



# The asymmetric Granger causality between banking-sector and stock-market development and economic growth in quantiles considering Fourier

Hao Fang<sup>a</sup>, Chieh-Hsuan Wang<sup>b</sup>, Joseph C. P. Shieh<sup>c</sup> and Chien-Ping Chung<sup>d</sup>

<sup>a</sup>Department of International Business, Chung Yuan Christian University, Taoyuan, Taiwan; <sup>b</sup>Department of Economics, Shih Hsin University, Taipei, Taiwan; <sup>c</sup>Graduate Institute of Finance, National Taiwan University of Science and Technology, Taipei, Taiwan; <sup>d</sup>Department of Information and Finance Management, National Taipei University of Technology, Taipei, Taiwan

## ABSTRACT

Utilizing an asymmetric causality test and a bootstrap procedure in conjunction with quantile VAR and Fourier functions, this study considers the rate of banking sector over GDP and the rate of stock market capitalization over GDP as bank-based development and market-based development, respectively. Using this approach, we examine the simultaneous causation between both measures of financial development and economic growth. Our samples include Germany, Japan, the United States and the United Kingdom for the period of 1975–2019. Expectedly, our findings of asymmetric Quantile VAR Granger causality present that bank-based development is better at raising long-term economic growth in Germany and Japan and that stock-based development is more likely to drive economic output in the U.K. and the U.S. Asymmetric Granger causality is adopted since positive or negative shocks can exhibit diverse causal effects. The bootstrapping simulation technique can overcome nonnormal distributions and time-varying volatility through leverage adjustment. The simultaneous consideration of quantile causality and the Fourier function can identify which part of the output distribution is predicted and can lead the smooth breaks in the deterministic parts to be controlled by Fourier expansions.

## KEYWORDS

Financial development;  
Economic growth;  
Asymmetric causality;  
Bootstrap simulation;  
Quantile causality; Fourier  
function

## JEL CLASSIFICATION

C22; E44; E51; F36; G21

## I. Introduction

Numerous studies have identified the causal association between financial development and economic growth. Most of these studies have focused on examining the causation between bank-based development and growth (Ang and McKibbin 2007; Gozgor 2015; Levine, Loayza, and Beck 2000; Rousseau and Vuthipadadorn 2005; Stolbov 2017); however, few have investigated the causation between stock market development and growth (Marques, Fuinhas, and Marques 2013). Few studies have simultaneously identified the causation between bank sector and stock market development and growth (Lee 2012; Peia and Roszbach 2015). However, both financial institutions and markets mobilize capital, decrease information asymmetries and facilitate resource allocation, resulting in the promotion of long-run economic growth. Meanwhile, there is less of a consensus over the impact stemming primarily from banks, stock markets or both. This phenomenon must be further explored.

The cross-sectional literature on the association between financial development and economic growth empirically provides results based on the opinions of both financial intermediaries and legal systems, in which the overall role of financial development rather than financial structure promotes real sector outcomes (Beck and Levine 2002). In contrast, time-series research proposes that the causality of cross-sectional studies can present just one edge of the causality association (Arestis, Demetriades, and Luintel 2001; Luintel et al. 2008). These studies indicate that a country's financial development exhibits a causal association that cannot be shown in cross-sectional literature. They identify causality in a country by considering data dynamics and cointegration, which requires longer periods (Christopoulos and Tsionas 2004). Thus, when investigating the association between bank-dominated and stock-based development and growth, most of the time-series literature has been restricted to bank development indicators

due to the lack of data on stock market development (Ang and Mckibbin 2007; Peia and Roszbach 2015; Rousseau and Vuthipadadorn 2005).

Recently, a few studies have used time-series analysis to explore the causal link among bank-based development, stock-based development and economic output. Peia and Roszbach (2015) use a wide breadth of both short- and long-term causality tests based on vector autoregression (VAR) to test causality in banking-based development, stock-based development and growth. Similarly, Lee (2012) adopts the VAR model to investigate causal links between both measures of financial development and economic growth. Similar to Lee (2012), Peia and Roszbach (2015) uses the level and growth of banking sector and stock market development. In contrast, Lee (2012) considers only GDP growth rather than its level. The measurement approach in Lee (2012) more closely captures the impact of financial development on economic growth since the links between the growth in both measures of financial development and economic growth are short-term dynamics. Additionally, the results of Lee (2012) show that banking sector growth, stock market growth and economic growth have more causations than those that exist among banking sector level, stock level and economic growth.

Recent findings on short-run dynamics exist in investigations of causal links between finance and growth (Lee 2012; Loayza and Ranciere 2006). However, time-series analysis commonly emphasizes long-term causations (Croux and Reusens 2013, Rocha and Souza, 2014; Gozgor 2015; Peia and Roszbach 2015; Stolbov 2017). This statement is plausible because long-term causality considers long-run relationships among related variables (Arestis, Demetriades, and Luintel 2001). Thus, by using the ratio of the banking sector to GDP and the ratio of stock market capitalization to GDP to measure financial development, we emphasize an analysis of the long-term causal relation between financial development and growth. Meanwhile, previous studies tend to use a linear time-series model to analyse the causation between both measures of financial development and economic output. However, the relationships among the three variables are perhaps nonlinear; thus,

adopting a nonlinear model to investigate causation among the three variables is worthwhile.

Almost no study until now analyses nonlinear causality between both measures of financial development and economic growth. However, few studies analyse nonlinear causal links between banking sector development and output. Using asymmetric Granger causality based on a bootstrap simulation approach, Gozgor (2015) analyzes the causation between domestic credit and growth. The asymmetric causality test is allowed by summing positive and negative shocks (Hatemi-J 2012). This method is considered because positive or negative shocks can exhibit diverse causal effects. Causality testing applied in the bootstrap distribution has better size and power than that based on the asymptotic distribution. This is especially true when the assumptions of a normal distribution and constant variance are violated (Hatemi-J 2012). Thus, we use the bootstrapping simulation technique to assess the asymmetric causality between the two measures of financial development and economic growth.

Many studies use quantile causality tests to examine causality; however, no study uses this test to examine the causation between financial development and economic growth. However, quantile causality allows us to investigate whether smaller or larger changes in economic growth are associated with the causation between both measures of financial development and economic growth. Moreover, the Fourier function can capture gradual or smoothing shifts without knowing the number, time and type of breaks (Nazlioglu, Gormus, and Soytas 2016; Enders and Lee 2012a, 2012b). The combination of quantile causality and the Fourier function can allow the specific causality to be identified in terms of which part of the dependent variable distribution this causality occurs and can allow smooth breaks in the model's variables to be controlled by Fourier expansions Cheng et al. (2022). Thus, to capture long-term structural changes, including a Fourier function in our model estimation to investigate asymmetric Granger causation between measures of financial development and growth in quantiles given the consideration of the Fourier function is appropriate.

One of the causations between financial development and economic growth can be through a sustainable environment. Regarding the effects of financial development on a sustainable environment, we observe in Panel A of Figure 1(a) that there are

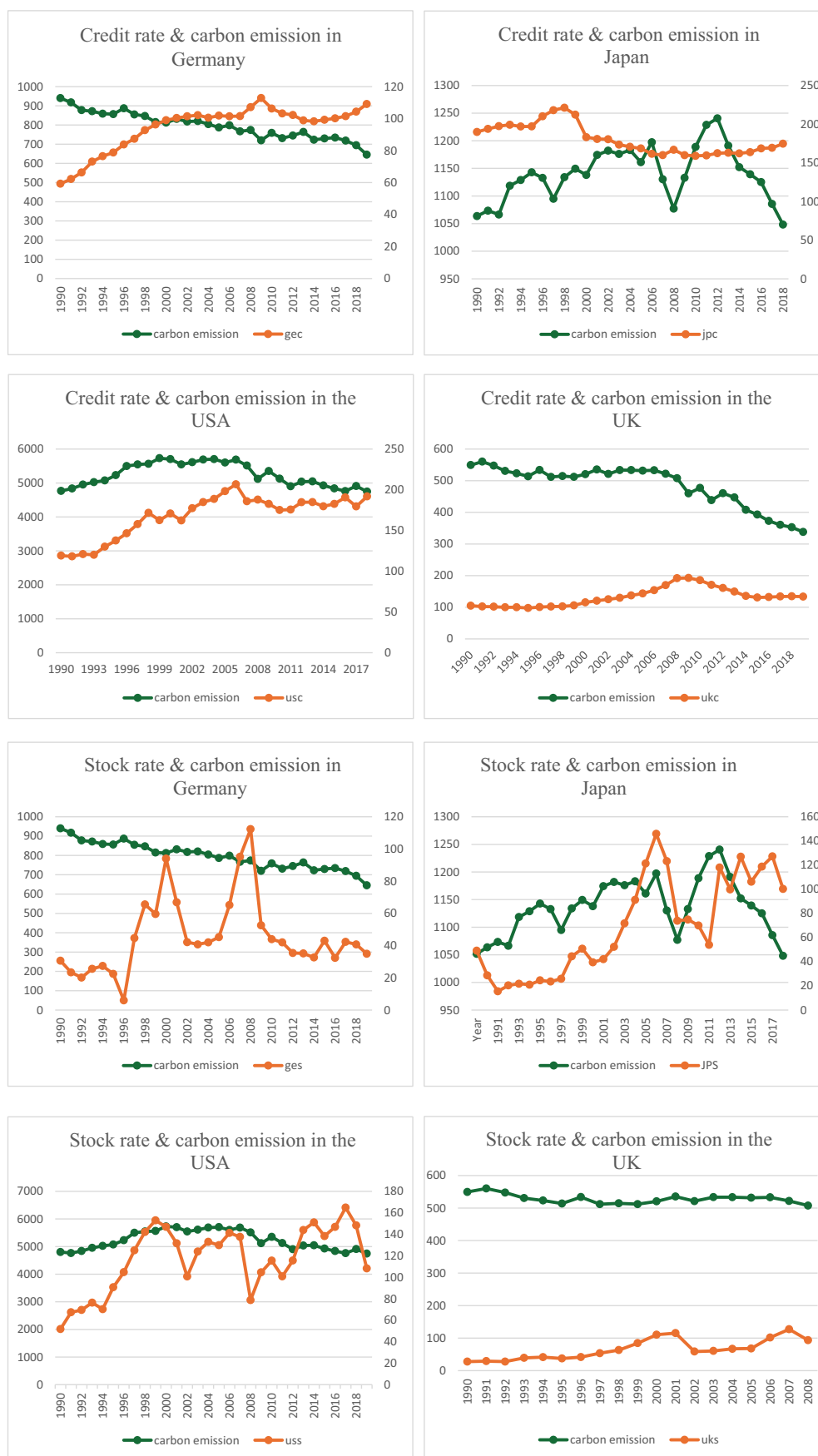


Figure 1. The association between credit rate and carbon emission in Germany, Japan, U.S.A. and UK.

tendencies towards positive associations between banking development and carbon emissions in Germany, the United States and the U.K. Meanwhile, we see in Panel B that there are the tendencies towards positive associations between stock development and carbon emissions in Japan, the United States and the U.K.

