respectively refer to wavelet detail series (wavelet scales) based on scales of 1–2 years, 2–4 years, and 4–8 years, respectively. For different country groups of different development levels, the table presents the results from tests of various forms of causality between same-type filtered series (first-difference or wavelet detail) of *findep* and *ecdev*. For a given type of filtered series, the table presents results on Granger causality from *findep* to *ecdev* (*findep* → *ecdev*), from *ecdev* to *findep* (*ecdev* → *findep*), along with results on instantaneous causality between *findep* and *ecdev* (Instantaneous). Some results for bidirectional Granger causality between *findep* and *ecdev* (*findep* → *ecdev*), based finding both *findep* → *ecdev* and *ecdev* → *findep* for a country, are also presented.

The columns with the heading "Panel Sig." show for each type of causality considered a p value for a panel test in which the null hypothesis is that all of the countries of the noted development level do not have causality of the noted type and detail series level. The panel test referred to is Fisher's combined probability test, based on Fisher's inverse Chi-square test (Fisher 1932). For Fisher's combined probability test the following statistic C is found based on the N individual-country p-values for the causality test being considered:

$$C = -2 \sum_{i=1}^{N} \ln p_i.$$

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[9] This is implemented using the *causality* command in the *vars* R package maintained by Bernhard Pfaff.

Table 3 Causality between filtered series for financial depth economic development

Filtered data (scale)	Causality type	Low income		Lower middle income		Upper-middle income		High income	
		Panel Sig.	% Sig.	Panel Sig.	% Sig.	Panel Sig.	% Sig.	Panel Sig.	% Sig.
First difference	$findep \rightarrow ecdev$	0.121	15.4	0.093	9.5	**0.014**	14.3	**0.000**	14.3
	$ecdev \rightarrow findep$	**0.013**	15.4	**0.001**	19.0	**0.000**	28.6	**0.003**	14.3
	$findep \leftrightarrow ecdev$		0.0		0.0		9.5		4.8
	Instantaneous	**0.001**	38.5	**0.002**	23.8	**0.001**	14.3	**0.000**	28.6
$d1$ (1–2 years)	$findep \rightarrow ecdev$	**0.011**	15.4	**0.000**	28.6	**0.006**	19.0	**0.000**	47.6
	$ecdev \rightarrow findep$	**0.046**	23.1	**0.000**	28.6	**0.000**	28.6	**0.000**	52.4
	$findep \leftrightarrow ecdev$		7.7		14.3		9.5		33.3
	Instantaneous	**0.000**	53.8	**0.000**	57.1	**0.000**	47.6	**0.000**	66.7
$d2$ (2–4 years)	$findep \rightarrow ecdev$	0.157	15.4	**0.024**	19.0	0.774	4.8	**0.000**	28.6
	$ecdev \rightarrow findep$	0.443	7.7	0.773	0.0	0.990	0.0	**0.000**	19.0
	$findep \leftrightarrow ecdev$		0.0		0.0		0.0		19.0
	Instantaneous	**0.000**	61.5	**0.000**	66.7	**0.000**	52.4	**0.000**	81.0
$d3$ (4–8 years)	$findep \rightarrow ecdev$	**0.000**	30.8	**0.000**	33.3	**0.000**	19.0	**0.000**	28.6
	$ecdev \rightarrow findep$	**0.000**	15.4	**0.000**	33.3	**0.000**	19.0	**0.000**	33.3
	$findep \leftrightarrow ecdev$		7.7		19.0		9.5		14.3
	Instantaneous	**0.000**	53.8	**0.000**	71.4	**0.000**	66.7	**0.000**	71.4
Number of countries		13	13	21	21	21	21	21	21