Utilizing an asymmetric causality test and a bootstrap procedure in conjunction with quantile VAR and Fourier functions, we examine the simultaneous causation between both bank sector and stock market development and economic growth. Our contribution may be that this study is almost the first to analyse nonlinear causality between both bank sector and stock market development and economic growth. Asymmetric Granger causality is adopted since positive or negative shocks can exhibit various causal effects. The bootstrapping simulation technique can overcome nonnormal distributions and time-varying volatility through leverage adjustments. The remainder of our article proceeds as follows: Section 2 describes the literature review. Section 3 reports our data and methodology. Section 4 shows the related empirical results. Section 5 concludes this study.

## II. Literature review

### *Cross-sectional and panel-based causality between financial development and growth*

Most studies on the causation between financial development and economic growth either focus on cross-sectional analyses or are centred around panel-based research. Demetriades and Hussein (1996) and Luintel and Khan (1999), who analyse the linkage between banking development and growth, deem that pooling countries in cross-sectional regressions is simpler than pooling time-series dynamics. Using a cross-sectional and dynamic panel approach, Levine, Loayza, and Beck (2000) empirically find that banking sector development is positively related to economic growth. Similarly, Christopoulos and Tsionas (2004) use panel cointegration because this technique overcomes the low data availability over long periods. Due to the significant cross-country heterogeneity, cross-sectional data cannot be pooled to

estimate the effect of financial depth on growth (Luintel et al. 2008). Meanwhile, the finance-growth relationship for a specific country hinges on the degree of its economic development (Rioja and Valev 2004).

### *Time-series causality between financial development and growth*

Recently, several studies use time-series analysis to examine the causality between financial development and growth. Stolbov (2017) examines the causality between domestic credit and GDP growth for 24 OECD countries. His result indicates the causality from domestic credit to economic growth for the U.K., Australia, Switzerland, and Greece. Using VAR modelling, Granger causality, variance decomposition and impulse response functions, Marques, Fuinhas, and Marques (2013) examine the causation between the stock market and economic growth and that between bank financing and economic growth for Portugal. They found that Granger bidirectional causality between the stock market and economic growth exists but that there is no evidence of causality between bank financing and economic growth. Using a wide breadth of both short- and long-term causality tests based on VAR, Peia and Roszbach (2015) test the causation among banking sector development, stock market development and growth for 22 advanced countries. Their results show that stock market development tends to result in output growth; however, the causality between banking sector development and economic growth mostly exhibits the reverse direction. Similarly, Lee (2012) uses the VAR model to investigate the causal links between both measures of financial development and economic growth for the U.S., the U.K., Germany, Japan, France and Korea. The results show that financial development leads to economic growth in all countries, except for Korea. The stock market plays a critical role in economic growth in the U.S., the U.K., and Japan; however, the banking sector plays a more critical role in Germany, France and Korea.

First, Stolbov (2017) is compared with this study as follows: (1) Similarities in methodologies: Time-series causality. (2) Differences in methodologies: Stolbov (2017) uses a linear model of lag-

augmented VAR and Breitung-Candelon causality; however, we use a nonlinear model of asymmetric causality combined with quantile VAR and Fourier functions. (3) Differences in results and interpretations: The results of Stolbov (2017) indicate causality from domestic credit to economic growth for the U.K. Our results show that in the boom period with positive shocks in the U.K., growth increases banking credit as such credit is higher. Second, the results of Marques, Fuinhas, and Marques (2013) are compared with those of this study and are illustrated as follows: (1) Similarities in methodologies: Time-series causality. (2) Differences in methodologies: Marques, Fuinhas, and Marques (2013) uses a linear model of VAR causality; however, we use a nonlinear model of asymmetric causality combined with quantile VAR and Fourier functions. (3) Differences in results and interpretations: Marques, Fuinhas, and Marques (2013) find that Granger bidirectional causality between the stock market and economic growth exists; however, no evidence exists in causality between bank financing and economic growth in Portugal. Our results show that in Germany and Japan, the banking sector dominates economic growth more than does the stock market. In the U.K. and U.S., an increase in stock market capitalization promotes growth. Third, the results of Peia and Roszbach (2015) are compared with those of this study and are illustrated as follows: (1) Similarities in methodologies: Time-series causality. (2) Differences in methodologies: Peia and Roszbach (2015) use a linear model of short- and long-term VAR causality; however, we use a nonlinear model of asymmetric causality combined with quantile VAR and Fourier functions. (3) Differences in results and interpretations: Peia and Roszbach (2015) show that stock market development is inclined to result in output growth; however, economic growth mostly results in bank sector development. Our results show that the banking sector dominates economic growth more than does the stock market in Germany and Japan. The stock market dominates economic growth more than does the banking sector in the U.K. and U.S. Fourth, the results of Lee (2012) are compared with those of this study and illustrated as follows: (1) Similarities in methodologies: Time-series causality. (2) Differences in methodologies:

Lee (2012) uses the linear model of VAR causality; however, we use a nonlinear model of asymmetric causality combined with quantile VAR and Fourier functions. (3) Differences in results and interpretations: Lee (2012) shows that the stock market mainly drives economic growth in the U.S., the U.K., and Japan; however, the banking sector mainly drives economic growth in Germany, France and Korea. Our results show that the banking sector dominates economic growth more than does the stock market in Germany and Japan. The stock market dominates economic growth more than does the banking sector in the U.K. and U.S.

### *Asymmetric Granger causality*

Gozgor (2015) is the first study to analyse the causation between domestic credit and economic growth by using asymmetric Granger causality based on bootstrapped critical values. Their results in 58 countries show a significant causation only from domestic credit to economic growth in 7 developing countries. In contrast, causation exists from economic growth to domestic credit in 5 developed countries and 10 developing countries. Moreover, the results of Gozgor (2015) are compared with those of this study and illustrated as follows: (1) Similarities in methodologies: Both methodologies use the nonlinear model of asymmetric causality. (2) Differences in methodologies: The financial development of Gozgor (2015) does not include stock-based measures. Additionally, the asymmetric causality of Gozgor (2015) does not consider quantile VAR and Fourier functions; however, that of this study does. (3) Differences in results and interpretations: The results of Gozgor (2015) show a significant causation from economic growth to banking credit for only five developed countries; however, our results indicate that causation exists from banking credit to economic growth for Germany and Japan.

Hatemi-J (2012) uses the asymmetric causality test combined with a bootstrap simulation approach to indicate that, regardless of whether oil price shocks are positive or negative, the stock market is efficient in the presence of oil shocks. The bootstrap simulation approach with leveraged adjustments performs more precisely when the assumptions for the validity of the data distributions are violated. This situation occurs especially when the data are not normally distributed

or when time-varying volatility exists. By using asymmetry in causality, Hatemi-J and Uddin (2012) investigate the causation between U.S. energy utilization and GDP per capita. Their results show that a negative energy consumption shock leads to a negative shock in GDP per capita. However, positive shocks have no effect.

***One of the causation between financial development and economic growth may occur through a sustainable environment***

Regardless of whether it is financial development or economic growth, both have a significant effect on a sustainable environment (Jahanger et al., 2022a; Chen et al. 2022; Rafei, Esmaeili, and Balsalobre-Lorente 2022; Jahanger et al., 2022b). The arguments imply that one of the causations between financial development and economic growth can be through a sustainable environment. On the one hand, some studies demonstrate the effects of financial development on a sustainable environment. Jahanger et al. (2022b) empirically show that financial development evidently deteriorates environmental quality. This phenomenon is possible because banks tend to increase their loans for energy-concentrated consumer products, which results in more energy consumption and thus increases environmental pollution (Usman, Makhdom, and Kousar 2021; Yang, Jahanger, and Khan 2020). Chen et al. (2022) report that financial development significantly and negatively influences the eco-environment during a long period. This finding is probable since financial institutions provide credits for firms experiencing environmental destruction and, thus, intensifies environmental pollution. Hence, the effect of financial development on a sustainable environment can further influence economic growth, reflecting causation between financial development and economic growth.

On the other hand, other studies find the effects of economic growth on a sustainable environment. Rafei, Esmaeili, and Balsalobre-Lorente (2022) empirically show that economic growth harms the ecological footprint and thus results in environmental

pollution, whereas economic growth due to natural resources positively affects environmental quality. Jahanger et al. (2022) demonstrate unidirectional causalities from economic growth, foreign direct investment to carbon emissions in the form of an inverted U-shaped relationship in the long term. Hence, the effect of economic growth on a sustainable environment can further influence financial development, which results in causation between economic growth and financial development.

### **III. Data and methodology**

#### ***Data***

Our sample includes four developed countries – Germany, Japan, the United States, and the United Kingdom – with a fair level of financial development. These four countries are considered because Germany and Japan have bank-based development, and the U.S. and the U.K. have market-based development. We adopt annual data from the 1960s. Nevertheless, because of data availability in the stock market, our sample period in each country is slightly different. Our period is 1975–2019 for Germany,<sup>1</sup> Japan, and the U.K. and is 1979–2019 for the U.S.<sup>2</sup>

Data on the rate of domestic credit of the banking sector over GDP (*CreditRa*) are obtained from the International Monetary Fund and World Bank databases, and data on the rate of stock market capitalization over GDP (*StockRa*) are collected from International Financial Statistics (*IFS*). The data on *log per capita GDP* (*GDP*) are collected from the *IFS*. Our raw sample is unbalanced. Table 1 shows the detailed definitions of these variables.

#### ***Methodology-asymmetric Granger causality using quantile VAR considering Fourier function***

We first use the traditional Granger causality test to detect whether the financial development of the banking sector (or of the stock market) drives economic growth.<sup>3</sup> Then, we examine the asymmetric causality test following Hatemi-J (2012)

<sup>1</sup>For Germany, we use data from West Germany from 1975 to 1991 and on the unification of Western and Eastern Germany from 1992 to 2019 since this unification was finalized in 1991.

<sup>2</sup>Our U.S. data begin from 1979 because U.S. stock market data are available from that year.

<sup>3</sup>Similarly, our traditional Granger causality test only investigates the causality of positive shocks and level terms.

**Table 1.** Variable definitions.

| Classification             | Variable name   | Description or formula                                                                                               | Source          |
|----------------------------|-----------------|----------------------------------------------------------------------------------------------------------------------|-----------------|
| Economic development var.  | <i>GDP</i>      | log per capita GDP                                                                                                   | IFS             |
|                            | <i>GROWTH</i>   | (log per capita GDP <sub>t</sub> - log per capita GDP <sub>t-1</sub> )                                               |                 |
| Financial development var. | <i>CreditRa</i> | Credit rate:<br>= $\frac{\text{Credit provided by financial sector}}{\text{GDP}} \times 100\%$                       | IMF, World bank |
|                            | <i>StockRa</i>  | Stock market capitalization to nominal GDP<br>= $\frac{\text{Stock market capitalization}}{\text{GDP}} \times 100\%$ | IFS             |

1. IMF: International Monetary Fund, <http://www.imf.org/en/Data#data>; 2. IFS: International Financial Statistics.

since positive shocks, negative shocks and level terms can have different causal impacts. Following the approach of Gozgor (2015), which focuses only on positive causality, we focus on causality with cumulative positive errors and level terms between the financial development of the banking sector (or of the stock market) and economic growth. The consideration of only the causality of positive shocks and level terms is mainly because there are fewer negative shocks to the GDP of many countries. The two integrated variables  $y_t$  and  $x_t$  are assumed to have a data generating process (DGP) as follows.

$$y_t = y_{t-1} + \varepsilon_{1t} = y_0 + \sum_{i=1}^t \varepsilon_{1i} \quad (1)$$

$$x_t = x_{t-1} + \varepsilon_{2t} = x_0 + \sum_{i=1}^t \varepsilon_{2i} \quad (2)$$

where  $y_0$  and  $x_0$  are the initial values of  $y_t$  and  $x_t$ , respectively, and  $\varepsilon_{1t}$  and  $\varepsilon_{2t}$  are i.i.d. with variances  $\sigma_{\varepsilon_1}^2$  and  $\sigma_{\varepsilon_2}^2$ , respectively. Additionally, the definitions of  $y_t$  and  $x_t$  in (4) and (5) are per capita GDP (*GDP*) and *CreditRa* (or *StockRa*), which measure economic output and bank-based development (or stock-based development), respectively. The definitions of positive and negative shocks are shown as follows:

$$\varepsilon_{1i}^+ = \max(\varepsilon_{1i}, 0), \varepsilon_{2i}^+ = \max(\varepsilon_{2i}, 0),$$

$$\varepsilon_{1i}^- = \max(\varepsilon_{1i}, 0), \varepsilon_{2i}^- = \max(\varepsilon_{2i}, 0).$$

Thus,  $\varepsilon_{1i} = \varepsilon_{1i}^+ + \varepsilon_{1i}^-$  and  $\varepsilon_{2i} = \varepsilon_{2i}^+ + \varepsilon_{2i}^-$  can be obtained, and Equation (1) and (2) can be rewritten as follows:

$$y_t = y_{t-1} + \varepsilon_{1t} = y_0 + \sum_{i=1}^t \varepsilon_{1i}^+ + \sum_{i=1}^t \varepsilon_{1i}^- \quad (3)$$

$$x_t = x_{t-1} + \varepsilon_{2t} = x_0 + \sum_{i=1}^t \varepsilon_{2i}^+ + \sum_{i=1}^t \varepsilon_{2i}^- \quad (4)$$

Due to our focus on positive shocks, we only define the cumulative positive shocks of each variable as  $y_t^+ = \sum_{i=1}^t \varepsilon_{1i}^+$  and  $x_t^+ = \sum_{i=1}^t \varepsilon_{2i}^+$ . Next, in addition to examining the causation of level terms ( $y_t, x_t$ ) of different variables, we examine the causation of positive shocks ( $y_t^+, x_t^+$ ) by extending the test statistics of Hatemi-J (2012) and Hatemi-J and Uddin (2012). Moreover, several studies propose that a Fourier approximation often captures unknown breaks in structural changes (Chang and Chang 2012; Enders and Lee 2009; Pascalau 2010). The testing framework of a Fourier function requires only a specific frequency in model estimation. That is, the decrease in the number of parameters of flexible Fourier transforms can lead the examinations to have good size and power regardless of the date or form of the break. Thus, we consider a Fourier function in the model estimation. The simultaneous consideration of quantile causality and the Fourier function can identify which part of the distribution of dependent variables is predicted by covariates and can cause smooth breaks in the deterministic parts to be controlled by Fourier expansions.

Specifically, we identify the existence of a Fourier function by using restricted F statistics. If the null hypothesis of no Fourier function is accepted, we use a Wald test without a Fourier function to examine asymmetric Granger causality through the QVAR ( $p$ ) model. Otherwise, a Wald test with a Fourier function is adopted. Furthermore, compared with the VAR model of Hatemi-J (2012) and Hatemi-J and Uddin (2012), we adopt the QVAR model to examine asymmetric causality. Our consideration of the QVAR is because the causality between financial development and economic output can be influenced by the degree of a country's economic growth. Using the QVAR model with a Fourier function as an example, the related QVAR model is shown as follows:

$$\begin{aligned}
Q(Y_t^k(\tau)) = & \eta + A_1(\tau)Y_{t-1}^k + \dots + A_p(\tau)Y_{t-p}^k \\
& + \gamma_1 \sin\left(\frac{2\pi f t}{T}\right) + \gamma_2 \cos\left(\frac{2\pi f t}{T}\right) \\
& + v_t^k(8)
\end{aligned} \quad (5)$$

where  $Y_t^k = (y_t^k, x1_t^k, x2_t^k)$ ,  $k$  is the form of the elements of positive shocks or level terms, and  $p$  is the order of the VAR model.  $A_r$  is the parameter matrix of lag order  $r$  ( $r = 1 \dots p$ ), and  $f$  is the frequency in the Fourier function.

We simplify the QVAR ( $p$ ) model as follows:

$$Y = ZD + \delta \quad (6)$$

The null hypothesis of non-Granger causality,  $R\beta = 0$ , is examined by the following Ward test:

$$Ward = (R\beta)' \left[ R \left( (Z'Z)^{-1} \otimes S \right) R' \right]^{-1} (R\beta) \quad (7)$$

where  $R$  is a parameter matrix with restricted parameters of one,  $\beta$  is the column pile of  $D$ ,  $S$  is the variance–covariance matrix of the unrestricted model, and  $\otimes$  is the Kronecker product. Thus, we adopt the bootstrap simulation proposed by Hatemi-J and Uddin (2012) with 5,000–10,000 iterations to establish 10%, 5%, and 1% critical values. To identify the existence of a Fourier function, we first adopt the Wald test to detect the null hypothesis:  $\gamma_1 = \gamma_2 = 0$ .

## IV. Empirical results

### Basic statistics and cointegration between finance and growth

The results of the descriptive statistics in Table 2 show that on average, the average per capita GDP is the highest for Germany, second for the U.S., third

for Japan, and the lowest for the U.K. The average ratio of domestic credit to GDP is the highest for Japan, whereas the average ratio of stock market capitalization to GDP is the highest for the U.S. Overall, all of the average values of the banking sector are greater than those of stock market in the U.S., U.K., Japan and Germany.

Table 3 presents the results of the cointegration test of *CreditRa*, *StockRa* and *GDP*. Regarding the level terms of these variables, both the maximum eigenvalue and trace statistics reject the critical value of no cointegration and find evidence of one cointegrating vector in Germany, Japan and the U.S., except for the U.K. Regarding the positive shocks, both statistics show the existence of one cointegrating vector in the U.K. and one in the U.S. but no evidence of cointegration in Germany and Japan. These results show evidence of cointegration between finance and output only for the level terms in Germany and Japan, only for the positive shocks in the U.K., and both for the level terms and positive shocks in the U.S. The findings indicate that cointegration exists in our four sample countries for either the level terms or the positive shocks. We subsequently examine the causality of this long-run relationship.

### The results of the traditional Granger causality test

Our results of traditional Granger causality tests of the positive shocks and level terms are shown in Table 4. For simplicity, we only consider one lag to justify the test results. Panel A shows that in Germany, domestic banking credit Granger-causes per capita GDP in level terms at 5% significance and in positive shocks at 1% significance. However, stock market capitalization does not Granger-cause GDP.