For each country there were 32 years of data, 1976–2007 used. Financial depth (*findep*) is measured by liquid liabilities as a percentage of GDP and economic development (*ecdev*) is measure by the natural log of real GDP per capita. *findep* → *ecdev* and *ecdev* → *findept* respectively refer to Granger causality from *findep* to *ecdev* and Granger causality from *ecdev* to *findep* for the noted filtered series to the left (regardless of whether there is bidirectional Granger causality). *findep* ↔ *ecdev* refers to bidirectional Granger causality between *findep* and *ecdev* and "Instantaneous" refers to instantaneous causality between *findep* and *ecdev* for the noted filtered series to the left. "% Sig." refers to the percent of countries indicating causality of a given type and filtered series type at the 5% significance level. Panel Sig. indicates the p value for a panel test with the null hypothesis being that none of the countries of the noted development level have causality of the noted type and filtered series type. Bolded values under "Panel Sig." represent significant values at the 5% significance level

Under the null hypothesis, C follows a Chi-square distribution with $2N$ degrees of freedom. Based on these panel tests we can see that there is support for each of the three types of causality (*findep* → *ecdev*, *ecdev* → *findep*, and instantaneous) at the 5% significance level for all four economic development levels and every filter type *except* for (a) *findep* → *ecdev* for Low-income and Lower-middle-income countries using first differences, (b) *findep* → *ecdev* for Low-income and Upper-middle-income countries using $d2$, and (c) *ecdev* → *findep* using $d2$ with development levels below the High-income category. Unfortunately, this Fisher combined probability test does not indicate anything about how common causality relationships are among the countries; it is simply testing whether we can reject that all of them have no causality of a particular type.

Arguably it is more relevant to consider what percentage of countries within a development category have causality indicated for any one of the three causality types for each of the filter types. That is why the columns with "% Sig." heading are presented. In these columns, the percent of countries in a country-income category indicating causality of a given filter type at the 5% significance level are provided. What can be seen here is that Granger causality in either direction is not found for most countries in any of the combinations of development category and filter type, except (just slightly at 52.4%) *ecdev* → *findep* for the $d1$ series with the High-income countries. Nevertheless, we can also see that High-income countries tend to have higher fractions of countries showing Granger causality, in either direction, for the $d1$ and $d2$ scales in comparison to other development-level groups. For all three wavelet-detail filter types, the percent of countries indicating Granger causality *findep* → *ecdev* is lower for Upper-middle-income countries than for other countries. These results suggest that financial development can support economic development more in the earlier stages of development than in the upper-middle-income stage, and that at the 1–2 year and 2–4 scales it is more common to see financial development and economic development supporting each other once a high-income level is achieved.

What stands out most in Table 3, however, is the dominant effect of instantaneous causality. Every one of the country groups and detail series combinations indicate that most of the countries have instantaneous causality supported, except for the $d3$ series for the Upper-middle income category in which 47.6% of the countries were found to have instantaneous causality. Note that in contrast, when using first differences none of the country groups have most of the members showing significance in instantaneous causality. It is also noteworthy that for each of the wavelet detail scale levels the high-income category has the highest percentage of countries with instantaneous causality indicated. Unfortunately, direction of causality is impossible to extract with instantaneous causality.

As noted previously, the first-difference results dismiss as insignificant the causal relationship *findep* → *ecdev* for the lower-middle-income countries using the panel test, whereas that is not the case for the $d1$, $d2$, and $d3$ results. When considering the percent of countries indicating a significance of such a causal relationship, the first-difference results indicate only 9.5% do so, whereas the $d1$, $d2$, $d3$ results indicate a larger percentage of countries showing such a relationship: 28.6%, 19%, and 33.3% respectively. This demonstrates how considering the relationships at the three wavelet-detail levels allow us to capture some relationships that are not observable with first

Table 4 1-lag impulse responses between economic development and financial development