**Table 2.** Descriptive statistics.

| Country | Variable        | Obs. | Mean      | Std. Dev. | Max       | Min       |
|---------|-----------------|------|-----------|-----------|-----------|-----------|
| Germany | <i>CreditRa</i> | 50   | 72.283    | 29.854    | 112.860   | 26.481    |
|         | <i>StockRa</i>  | 45   | 33.258    | 26.425    | 112.322   | 1.489     |
|         | <i>GDP</i>      | 49   | 34243.420 | 8085.678  | 47446.730 | 20260.670 |
| Japan   | <i>CreditRa</i> | 50   | 163.048   | 28.924    | 221.289   | 108.270   |
|         | <i>StockRa</i>  | 45   | 57.665    | 40.084    | 145.857   | 11.545    |
|         | <i>GDP</i>      | 60   | 22187.450 | 16505.190 | 48603.480 | 478.995   |
| UK      | <i>CreditRa</i> | 60   | 83.250    | 55.726    | 192.592   | 17.339    |
|         | <i>StockRa</i>  | 34   | 43.825    | 35.494    | 127.309   | 5.825     |
|         | <i>GDP</i>      | 60   | 20151.680 | 16517.910 | 50566.830 | 1397.595  |
| US      | <i>CreditRa</i> | 60   | 129.160   | 42.757    | 206.671   | 70.875    |
|         | <i>StockRa</i>  | 40   | 100.130   | 39.829    | 164.850   | 39.352    |
|         | <i>GDP</i>      | 60   | 26093.910 | 19121.400 | 65297.520 | 3007.124  |

**Table 3.** Cointegration test.

|                                                 | Hypothesized<br>No. of CE(s) | Eigenvalue | Trace<br>Statistic | 0.05<br>Critical value | Prob.  | Max-Eigen<br>Statistic | Critical value | Prob.  |
|-------------------------------------------------|------------------------------|------------|--------------------|------------------------|--------|------------------------|----------------|--------|
| <b>Panel A Cointegration for level terms</b>    |                              |            |                    |                        |        |                        |                |        |
| Germany                                         | None                         | 0.352152   | 39.872             | 42.915                 | 0.0976 | 24.744                 | 25.823         | 0.0689 |
|                                                 | At most 1                    | 0.162067   | 15.128             | 25.872                 | 0.5639 | 10.079                 | 19.387         | 0.6104 |
|                                                 | At most 2                    | 0.084776   | 5.049              | 12.518                 | 0.5893 | 5.049                  | 12.518         | 0.5893 |
| Japan                                           | None                         | 0.414147   | 42.376             | 42.915                 | 0.0566 | 30.477*                | 25.823*        | 0.0113 |
|                                                 | At most 1                    | 0.12654    | 11.899             | 25.872                 | 0.819  | 7.712                  | 19.387         | 0.8465 |
|                                                 | At most 2                    | 0.070822   | 4.187              | 12.518                 | 0.7149 | 4.187                  | 12.518         | 0.7149 |
| UK                                              | None                         | 0.224973   | 29.532             | 42.915                 | 0.5301 | 14.527                 | 25.823         | 0.6766 |
|                                                 | At most 1                    | 0.162564   | 15.005             | 25.872                 | 0.5741 | 10.112                 | 19.387         | 0.6068 |
|                                                 | At most 2                    | 0.082255   | 4.893              | 12.518                 | 0.6118 | 4.893                  | 12.518         | 0.6118 |
| US                                              | None                         | 0.390757   | 51.389*            | 42.915*                | 0.0058 | 28.246*                | 25.823*        | 0.0235 |
|                                                 | At most 1                    | 0.236362   | 23.143             | 25.872                 | 0.1053 | 15.371                 | 19.387         | 0.1743 |
|                                                 | At most 2                    | 0.127476   | 7.773              | 12.518                 | 0.2708 | 7.773                  | 12.518         | 0.2708 |
| <b>Panel B Cointegration for positive terms</b> |                              |            |                    |                        |        |                        |                |        |
| Germany                                         | None                         | 0.265746   | 37.314             | 42.915                 | 0.1623 | 17.607                 | 25.823         | 0.4079 |
|                                                 | At most 1                    | 0.200436   | 19.707             | 25.872                 | 0.2411 | 12.750                 | 19.387         | 0.3486 |
|                                                 | At most 2                    | 0.114895   | 6.957              | 12.518                 | 0.3491 | 6.957                  | 12.518         | 0.3491 |
| Japan                                           | None                         | 0.253884   | 34.491             | 42.915                 | 0.2666 | 16.694                 | 25.823         | 0.4838 |
|                                                 | At most 1                    | 0.203534   | 17.797             | 25.872                 | 0.3577 | 12.972                 | 19.387         | 0.3304 |
|                                                 | At most 2                    | 0.081175   | 4.826              | 12.518                 | 0.6215 | 4.826                  | 12.518         | 0.6215 |
| UK                                              | None                         | 0.424998   | 43.440*            | 42.915*                | 0.0443 | 31.543*                | 25.823*        | 0.0079 |
|                                                 | At most 1                    | 0.124015   | 11.897             | 25.872                 | 0.8191 | 7.547                  | 19.387         | 0.86   |
|                                                 | At most 2                    | 0.073478   | 4.350              | 12.518                 | 0.691  | 4.350                  | 12.518         | 0.691  |
| US                                              | None                         | 0.389112   | 47.825*            | 42.915*                | 0.015  | 28.092*                | 25.823*        | 0.0247 |
|                                                 | At most 1                    | 0.243276   | 19.733             | 25.872                 | 0.2397 | 15.889                 | 19.387         | 0.15   |
|                                                 | At most 2                    | 0.065209   | 3.844              | 12.518                 | 0.7646 | 3.844                  | 12.518         | 0.7646 |

CE denotes the cointegration test of *CreditRa*, *StockRa* and *GDP*.

\*, \*\*, and \*\*\*denote significances at the 10%, 5% and 1% levels, respectively.

Moreover, per capita GDP Granger-causes stock market capitalization at 10% significance regardless of the level terms or positive shocks. Panel B presents the results for Japan, which are very similar to those for Germany. In Japan, banking credit Granger-causes per capita GDP both in level terms and positive shocks; however, no causality exists between the stock market and output. Additionally, causation occurs from GDP to the stock market. As expected, in Germany and Japan, the banking sector acts as a more important driving factor for economic growth than does the stock market.

In contrast, Panel C shows that in the U.K., stock market capitalization Granger-causes GDP both in level terms and positive shocks. However, no causal link runs from banking credit to output. Panel D shows that in the U.S., stock market capitalization Granger-causes GDP only in level terms. In addition, causality exists from stock market capitalization to banking credit regardless of the level terms or positive shocks. In the U.K. and the U.S., the stock market acts as a more critical driving force for economic growth than does the banking sector; however, the driving force is only centred around level terms rather than positive shocks.

### **The results of asymmetric Granger causality based on Fourier quantile VAR**

Before examining asymmetric Granger causality under quantile VAR, we first use restricted F statistics to examine the absence of Fourier expansion in Equation (5) for both level terms and positive shocks. The maximum lag length ( $p = 4$ ) and frequency ( $k = 5$ ) are set. Panel A in Table 5 shows the results of the restricted F statistics of the Fourier function for the level terms of these variables. In Germany, the F statistics for the causality from credit to growth, from credit to stock market, from growth to credit, from growth to stock market, from stock market to credit and from stock market to growth are smaller than the corresponding bootstrap critical values regardless of the 10%, 5% or 1% significance. Our results indicate that the null hypothesis of no Fourier function is accepted in Germany for level terms. We also find the optimal frequency to be from 1.2 to 4.6 and the optimal lag lengths to be from 1 to 2. Similarly, we find that the null hypothesis of the absence of the Fourier function is accepted in Japan, the U.K., and the U.S. for level terms and in Germany, Japan, the U.K. and the U.S. for positive shocks (Panel B).

**Table 4.** The results of traditional Granger-causality tests.

| Level terms            |             |         | Positive shocks   |             |         |
|------------------------|-------------|---------|-------------------|-------------|---------|
|                        | F-statistic | P-value |                   | F-statistic | P-value |
| <b>Panel A Germany</b> |             |         |                   |             |         |
| $G \Rightarrow C$      | 0.3002      | 0.586   | $G \Rightarrow C$ | 0.0193      | 0.890   |
| $C \Rightarrow G$      | 6.3687**    | 0.015   | $C \Rightarrow G$ | 7.9203***   | 0.007   |
| $S \Rightarrow C$      | 1.5331      | 0.221   | $S \Rightarrow C$ | 0.1688      | 0.683   |
| $C \Rightarrow S$      | 6.7938**    | 0.012   | $C \Rightarrow S$ | 8.0603***   | 0.006   |
| $S \Rightarrow G$      | 0.0002      | 0.990   | $S \Rightarrow G$ | 0.5419      | 0.465   |
| $G \Rightarrow S$      | 3.3711*     | 0.072   | $G \Rightarrow S$ | 2.8672*     | 0.096   |
| <b>Panel B Japan</b>   |             |         |                   |             |         |
| $G \Rightarrow C$      | 0.0332      | 0.856   | $G \Rightarrow C$ | 0.1324      | 0.717   |
| $C \Rightarrow G$      | 3.8441*     | 0.055   | $C \Rightarrow G$ | 7.7450***   | 0.007   |
| $S \Rightarrow C$      | 0.0044      | 0.947   | $S \Rightarrow C$ | 0.0982      | 0.755   |
| $C \Rightarrow S$      | 1.1012      | 0.299   | $C \Rightarrow S$ | 1.5951      | 0.212   |
| $S \Rightarrow G$      | 2.2294      | 0.141   | $S \Rightarrow G$ | 0.0204      | 0.887   |
| $G \Rightarrow S$      | 2.9276*     | 0.093   | $G \Rightarrow S$ | 3.1761*     | 0.080   |
| <b>Panel C UK</b>      |             |         |                   |             |         |
| $G \Rightarrow C$      | 1.6395      | 0.206   | $G \Rightarrow C$ | 0.0909      | 0.764   |
| $C \Rightarrow G$      | 2.2362      | 0.140   | $C \Rightarrow G$ | 5.4835**    | 0.023   |
| $S \Rightarrow C$      | 33.5269***  | 0.000   | $S \Rightarrow C$ | 1.3529      | 0.250   |
| $C \Rightarrow S$      | 0.1709      | 0.681   | $C \Rightarrow S$ | 2.6107      | 0.112   |
| $S \Rightarrow G$      | 0.3498      | 0.557   | $S \Rightarrow G$ | 4.5345**    | 0.038   |
| $G \Rightarrow S$      | 0.0231      | 0.880   | $G \Rightarrow S$ | 0.7963      | 0.376   |
| <b>Panel D US</b>      |             |         |                   |             |         |
| $G \Rightarrow C$      | 3.0556*     | 0.086   | $G \Rightarrow C$ | 5.4896**    | 0.023   |
| $C \Rightarrow G$      | 0.5295      | 0.470   | $C \Rightarrow G$ | 1.9540      | 0.168   |
| $S \Rightarrow C$      | 4.0420**    | 0.049   | $S \Rightarrow C$ | 4.5360**    | 0.038   |
| $C \Rightarrow S$      | 0.1012      | 0.752   | $C \Rightarrow S$ | 0.7294      | 0.397   |
| $S \Rightarrow G$      | 8.6545***   | 0.005   | $S \Rightarrow G$ | 0.1566      | 0.694   |
| $G \Rightarrow S$      | 1.6515      | 0.204   | $G \Rightarrow S$ | 10.9593***  | 0.002   |

1. The C, S and G denote *CreditRa*, *StockRa*, and *GDP* in Table 1, respectively. Taking  $C \Rightarrow G$  for example, the hypothesis of GC behind  $C \Rightarrow G$  is *CreditRa* does not Granger cause *GDP*.

2. \*, \*\*, and \*\*\* denote significances at the 10%, 5% and 1% levels, respectively.

Tables 6–9 report the results of asymmetric quantile VAR Granger causality in our four sample countries for both level terms and positive shocks. Regarding the results for Germany for the level terms in Table 6, the significant causal parameters from credit to GDP are 7.559 and 20.474 within quantiles 0.6 and 0.8, respectively; thus, Granger causality occurs from banking credit to GDP as economic output increases. Meanwhile, the significant causal parameter from the stock market to credit is 6.946 within quantile 0.6; thus, there is causality from stock market capitalization to banking credit as there is higher domestic credit. Accordingly, stock market capitalization stimulates the need for banking credit, as there is greater domestic credit, and banking credit promotes economic growth as economic output is higher. Similar to the results of the level terms, our results of positive shocks indicate that the significant causal parameters are 7.546, 9.245 and 14.000 from credit to GDP within quantiles 0.4, 0.6 and 0.8, respectively; thus, Granger causality occurs from banking credit to GDP as economic output is

higher. Meanwhile, the significant causal parameter is 47.761 from the stock market to credit within quantile 0.8 and thus a causality from stock market capitalization to banking credit as there is higher domestic credit. Similarly, the stock market stimulates banking credit as it is higher, and banking credit promotes economic growth as output is nonlower. Furthermore, the findings are more significant during the boom period with positive shocks than during the normal period with level terms, which implies the existence of asymmetric causality. Similar to the results of traditional Granger causality, asymmetric quantile VAR Granger causality shows that in Germany, the banking sector dominates economic growth more than does the stock market. However, the latter findings indicate that the impacts of domestic credit on growth only focus on higher economic output, and the effects can partly stem from the push of stock market capitalization on domestic credit for higher domestic credit.

Similarly, the results for Japan in Table 7 show Granger causality from banking credit to GDP

**Table 5.** The results of the examination in the absence of Fourier expansion by using the restricted F statistics for both level terms and positive shocks.

| Country                         | GC   | Optimum frequency | Optimum lags | Restricted F statistics | CV(10%) res F stat | CV(5%) res F stat | CV(1%) res F stat |
|---------------------------------|------|-------------------|--------------|-------------------------|--------------------|-------------------|-------------------|
| <b>Panel A: Level terms</b>     |      |                   |              |                         |                    |                   |                   |
| Germany                         | C≠>G | 1.8               | 2            | 3.421                   | 7.671              | 8.992             | 13.858            |
|                                 | C≠>S | 4.6               | 1            | 2.350                   | 10.560             | 13.458            | 17.878            |
|                                 | G≠>C | 1.2               | 1            | 2.978                   | 21.840             | 24.104            | 29.479            |
|                                 | G≠>S | 4.6               | 1            | 2.350                   | 12.043             | 13.979            | 18.686            |
|                                 | S≠>C | 1.2               | 1            | 2.978                   | 22.538             | 25.285            | 32.624            |
| Japan                           | S≠>G | 1.8               | 2            | 3.421                   | 8.281              | 10.019            | 13.339            |
|                                 | C≠>G | 0.7               | 1            | 6.088                   | 16.976             | 19.385            | 25.539            |
|                                 | C≠>S | 0.9               | 1            | 0.232                   | 3.638              | 4.550             | 8.225             |
|                                 | G≠>C | 1.4               | 1            | 3.133                   | 12.575             | 14.642            | 20.535            |
|                                 | G≠>S | 0.9               | 1            | 0.232                   | 3.992              | 5.273             | 7.238             |
| UK                              | S≠>C | 1.4               | 1            | 3.133                   | 12.861             | 14.414            | 18.373            |
|                                 | S≠>G | 0.7               | 1            | 6.088                   | 17.411             | 19.661            | 23.958            |
|                                 | C≠>G | 0.7               | 2            | 3.106                   | 9.919              | 11.503            | 15.426            |
|                                 | C≠>S | 1.5               | 2            | 3.449                   | 10.491             | 12.210            | 16.343            |
|                                 | G≠>C | 3.3               | 1            | 3.403                   | 15.726             | 18.212            | 25.305            |
| US                              | G≠>S | 1.5               | 2            | 3.449                   | 11.288             | 12.938            | 16.678            |
|                                 | S≠>C | 3.3               | 1            | 3.403                   | 16.684             | 19.862            | 26.008            |
|                                 | S≠>G | 0.7               | 2            | 3.106                   | 9.921              | 12.320            | 16.385            |
|                                 | C≠>G | 0.7               | 3            | 6.802                   | 16.053             | 17.723            | 21.906            |
|                                 | C≠>S | 0.1               | 1            | 2.778                   | 5.939              | 7.346             | 9.762             |
|                                 | G≠>C | 1.6               | 1            | 5.911                   | 9.780              | 11.937            | 16.342            |
|                                 | G≠>S | 0.1               | 1            | 2.778                   | 5.603              | 7.727             | 11.621            |
|                                 | S≠>C | 1.6               | 1            | 5.911                   | 10.508             | 13.416            | 19.235            |
|                                 | S≠>G | 0.7               | 3            | 6.802                   | 16.654             | 18.661            | 22.587            |
| <b>Panel B: Positive Shocks</b> |      |                   |              |                         |                    |                   |                   |
| Germany                         | C≠>G | 1.8               | 3            | 6.009                   | 9.178              | 11.221            | 14.349            |
|                                 | C≠>S | 2.1               | 2            | 1.223                   | 3.928              | 5.387             | 7.050             |
|                                 | G≠>C | 1.3               | 3            | 7.948                   | 14.841             | 16.670            | 21.295            |
|                                 | G≠>S | 2.1               | 2            | 1.223                   | 4.088              | 5.268             | 8.234             |
|                                 | S≠>C | 1.3               | 3            | 7.948                   | 14.364             | 16.830            | 22.313            |
| Japan                           | S≠>G | 1.8               | 3            | 6.009                   | 9.532              | 11.708            | 16.515            |
|                                 | C≠>G | 0.1               | 4            | 9.769                   | 20.968             | 23.635            | 30.539            |
|                                 | C≠>S | 1                 | 1            | 2.495                   | 8.121              | 9.984             | 15.725            |
|                                 | G≠>C | 4.6               | 1            | 3.303                   | 9.047              | 10.609            | 14.303            |
|                                 | G≠>S | 1                 | 1            | 2.495                   | 7.733              | 9.268             | 12.183            |
| UK                              | S≠>C | 4.6               | 1            | 3.303                   | 9.294              | 10.593            | 15.969            |
|                                 | S≠>G | 0.1               | 4            | 9.769                   | 19.685             | 23.066            | 31.251            |
|                                 | C≠>G | 0.1               | 3            | 13.273                  | 16.614             | 18.923            | 23.188            |
|                                 | C≠>S | 1.3               | 1            | 3.650                   | 20.170             | 23.769            | 34.045            |
|                                 | G≠>C | 3.4               | 4            | 5.663                   | 28.190             | 37.988            | 53.610            |
| US                              | G≠>S | 1.3               | 1            | 3.650                   | 19.528             | 22.873            | 31.736            |
|                                 | S≠>C | 3.4               | 4            | 5.663                   | 26.983             | 36.275            | 54.461            |
|                                 | S≠>G | 0.1               | 3            | 13.273                  | 16.473             | 18.091            | 21.269            |
|                                 | C≠>G | 0.4               | 4            | 12.134                  | 21.676             | 24.520            | 31.045            |
|                                 | C≠>S | 1.1               | 1            | 7.596                   | 14.231             | 16.585            | 21.017            |
|                                 | G≠>C | 5                 | 4            | 5.886                   | 10.391             | 13.104            | 17.252            |
|                                 | G≠>S | 1.1               | 1            | 7.596                   | 14.320             | 16.451            | 22.933            |
|                                 | S≠>C | 5                 | 4            | 5.886                   | 10.448             | 12.540            | 16.531            |
|                                 | S≠>G | 0.4               | 4            | 12.134                  | 19.998             | 22.786            | 32.286            |

The C, S and G denote *CreditRa*, *StockRa*, and *GDP* in Table 1, respectively. GC means the Granger Causality, and taking C ≠> G for example, the hypothesis of GC behind C ≠> G is *CreditRa* does not Granger cause *GDP*.