Filtered data (scale)	Economic development percent response to a 1-percentage-point increase in financial development in previous period[a]				Financial development percentage-point response to a 1% increase in economic development in previous period[b]			
	Low income	Lower middle income	Upper-middle income	High income	Low income	Lower middle income	Upper-middle income	High income
*d*1 (1–2) years								
Median	0.01	− 0.72	− 0.20	− 0.54	− 0.05	− 0.20	− 0.06	− 0.35
%>0 (*p* value)	53.8 (1.00)	28.6 (0.08)	38.1 (0.38)	**23.8** **(0.03)**	46.15 (1.00)	33.33 (0.19)	38.1 (0.38)	**14.3** **(0.00)**
*d*2 (2–4) years								
Median	0.11	0.59	0.38	0.83	0.03	0.20	0.10	0.18
%>0 (*p* value)	61.5 (0.58)	71.4 (0.08)	71.4 (0.08)	**76.2** **(0.03)**	69.2 (0.27)	**81.0** **(0.00)**	66.7 (0.19)	**76.2** **(0.03)**
*d*3 (4–8) years								
Median	− 0.27	0.48	1.05	0.81	− 0.03	0.14	0.26	0.43
%>0 (*p* value)	30.8 (0.27)	66.7 (0.19)	**76.2** **(0.03)**	**81.0** **(0.01)**	46.2 (1.00)	66.7 (0.19)	**76.2** **(0.03)**	**81.0** **(0.01)**
Number of countries	13	21	21	21	13	21	21	21

The impulse responses are generated through a generalized impulse response function based on the same VAR models that were used in Table 3. The "%>0" values represent the percentage of countries within each category and scale that have positive impulse responses, with each associated *p* value for an unusually high or low percentage based on a two-tailed sign test given equal probabilities of positive or negative values. Bolded p values are those showing significance at the 5% level

[a]The percent increase in real GDP per capita after one period in response to a 1 percentage-point increase in liquid liabilities as a percentage of GDP

[b]The percentage-point increase in liquid liabilities as a percentage of GDP after one period in response to a 1% increase in real GDP per capita

difference series and for a richer number of time scales. First-differences are focused on the very short-scale of between-year movements.

What lacks in the Granger causality results is the sign and magnitude of relationships between variables in VAR model. To consider these issues for the various time scales and income groups, Table 4 presents the 1-lag results of generalized impulse response functions generated by the same VAR models used for the Granger causality results in Table 3. Generalized impulse response functions, which are invariant to the VAR ordering of variables, were proposed for unrestricted VAR models by Pesaran and Shin (1998), who built on the generalized impulse response function concept developed in Koop et al. (1996).

The left half of Table 4 provides results on the percent increase in real GDP per capita in response to a 1 percentage-point increase in liquid liabilities as a percentage of GDP in the previous period (where "previous period" means the previous 1–2-year, 2–4-year, or 4–8-year period when dealing with the *d*1, *d*2 and *d*3 series respectively).

It shows the median value for this impulse response over the countries in the noted income category. It also indicates the percent of these countries with the impulse response greater than zero and the significance of this percentage being unusually high or low if positive and negative values were equally likely, based on a two-sided sign test. The right half of the table presents the same information as the left half, except the results are for the percentage-point increase in liquid liabilities as a percentage of GDP in response to a 1 percent increase in real GDP per capita in the previous period.[10]

For the lower-middle-, upper-middle- and high-income groups at the $d2$ and $d3$ scales, Table 4 shows that the median impulse responses in both directions (i.e. the 1-lag economic development impulse response to a positive financial development shock and the 1-lag financial development impulse response to a positive economic development shock) are positive and that most countries in each income category show positive impulse responses in both directions, usually with statistical significance at the 10% level. Among the strongest impulse responses found in both tables is in the high-income group at the $d3$ level, for which a one percentage-point increase in *liquid liabilities as a percentage of GDP in one* 4–8-*year period* is on average associated with an 0.81% increase in *real GDP per capita in the subsequent* 4–8- *year period*, and for which a 1% increase in *real GDP per capita in one* 4–8-*year period* is on average associated with a 0.43 percentage-point increase in *liquid liabilities as a percentage of GDP in the subsequent* 4–8-*year period*. For the low-income countries, negative impulse responses appear to be more dominant in both directions between the variables, as indicated for both the median values reported and the percent of countries with positive impulse responses.

At the $d2$ and $d3$ scales, positive impulse responses are dominant (as given by the median response or the percent positive response) in both response directions in the lower-middle-, upper-middle-, and high-income groups. Thus, for these country groups at these scales, it appears that economic development and financial development are positively influencing each other after a one-period lag. This is not evident at these scales, however, for the low-income category countries, for which the percent of positive impulse response is either below 50% or slightly above 50%, and at the $d3$ scale the median impulse response in both response directions is negative.

Tables 4 shows that at the $d2$ level, the positive impulse response in both directions appears stronger (either in the median response or the percent positive response) in the lower-middle-income group than in upper-middle-income group. This is similar to the Granger causality results in Table 3 when comparing lower-middle-income and upper-middle-income groups for $d2$ and $d3$. At the $d3$ scale, the opposite is true: the positive impulse response in both directions appear stronger in the upper-middle-income group

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[10] The generalized impulse response functions were generated through *Eviews*, version 10, which uses impulses in the form of the estimated standard deviation for the error terms for the VAR model. We converted these to 1-unit (rather than 1 standard deviation) impulses by dividing the impulse responses by the associated standard deviation. A one-unit increase in liquid liabilities as a percentage of GDP is simply a 1 percentage point increase in that variable and a 0.01 increase in ln (real GDP per capita) is approximately a 1 percent increase in real GDP per capita, and the same can arguably be applied to the associated detail series which altogether with the smooth series sum up to the raw series. Due to these interpretations, the median impulse responses in Table 4 are 100 times those in response to the 1-unit impulses in liquid liabilities as a percentage of GDP, and the median impulse responses in Table 4 are 0.01 times those in response to the 1-unit impulses in ln (real GDP per capita).

than in the lower-middle-income group. All the impulse responses reported in Tables 4 are 1-lag impulse responses. These impulse responses for $d2$ and $d3$ are similar to contemporaneous (same-period) impulse response results (provided in Appendix 3), which is not surprising given the strength of the instantaneous causality results found in Table 3.

At the $d1$ scale, the median 1-lag response of economic development to an increase in financial development is negative for all country groups. Similarly, at the $d1$ scale, the median 1-lag response of financial development to an increase in economic development is negative for all country groups except the low-income group. At the $d1$ scale, most countries in each country group show negative rather than positive 1-lag impulse responses in either direction (with the exception of the low-income category in Table 4), and this higher percentage of negative impulse responses is statistically significant at the 10% significance level for the lower-middle-income and high-income groups.

However, when we consider contemporaneous impulse responses rather than 1-lag impulse responses, the median responses at the $d1$ level are all positive in both directions, and the percent positive is significantly high (5% level) for the high-income group (see Appendix 3). Therefore, even though there is typically a positive contemporaneous correlation between economic development and financial development at the scale of 1–2 years, there is also often a negative feedback in the subsequent 1–2-year period in both directions. This may reflect an actual economic phenomenon of normalization after an initial shock; e.g. a spurt in economic growth demands some immediate financial responses which die out when moving to the next 1–2-year period, or a temporary increase in financial development results in a persistent economic expansion into the next 1–2-year period. Notably, GDP is in the denominator of the financial development indicator and in the numerator of the economic development indicator, so a negative relationship can arise when GDP increases are stronger than increases in liquid liabilities. Otherwise, positive contemporaneous impulse responses in both directions followed by negative impulse responses in both directions may simply reflect more volatility in measured economic development and financial development at the scale of 1–2 years than at higher scales. Due to the lack of clarity of the sign of the relationship between financial development and economic development, we avoid making conclusions on lagged economic relationships at this scale.

6 Conclusions and policy implications

Investigating the directions of the causality between financial development and economic development has very important implications for development policies. Expanding financial sector should be aimed at if a supply-leading relationship holds between financial development and economic growth. However, policies that are more geared toward enhancing real economic growth, other than financial market deepening, should be designed in case a demand-following relationship holds between the two variables. The current paper fills a gap in the previous research by using a relatively new time series technique as well as identifying both Granger- and instantaneous-causal relationships between financial development and economic development along with impulse-response relationships between these variables.

Six major findings obtained from the current study are as the following.

First, at the scale of 4–8 years it is more common for financial development and economic development to support each other once a country achieves at least lower-middle-income status, based on the proportion of economies showing positive 1-lag or contemporaneous impulse responses and on the percent of countries indicating bidirectional causality. This suggests that for these country groups at this scale, financial development fuels and, simultaneously, growth boosts financial development. At this scale, most low-income countries indicate a negative (albeit insignificantly so) interaction between financial development and economic development.