CV10%, CV 5%, and CV1% are the critical values of Restricted F statistics, respectively.

within quantiles 0.6 and 0.8 for level terms and within quantiles 0.4 and 0.6 for positive shocks. Hence, banking credit causes growth, as output is higher in the normal period with level terms and is moderate in the boom period with positive shocks. The former is possible because higher output easily accelerates the effects of domestic credit on growth only during the normal period with level terms, which again denotes the asymmetric effects of credit on growth for level terms and positive

shocks. Similar to the results in Table 4, the results in Table 7 show that in Japan, the banking sector causes more economic growth than does the stock market. In contrast to Table 4, our results in Table 7 show that the impacts of domestic credit on growth occur in nonlower economic output, and the driving force of output on the stock market disappears.

Next, our U.K. results for the level terms in Table 8 exhibit Granger causality from banking

**Table 6.** The results of asymmetric quantile VAR granger causality in Germany for both level terms and positive shocks.

| Country | GC                | Quantile. | Wald test.           | CV 10%. | CV 5%. | CV 1%. | Wald test.               | CV 10%. | CV 5%. | CV 1%. |
|---------|-------------------|-----------|----------------------|---------|--------|--------|--------------------------|---------|--------|--------|
|         |                   |           | Panel A: Level terms |         |        |        | Panel B: Positive shocks |         |        |        |
| Germany | C $\Rightarrow$ G | 0.2       | 1.793                | 4.669   | 6.514  | 9.643  | 4.455                    | 7.017   | 9.296  | 14.470 |
|         |                   | 0.4       | 2.935                | 5.029   | 6.593  | 10.236 | 7.546*                   | 6.832   | 9.463  | 18.266 |
|         |                   | 0.6       | 7.559*               | 6.280   | 8.446  | 14.183 | 9.245*                   | 8.476   | 10.660 | 18.218 |
|         |                   | 0.8       | 20.474**             | 9.038   | 13.585 | 25.915 | 14.000**                 | 10.210  | 12.342 | 23.493 |
|         | C $\Rightarrow$ S | 0.2       | 2.435                | 2.863   | 3.697  | 6.024  | 0.000                    | 4.305   | 6.028  | 9.342  |
|         |                   | 0.4       | 0.318                | 1.891   | 2.893  | 5.866  | 0.000                    | 2.466   | 3.522  | 5.802  |
|         |                   | 0.6       | 0.083                | 1.913   | 2.941  | 5.722  | 0.494                    | 3.066   | 4.574  | 7.163  |
|         |                   | 0.8       | 0.209                | 2.878   | 4.194  | 6.138  | 0.971                    | 5.184   | 6.941  | 13.371 |
|         | G $\Rightarrow$ C | 0.2       | 2.888                | 4.048   | 5.386  | 11.351 | 0.363                    | 4.832   | 6.099  | 16.628 |
|         |                   | 0.4       | 2.390                | 2.488   | 3.732  | 6.500  | 0.587                    | 3.946   | 5.505  | 8.886  |
|         |                   | 0.6       | 0.518                | 2.751   | 4.028  | 5.891  | 1.539                    | 5.892   | 7.665  | 11.682 |
|         |                   | 0.8       | 0.012                | 4.152   | 5.881  | 11.501 | 1.176                    | 8.272   | 11.174 | 17.007 |
|         | G $\Rightarrow$ S | 0.2       | 0.714                | 2.580   | 3.629  | 7.346  | 0.000                    | 2.580   | 3.260  | 5.452  |
|         |                   | 0.4       | 0.820                | 1.610   | 2.359  | 3.972  | 0.000                    | 1.652   | 2.575  | 4.898  |
|         |                   | 0.6       | 0.488                | 1.923   | 2.671  | 4.796  | 0.231                    | 2.688   | 3.418  | 8.842  |
|         |                   | 0.8       | 1.916                | 2.164   | 3.172  | 6.915  | 0.276                    | 4.806   | 6.279  | 16.806 |
|         | S $\Rightarrow$ C | 0.2       | 0.246                | 5.410   | 11.455 | 25.253 | 7.787                    | 8.420   | 11.382 | 20.165 |
|         |                   | 0.4       | 0.127                | 4.288   | 8.041  | 19.114 | 3.637                    | 8.057   | 10.489 | 16.588 |
|         |                   | 0.6       | 6.946*               | 4.723   | 7.884  | 19.804 | 7.597                    | 9.430   | 12.194 | 19.029 |
|         |                   | 0.8       | 0.032                | 6.403   | 8.930  | 20.386 | 47.761***                | 14.881  | 17.568 | 26.069 |
|         | S $\Rightarrow$ G | 0.2       | 1.246                | 13.612  | 16.942 | 25.707 | 6.226                    | 7.738   | 10.494 | 17.656 |
|         |                   | 0.4       | 0.564                | 8.217   | 10.918 | 17.420 | 5.660                    | 5.671   | 7.271  | 12.463 |
|         |                   | 0.6       | 0.097                | 6.752   | 9.313  | 15.271 | 6.054                    | 6.510   | 8.374  | 12.447 |
|         |                   | 0.8       | 0.165                | 8.173   | 11.809 | 21.341 | 8.457                    | 9.455   | 11.697 | 18.295 |

The C, S and G denote *CreditRa*, *StockRa*, and *GDP* in Table 1, respectively. GC means the Granger Causality, and taking C  $\Rightarrow$  G for example, the hypothesis of GC behind C  $\Rightarrow$  G is *CreditRa* does not Granger cause *GDP*. CV10%, CV 5%, and CV1% are the critical values of Restricted F statistics, respectively. \*, \*\*, and \*\*\* denote significances at the 10%, 5% and 1% levels, respectively.

credit to stock market capitalization within the 0.8 quantile and causality from stock market capitalization to GDP within the 0.6 and 0.8 quantiles. The results of positive shocks show a causal relation from stock market capitalization to GDP within quantiles 0.4 and 0.6 and a causation from GDP to banking credit within quantiles 0.6 and 0.8. Similar to the results in Table 4, the results in Table 8 show that in the U.K., the stock market dominates economic growth more than does the banking sector. In contrast, Table 8 indicates that in the normal period with level terms, banking credit causes an increase in stock market capitalization as stock capitalization is higher, and the increase in stock market capitalization promotes growth as output is higher. This phenomenon tends to occur in the normal period, possibly because the impact of the stock market on growth is easily enhanced by the impact of banking credit on the stock market in this period. However, Table 8 shows that in a boom period with positive shocks, an increase in stock market capitalization promotes growth when output is moderate, and this growth causes an increase in banking credit as banking credit is higher. The results especially

occur in the boom period, possibly because the enhancement of stock market on growth lead to an increase in the output on banking credit in this period. The results of asymmetric QVAR considering Fourier in the U.K. also demonstrate the asymmetric impacts of the stock market on growth for level terms and positive shocks.

Finally, the results of the U.S. for the level terms in Table 9 denote Granger causality from stock market capitalization to GDP within quantiles 0.6 and 0.8 and causality running from banking credit to GDP within quantiles 0.4, 0.6 and 0.8. However, the results for positive shocks show causality from stock market capitalization to banking credit within quantile 0.4 and causality from banking credit to GDP within quantiles 0.2, 0.4, 0.6 and 0.8. Similar to the results in Table 4, the results in Table 9 show that in the U.S., the increase in stock market capitalization promotes economic growth in the normal period with level terms, and the increase in stock market capitalization creates the need for banking credit in the boom period with positive shocks. In contrast, Table 9 shows that in the normal period, both stock market capitalization and banking credit cause growth, and the rise of the stock market on growth only occurs

**Table 7.** The results of asymmetric quantile VAR Granger causality in Japan for both level terms and positive shocks.

| Country | GE          | Quantile. | Wald test.     | CV 10%. | CV 5%. | CV 1%. | Wald test.              | CV 10%. | CV 5%. | CV 1%. |
|---------|-------------|-----------|----------------|---------|--------|--------|-------------------------|---------|--------|--------|
|         |             |           | Panel A: Level |         |        |        | Panel B: Positive shock |         |        |        |
| Japan   | C $\neq$ >G | 0.2       | 0.091          | 2.454   | 3.801  | 8.886  | 1.561                   | 11.140  | 14.934 | 24.194 |
|         |             | 0.4       | 1.009          | 1.955   | 2.897  | 6.258  | 21.777***               | 7.812   | 10.779 | 15.668 |
|         |             | 0.6       | 2.743*         | 2.289   | 3.258  | 4.271  | 18.670***               | 7.574   | 9.454  | 15.550 |
|         |             | 0.8       | 5.190**        | 2.803   | 4.563  | 9.321  | 4.038                   | 13.874  | 16.817 | 27.547 |
|         | C $\neq$ >S | 0.2       | 0.001          | 3.400   | 5.160  | 10.786 | 0.000                   | 1.492   | 2.245  | 5.115  |
|         |             | 0.4       | 0.000          | 1.694   | 2.487  | 7.380  | 0.000                   | 1.249   | 1.833  | 5.025  |
|         |             | 0.6       | 0.000          | 1.860   | 3.438  | 6.186  | 0.014                   | 2.310   | 3.661  | 9.395  |
|         |             | 0.8       | 2.293          | 4.000   | 5.490  | 9.712  | 2.370                   | 4.621   | 7.430  | 17.861 |
|         | G $\neq$ >C | 0.2       | 1.246          | 2.957   | 4.700  | 8.746  | 0.000                   | 1.382   | 2.227  | 4.838  |
|         |             | 0.4       | 0.246          | 1.836   | 2.656  | 5.774  | 0.000                   | 1.482   | 2.008  | 3.557  |
|         |             | 0.6       | 0.031          | 1.428   | 1.988  | 3.587  | 0.018                   | 1.990   | 2.621  | 5.134  |
|         |             | 0.8       | 0.006          | 2.506   | 3.818  | 5.958  | 0.026                   | 3.172   | 5.060  | 8.990  |
|         | G $\neq$ >S | 0.2       | 0.001          | 3.103   | 4.433  | 8.926  | 0.000                   | 1.639   | 2.862  | 6.452  |
|         |             | 0.4       | 0.012          | 1.175   | 1.885  | 3.658  | 0.000                   | 1.254   | 1.891  | 4.243  |
|         |             | 0.6       | 0.052          | 1.701   | 2.543  | 5.203  | 0.000                   | 2.373   | 3.181  | 6.224  |
|         |             | 0.8       | 0.189          | 3.375   | 4.977  | 8.351  | 0.812                   | 4.431   | 6.167  | 13.303 |
|         | S $\neq$ >C | 0.2       | 0.154          | 3.697   | 4.770  | 7.013  | 0.000                   | 3.325   | 4.848  | 8.679  |
|         |             | 0.4       | 0.384          | 1.735   | 2.307  | 4.224  | 0.000                   | 2.551   | 3.597  | 5.489  |
|         |             | 0.6       | 0.300          | 1.466   | 2.180  | 4.213  | 0.440                   | 2.352   | 3.348  | 5.133  |
|         |             | 0.8       | 0.822          | 2.757   | 4.623  | 8.792  | 0.570                   | 2.491   | 3.894  | 6.848  |
|         | S $\neq$ >G | 0.2       | 0.099          | 2.966   | 4.008  | 6.680  | 2.763                   | 13.205  | 17.382 | 24.113 |
|         |             | 0.4       | 0.023          | 1.977   | 3.007  | 5.135  | 5.765                   | 9.331   | 12.224 | 18.783 |
|         |             | 0.6       | 1.041          | 2.132   | 2.966  | 7.133  | 6.712                   | 9.511   | 12.164 | 17.873 |
|         |             | 0.8       | 0.140          | 2.643   | 3.777  | 7.878  | 4.385                   | 12.288  | 15.745 | 26.253 |

The C, S and G denote *CreditRa*, *StockRa*, and *GDP* in Table 1, respectively. GC means the Granger Causality, and taking C  $\neq$ > G for example, the hypothesis of GC behind C  $\neq$ > G is *CreditRa* does not Granger cause *GDP*.

CV10%, CV 5%, and CV1% are the critical values of Restricted F statistics, respectively. \*, \*\*, and \*\*\*denote significances at the 10%, 5% and 1% levels, respectively.

as output is higher. Because profits from the stock market are more likely to be invested than consumed in the normal period, the investment

tendency in this period promotes economic growth, which occurs in particular as output is higher. However, in a boom period with positive

**Table 8.** The results of asymmetric quantile VAR granger causality in the U.K. for both level terms and positive shocks.

| Country | GE          | Quantile. | Wald test.     | CV 10%. | CV 5%. | CV 1%. | GE test | Wald test.              | CV 10%. | CV 5%.  | CV 1%.  | GE test |
|---------|-------------|-----------|----------------|---------|--------|--------|---------|-------------------------|---------|---------|---------|---------|
|         |             |           | Panel A: Level |         |        |        |         | Panel B: Positive shock |         |         |         |         |
| UK      | C $\neq$ >G | 0.2       | 4.736          | 6.792   | 9.526  | 15.420 | No      | 1.806                   | 15.904  | 21.317  | 31.979  | No      |
|         |             | 0.4       | 0.382          | 4.362   | 5.716  | 9.056  | No      | 0.752                   | 11.516  | 14.218  | 21.589  | No      |
|         |             | 0.6       | 0.481          | 4.185   | 5.195  | 8.080  | No      | 2.015                   | 10.876  | 13.900  | 21.294  | No      |
|         |             | 0.8       | 0.024          | 4.894   | 6.665  | 9.582  | No      | 0.117                   | 15.938  | 20.866  | 33.784  | No      |
|         | C $\neq$ >S | 0.2       | 1.303          | 8.979   | 13.295 | 32.488 | No      | 0.000                   | 7.150   | 11.714  | 176.510 | No      |
|         |             | 0.4       | 1.155          | 5.424   | 7.671  | 17.091 | No      | 0.004                   | 5.204   | 8.717   | 315.673 | No      |
|         |             | 0.6       | 0.740          | 4.820   | 6.480  | 11.272 | No      | 0.016                   | 5.386   | 8.640   | 319.784 | No      |
|         |             | 0.8       | 72.329***      | 8.601   | 12.287 | 58.222 | Yes     | 0.014                   | 8.244   | 13.946  | 336.273 | No      |
|         | G $\neq$ >C | 0.2       | 2.264          | 2.425   | 3.807  | 6.207  | No      | 0.379                   | 10.191  | 12.148  | 16.863  | No      |
|         |             | 0.4       | 0.423          | 2.030   | 2.815  | 5.163  | No      | 0.323                   | 6.349   | 8.336   | 11.693  | No      |
|         |             | 0.6       | 0.827          | 1.810   | 2.441  | 5.100  | No      | 12.118***               | 5.816   | 7.108   | 10.644  | Yes     |
|         |             | 0.8       | 2.129          | 2.348   | 3.327  | 8.261  | No      | 15.566**                | 8.048   | 10.773  | 21.466  | Yes     |
|         | G $\neq$ >S | 0.2       | 4.371          | 6.072   | 8.616  | 13.359 | No      | 0.000                   | 4.368   | 5.782   | 9.181   | No      |
|         |             | 0.4       | 0.403          | 3.240   | 4.600  | 8.635  | No      | 0.132                   | 2.412   | 4.572   | 8.522   | No      |
|         |             | 0.6       | 1.441          | 1.987   | 2.410  | 4.298  | No      | 0.168                   | 0.953   | 1.551   | 4.122   | No      |
|         |             | 0.8       | 2.228          | 3.405   | 4.467  | 7.158  | No      | 0.185                   | 2.292   | 4.409   | 7.778   | No      |
|         | S $\neq$ >C | 0.2       | 3.262          | 3.471   | 5.257  | 10.044 | No      | 5.396                   | 18.287  | 25.408  | 117.858 | No      |
|         |             | 0.4       | 2.097          | 2.723   | 4.020  | 7.799  | No      | 2.939                   | 15.372  | 71.406  | 218.574 | No      |
|         |             | 0.6       | 1.651          | 2.046   | 3.507  | 7.590  | No      | 6.149                   | 56.222  | 139.652 | 233.679 | No      |
|         |             | 0.8       | 0.999          | 4.172   | 5.449  | 24.566 | No      | 7.621                   | 72.689  | 186.426 | 347.063 | No      |
|         | S $\neq$ >G | 0.2       | 0.966          | 6.290   | 8.759  | 13.779 | No      | 10.198                  | 15.784  | 20.639  | 28.891  | No      |
|         |             | 0.4       | 0.724          | 4.523   | 5.700  | 10.986 | No      | 10.379*                 | 9.291   | 12.543  | 20.108  | Yes     |
|         |             | 0.6       | 4.968*         | 4.297   | 5.994  | 9.755  | Yes     | 13.050**                | 9.943   | 12.790  | 18.272  | Yes     |
|         |             | 0.8       | 13.882***      | 6.064   | 8.586  | 12.321 | Yes     | 15.145                  | 16.361  | 20.597  | 31.250  | No      |

1. The C, S and G denote *CreditRa*, *StockRa*, and *GDP* in Table 1, respectively. GC means the Granger Causality, and taking C  $\neq$ > G for example, the hypothesis of GC behind C  $\neq$ > G is *CreditRa* does not Granger cause *GDP*.

2. CV10%, CV 5%, and CV1% are the critical values of Restricted F statistics, respectively. \*, \*\*, and \*\*\*denote significances at the 10%, 5% and 1% levels, respectively.