Second, at the 2–4 year scale, most countries in every country group appear to have positive interactions between financial and economic development, but Granger causality is more frequently found from financial development to economic development than the reverse.

Third, at the 2–4 year scale, bidirectional causal relationships between economic development and financial development are found only in the high-income group, and at the 4–8 year scale it is more common in the high-income group than the upper-middle-income group. The finding that this feedback mechanism works better for the high-income economies stands in accordance with Calderon and Liu (2003).

Fourth, financial development appears to more frequently support economic development in lower-middle-income stage economic development than in the upper-middle-income stage at the 2–4-year scale, considering the Granger causality and median impulse response results together. For this scale, this finding supports the hypothesis that lower-middle-income countries have more to benefit (in terms of output per capita) from financial deepening than upper-middle-income countries due to a supply-leading relationship holding. At the 4–8 year scale, however, financial deepening may very well benefit upper-middle income countries more than lower-middle-income countries based on the 1-lag impulse-response results.

Fifth, causal relationships between financial development and economic development are very often instantaneous at any of the three time scales considered, and that relationship is strongest for the high-income countries, which also tend to show at all time scales strong positive contemporaneous impulse responses in both directions between economic development and financial development. This finding along with the first, third, and fourth findings can be explained by the view that developing economies have more dominant bank-based financial systems than those of developed economies where stock and bond markets, for example, fulfill their functions in the financial system (Gambacorta et al. 2014). At the early stage of economic growth, the size of the financial market is important in economic development, yet, as during the development process, the roles of different functions in the financial system would be desired.

Sixth, our results indicate increasingly positive relationships between financial development and economic development as time scale increases for the upper-middle- and high-income groups based on 1-lag impulse responses, but the same cannot be said for the low- and lower-middle-income groups. Bidirectional causality between the economic development and financial development tend to be more commonly found at the 4–8 year scale than at the 2–4 year scale for all country groups except high-income, and for all country groups, Granger causality from economic development to financial development appears stronger at the 4–8 year scale than at the 2–4 year scale.

The findings above suggest an important policy implication, especially for developing countries. To propel economic growth, it could be desirable to further expand the financial sector at an earlier development stage, such as when a country is in the lower-middle-income or upper-middle-income stage rather than the upper-middle-income stage, but doing so may not be beneficial (it could even be detrimental), if such expansion occurs too early, as in the low-income stage. It should be noted, however, that it is important to investigate how the effectiveness of policies in improving financial development and, through that, economic development, depends on the institutional environment, such as legal and regulatory frameworks. This question is left for future study.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Declarations Not applicable.

Data and code availability The data used in this study are publicly available from World bank database. Instructions for how to proceed from the dataset to the results of the paper (including code), are, however, available from the corresponding author upon reasonable request.

Appendix 1: List of countries included in the study

Country	Region	Income group
Argentina	Latin America and Caribbean	Upper middle income
Australia	East Asia and Pacific	High income
Benin	Sub-Saharan Africa	Low income
Bolivia	Latin America and Caribbean	Lower middle income
Botswana	Sub-Saharan Africa	Upper middle income
Brazil	Latin America and Caribbean	Upper middle income
Burkina Fas	Sub-Saharan Africa	Low income
Cameroon	Sub-Saharan Africa	Lower middle income