**Table 9.** The results of asymmetric quantile VAR Granger causality in the U.S. for both level terms and positive shocks.

| Country | GE          | Quantile. | Wald test.     | CV 10%. | CV 5%. | CV 1%. | GE test | Wald test.              | CV 10%. | CV 5%. | CV 1%. | GE test |
|---------|-------------|-----------|----------------|---------|--------|--------|---------|-------------------------|---------|--------|--------|---------|
|         |             |           | Panel A: Level |         |        |        |         | Panel B: Positive shock |         |        |        |         |
| US      | C $\neq$ >G | 0.2       | 7.567          | 7.991   | 11.729 | 20.296 | No      | 21.508**                | 14.216  | 18.402 | 30.720 | Yes     |
|         |             | 0.4       | 5.451*         | 5.295   | 7.002  | 10.826 | Yes     | 30.000***               | 8.992   | 12.057 | 16.842 | Yes     |
|         |             | 0.6       | 6.200**        | 4.683   | 6.056  | 9.078  | Yes     | 24.356***               | 8.959   | 12.700 | 18.816 | Yes     |
|         |             | 0.8       | 7.857**        | 5.100   | 6.882  | 9.873  | Yes     | 32.436***               | 12.568  | 16.897 | 22.852 | Yes     |
|         | C $\neq$ >S | 0.2       | 0.000          | 4.891   | 7.297  | 12.142 | No      | 0.000                   | 4.731   | 9.773  | 20.829 | No      |
|         |             | 0.4       | 0.000          | 3.276   | 4.241  | 6.707  | No      | 0.000                   | 3.487   | 6.205  | 11.851 | No      |
|         |             | 0.6       | 0.141          | 3.783   | 5.221  | 9.664  | No      | 0.104                   | 4.934   | 7.620  | 15.334 | No      |
|         |             | 0.8       | 0.117          | 4.302   | 6.379  | 12.452 | No      | 0.255                   | 7.107   | 9.891  | 17.353 | No      |
|         | G $\neq$ >C | 0.2       | 1.437          | 3.434   | 4.705  | 8.892  | No      | 11.358                  | 16.349  | 18.940 | 25.673 | No      |
|         |             | 0.4       | 0.912          | 2.459   | 3.446  | 6.287  | No      | 9.189                   | 12.962  | 15.063 | 22.310 | No      |
|         |             | 0.6       | 0.235          | 2.045   | 3.385  | 5.604  | No      | 5.915                   | 12.971  | 15.775 | 22.633 | No      |
|         |             | 0.8       | 0.041          | 2.262   | 3.026  | 4.649  | No      | 6.186                   | 14.873  | 18.607 | 27.861 | No      |
|         | G $\neq$ >S | 0.2       | 0.000          | 2.918   | 4.340  | 7.717  | No      | 0.000                   | 10.456  | 17.074 | 39.331 | No      |
|         |             | 0.4       | 0.107          | 1.662   | 2.427  | 3.847  | No      | 0.000                   | 5.527   | 6.699  | 24.467 | No      |
|         |             | 0.6       | 3.984**        | 1.953   | 2.821  | 4.721  | Yes     | 0.206                   | 4.881   | 7.684  | 19.080 | No      |
|         |             | 0.8       | 4.802*         | 3.409   | 5.002  | 7.298  | Yes     | 0.550                   | 8.601   | 10.917 | 20.028 | No      |
|         | S $\neq$ >C | 0.2       | 0.305          | 4.991   | 7.529  | 11.946 | No      | 4.255                   | 13.274  | 15.898 | 24.323 | No      |
|         |             | 0.4       | 0.040          | 4.918   | 6.061  | 9.792  | No      | 14.416**                | 11.355  | 13.644 | 20.104 | Yes     |
|         |             | 0.6       | 0.108          | 4.022   | 5.338  | 8.031  | No      | 6.802                   | 10.542  | 13.784 | 21.550 | No      |
|         |             | 0.8       | 1.304          | 3.414   | 4.784  | 7.333  | No      | 8.008                   | 10.853  | 14.923 | 21.815 | No      |
|         | S $\neq$ >G | 0.2       | 3.522          | 8.358   | 11.216 | 18.350 | No      | 2.294                   | 8.730   | 10.848 | 19.020 | No      |
|         |             | 0.4       | 2.289          | 5.640   | 7.460  | 10.555 | No      | 3.660                   | 6.056   | 7.059  | 10.714 | No      |
|         |             | 0.6       | 0.844          | 4.528   | 5.540  | 8.137  | No      | 1.688                   | 5.711   | 7.521  | 11.692 | No      |
|         |             | 0.8       | 3.981          | 4.179   | 5.312  | 8.233  | No      | 2.706                   | 7.694   | 9.721  | 20.189 | No      |

1. The C, S and G denote *CreditRa*, *StockRa*, and *GDP* in Table 1, respectively. GC means the Granger Causality, and taking C  $\neq$  > G for example, the hypothesis of GC behind C  $\neq$  > G is *CreditRa* does not Granger cause *GDP*.

2. CV10%, CV 5%, and CV1% are the critical values of Restricted F statistics, respectively. \*, \*\*, and \*\*\* denote significances at the 10%, 5% and 1% levels, respectively.

shocks, an increase in stock market capitalization creates the need for banking credit and an increase in banking credit promotes growth. An increase in stock market capitalization indirectly leads to economic growth through an increase in banking credit, perhaps because the profit from the stock market tends to be consumed and invested simultaneously in the boom period. The dual increase in consumption and investment produces the need for banking credit, especially as credit is lower, and the increase in banking credit promotes economic growth. Hence, the results of asymmetric QVAR considering Fourier in the U.S. illustrate the direct impact of the stock market on growth in the normal period and the indirect impact of the stock market on growth through the banking sector in the boom period, which again demonstrates the asymmetric effects for level terms and positive shocks.

## V. Conclusions

By using the bootstrap procedure – the asymmetric causality test – in combination with the quantile VAR and Fourier functions, *CreditRa* and *StockRa* are both

considered measures of financial development for investigating the causation between bank- and stock-dominated development and economic growth. Asymmetric Granger causality is used since positive or negative shocks may have different causal effects. The bootstrapping simulation technique can overcome nonnormal distributions and time-varying volatility through leverage adjustments. The simultaneous consideration of quantile causality and the Fourier function can identify which part of the distribution of the output is predicted and causes smooth breaks in the deterministic parts to be controlled by Fourier expansions. Our samples include Germany, Japan, the U.S. and the U.K.

Regardless of level terms or positive shocks, no Fourier components exist for any causal links among banking credit, stock market capitalization, and economic growth in our four sample countries. Our results of asymmetric quantile VAR Granger causality show that in Germany, the banking sector dominates economic growth more than does the stock market, similar to our results of traditional Granger causality. In contrast, the effects of domestic credit on growth only focus on higher economic output, and the effects can partly result from the push of stock market capitalization on domestic credit in

higher domestic credit. This phenomenon is more evident during a boom period with positive shocks than during a normal period with level terms, confirming evidence of asymmetric causality. The results for Japan show that the banking sector results in more economic growth than does the stock market, similar to our traditional Granger causality results. In contrast, the effects of domestic credit on growth occur in nonlower economic output for both the normal and boom periods, and the driving force of output on the stock market disappears.

Because the financial systems of Germany and Japan should be considered as ‘banking centers’ (Han 2001; Tan 2000), our results expectedly indicate that bank-based development is better at increasing long-term economic growth in Germany and Japan. For banking centre countries, banking credit drives economic growth, which should be more likely to occur in middle or high economic output. This phenomenon occurs probably because the banking system is more likely to create money to promote economic growth during a country’s higher output. In addition, banking credit dominating economic growth is more significant during the boom period, probably because banking loans are more active especially during such a period and, thus, the effect of banking credit on growth is more evident.

To promote economic growth, financial authorities in Germany may directly drive domestic credit only when economic output is higher, especially during boom periods with positive shocks. When domestic credit is higher, these authorities can continually stimulate banking credit to raise growth through increases in stock market capitalization. Financial authorities in Japan may drive domestic credit to increase growth when economic output is in the non-lower part during both normal and boom periods.

The results of asymmetric quantile VAR Granger causality show that in the U.K., the stock market dominates economic growth more than does the banking sector, similar to the results of traditional Granger causality. In contrast, during a normal period with level terms, banking credit causes an increase in stock market capitalization as stock capitalization is higher, and an increase in stock market capitalization promotes growth as output is higher. However, during a boom period with positive shocks, an increase in stock market capitalization promotes growth when output is

moderate, and this growth causes an increase in banking credit as banking credit is higher. The results in the U.S. indicate that, in the normal period with level terms, the increase in stock market capitalization promotes economic output as this output is higher. In the boom period with positive shocks, the increase in stock market capitalization causes the need for banking credit as banking credit is lower, similar to the results of traditional Granger causality.

Because the financial systems of the U.K. and the U.S. should be considered as ‘market centers’ (Han 2001; Tan 2000), our results expectedly indicate that stock-based development is more likely to drive economic growth in the U.K. and the U.S. For market centre countries, in the normal period, the increase in the stock market on growth only occurs as output is higher. This phenomenon is possible because a country’s higher output is more likely to animate the stock market to promote economic growth in the normal period. However, in the boom period, the increase in stock market capitalization directly leads to economic growth, as output is moderate in the U.K., or indirectly leads to growth through a credit increase, as credit is lower in the U.S. This phenomenon is possible because, in the boom period, a country’s moderate output can cause the stock market to have a direct effect on growth, and a country’s lower credit can cause the stock market to have an indirect effect on growth through a credit increase.

To promote economic growth, financial authorities in the U.K. may indirectly increase banking credit to drive the impacts of stock market capitalization on growth during the normal period. However, during a boom period, these authorities may directly increase the impacts of stock market capitalization on growth. In contrast, financial authorities in the U.S. may directly increase the impacts of stock market capitalization on growth only when growth is higher during the normal period. However, they may indirectly drive the impacts of stock market capitalization on growth through an increase in banking credit, especially lower credit, during boom periods.

The limitation of this study is that we consider only causality using cumulative positive errors and level terms between the financial development of the banking sector (or of the stock market) and economic growth. This limitation is mainly considered because there are

fewer negative shocks to the GDP of many countries. However, we still use a U.S. sample to demonstrate the existence of differences in the causality using cumulative positive errors and negative errors, which illustrates the need for asymmetric Granger causality. Moreover, future research may either consider using other nonlinear time-series causality tests to examine the causation between both bank- and stock-based development and economic growth or consider other critical factors, such as banking crises, into models to examine the causation between dual financial development and economic growth.

We contribute to a series of studies on the causality between financial development and growth by elaborating on the following issues. First, we are almost the first to analyse nonlinear causality between both bank sector and stock market development and economic growth. Second, asymmetric Granger causality is adopted since positive or negative shocks can exhibit various causal effects. The bootstrapping simulation technique can overcome nonnormal distributions and time-varying volatility through leverage adjustments. Third, the simultaneous consideration of quantile causality and the Fourier function can reveal the deterministic parts of the output that are affected and can cause smooth breaks to be controlled by Fourier expansions.

## Disclosure statement

No potential conflict of interest was reported by the author(s).

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