Country	Region	Income group
Central African Republic	Sub-Saharan Africa	Low income
Chile	Latin America and Caribbean	High income
China	East Asia and Pacific	Upper middle income
Costa Rica	Latin America and Caribbean	Upper middle income
Cyprus	Europe and Central Asia	High income
Cote d'Ivoir	Sub-Saharan Africa	Lower middle income
Denmark	Europe and Central Asia	High income
Dominica	Latin America and Caribbean	Upper middle income
Dominican Republic	Latin America and Caribbean	Upper middle income
Ecuador	Latin America and Caribbean	Upper middle income
Egypt, Arab Rep.	Middle East and North Africa	Lower middle income
El Salvador	Latin America & Caribbean	Lower middle income
Fiji	East Asia and Pacific	Upper middle income
Finland	Europe and Central Asia	High income
Gabon	Sub-Saharan Africa	Upper middle income
Gambia, The	Sub-Saharan Africa	Low income
Germany	Europe and Central Asia	High income
Ghana	Sub-Saharan Africa	Lower middle income
Greece	Europe and Central Asia	High income
Guatemala	Latin America and Caribbean	Lower middle income
Guyana	Latin America and Caribbean	Upper middle income
Honduras	Latin America and Caribbean	Lower middle income
Iceland	Europe and Central Asia	High income
India	South Asia	Lower middle income
Indonesia	East Asia and Pacific	Lower middle income
Ireland	Europe and Central Asia	High income
Israel	Middle East and North Africa	High income
Italy	Europe and Central Asia	High income
Jamaica	Latin America and Caribbean	Upper middle income
Japan	East Asia and Pacific	High income
Kenya	Sub-Saharan Africa	Lower middle income
Korea, Rep.	East Asia and Pacific	High income
Madagascar	Sub-Saharan Africa	Low income
Malawi	Sub-Saharan Africa	Low income
Malaysia	East Asia and Pacific	Upper middle income
Mali	Sub-Saharan Africa	Low income
Malta	Middle East and North Africa	High income
Mexico	Latin America and Caribbean	Upper middle income
Morocco	Middle East and North Africa	Lower middle income
Myanmar	East Asia and Pacific	Lower middle income

Country	Region	Income group
Nepal	South Asia	Low income
Nicaragua	Latin America and Caribbean	Lower middle income
Niger	Sub-Saharan Africa	Low income
Nigeria	Sub-Saharan Africa	Lower middle income
Norway	Europe and Central Asia	High income
Pakistan	South Asia	Lower middle income
Papua New Guinea	East Asia and Pacific	Lower middle income
Paraguay	Latin America and Caribbean	Upper middle income
Peru	Latin America and Caribbean	Upper middle income
Philippines	East Asia and Pacific	Lower middle income
Portugal	Europe and Central Asia	High income
Rwanda	Sub-Saharan Africa	Low income
Senegal	Sub-Saharan Africa	Low income
Sierra Leone	Sub-Saharan Africa	Low income
Singapore	East Asia and Pacific	High income
South Africa	Sub-Saharan Africa	Upper middle income
Spain	Europe and Central Asia	High income
Sri Lanka	South Asia	Lower middle income
Sudan	Sub-Saharan Africa	Lower middle income
Suriname	Latin America and Caribbean	Upper middle income
Swaziland	Sub-Saharan Africa	Lower middle income
Sweden	Europe and Central Asia	High income
Thailand	East Asia and Pacific	Upper middle income
Togo	Sub-Saharan Africa	Low income
Turkey	Europe and Central Asia	Upper middle income
UK	Europe and Central Asia	High income
USA	North America	High income
Venezuela, RB	Latin America and Caribbean	Upper middle income

Appendix 2: Panel cointegration tests of financial development and economic growth

Income groups	Pedroni			Kao	Fisher-type		
		Without trend	With trend			$\gamma = 0$	$\gamma \leq 1$
Low	Panel v-statistic	**0.06***	0.47	0.33	Model1	**0.00***	0.48
	Pane rho-statistic	**0.02**	0.25		Model2	**0.00***	**0.02**
	Pane PP-statistic	**0.00***	**0.01**		Model3	**0.04**	**0.00**
	PaneADF-statistic	**0.00***	**0.00***		Model4	**0.00***	0.48
	Group rho-statistic	0.10	0.82				
	Group PP-statistic	**0.00***	**0.00***				
	Group ADF-statistic	**0.00***	**0.00***				
Lower middle	Panel v-statistic	**0.09***	0.19	**0.04**	Model1	**0.00***	**0.01**
	Pane rho-statistic	0.38	0.81		Model2	**0.00***	**0.00***
	Pane PP-statistic	0.13	0.61		Model3	**0.00***	**0.00***
	PaneADF-statistic	**0.01**	**0.00***		Model4	**0.00***	**0.00***
	Group rho-statistic	0.45	0.99				
	Group PP-statistic	**0.08**	0.89				
	GroupADF-statistic	**0.00***	**0.00***				
Upper middle	Panel v-statistic	**0.02**	0.50	**0.00***	Model1	**0.00***	**0.00***
	Pane rho-statistic	**0.05***	0.78		Model2	**0.00***	**0.00***
	Pane PP-statistic	**0.05***	0.56		Model3	**0.00***	**0.00***
	PaneADF-statistic	**0.00***	**0.00***		Model4	**0.00***	**0.00***
	Group rho-statistic	0.64	0.99				
	Group PP-statistic	0.32	0.96				
	Group ADF-statistic	**0.00***	**0.00***				
High	Panel v-statistic	**0.01**	0.64	0.18	Model1	**0.00***	**0.00***

Income groups	Pedroni			Kao	Fisher-type		
		Without trend	With trend			$\gamma = 0$	$\gamma \leq 1$
	Pane rho-statistic	**0.02****	0.59	Model2		**0.00***	**0.00***
	Pane PP-statistic	**0.00***	0.24	Model3		**0.00***	**0.00***
	PaneADF-statistic	**0.00***	**0.00***	Model4		**0.00***	**0.00***
	Group rho-statistic	0.72	0.99				
	Group PP-statistic	0.31	0.98				
	Group ADF-statistic	0.00	0.00				

[a]The number of lags was selected using the AIC criteria. Boldface values denote evidence against the null hypothesis of no cointegration

[b]Barnett kernel was used for non-parametric estimation of the Pedroni (1999, 2004) and Kao (1999) tests. Bandwidth was selected by using Newey-West fixed

[c]The four models of the Fisher-type cointeration tests are: No intercept or trend in CE or VAR (model1); Intercept (no trend) in CE—no intercept in VAR (model2); Intercept (no trend) in CE and VAR (model3); Intercept and trend in CE and no trend in VAR (model4.)

***, **, * Signify rejection of the hypothesis at the 1%, 5% and 10% levels, respectively

Appendix 3: Contemporaneous impulse responses

Contemporaneous impulse responses between economic development and financial development

Filtered data (scale)	Economic development percent response to a 1-percentage-point increase in financial development in same period[a]				Financial development percentage-point response to a 1% increase in economic development in same period[b]			
	Low income	Lower middle income	Upper middle income	High income	Low income	Lower middle income	Upper middle income	High income
*d*1 (1–2) years								
Median	0.05	0.58	0.22	0.66	0.03	0.19	0.06	0.24
%>0 (*p* value)	53.8 (1.00)	66.7 (0.19)	52.4 (1.00)	**76.2** **(0.03)**	53.8 (1.00)	66.7 (0.19)	52.4 (1.00)	**76.2** **(0.03)**
*d*2 (2–4) years								
Median	0.15	0.77	0.41	1.21	0.00	0.23	0.07	0.24
%>0 (*p* value)	53.8 (1.00)	**76.2** **(0.03)**	61.9 (0.38)	**76.2** **(0.03)**	53.8 (1.00)	**76.2** **(0.03)**	61.9 (0.38)	**76.2** **(0.03)**
*d*3 (4–8) years								
Median	− 0.12	0.49	0.70	0.66	− 0.01	0.10	0.20	0.31
%>0 (*p* value)	46.2 (1.00)	71.4 (0.08)	**81.0** **(0.01)**	**81.0** **(0.01)**	46.2 (1.00)	71.4 (0.08)	**81.0** **(0.01)**	**81.0** **(0.01)**
Number of countries	13	21	21	21	13	21	21	21

The impulse responses are generated through a generalized impulse response function based on the same VAR models that were used in Table 3. The "%>0" values represent the percentage of countries within each category and scale that have positive impulse responses, with each associated *p* value for an unusually high or low percentage based on a 2-tailed sign test given equal probabilities of positive or negative values. Bolded *p* values are those showing significance at the 5% level

[a]The percent increase in real GDP per capita in the same period in response to a 1 percentage-point increase in liquid liabilities as a percentage of GDP

[b]The percentage-point increase in liquid liabilities as a percentage of GDP in the same period in response to a 1% increase in real GDP per capita

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