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Roles played by financial development in economic growth: application of the flexible regression model

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Abstract This study presents the nonlinear relationship that exists between financial development and economic growth. This study applies the flexible nonlinear regression model of Hamilton (Econometrica 69(3):537–573, 2001) because it imposes no specification restrictions. Two empirical results are obtained. First, an inverted U-shaped relation between banking sector development and economic growth is identified. Namely, the two variables are positively linked before the turning point, but negatively linked after it. Second, a positive relationship with asymmetric $\sqrt{}$-shape between stock market development and economic growth is found.

Keywords Banking development · Economic growth · Stock market development · Flexible nonlinear estimation

JEL Classification E44 · G10 · O16 · O50

1 Introduction

During the past two decades, issue on the relationship between financial development and economic growth has attracted considerable attention. Studies of this issue occur

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as far back as Schumpeter (1911), and were later followed by Lucas (1988), and then King and Levine (1993) who demonstrated that degree of financial development helps explain long-run economic growth. Numerous empirical studies have supported the idea that both banking sector and stock market development strongly and positively affect economic growth, for example, see Levine and Zervos (1998), Beck et al. (2000), Levine et al. (2000), Bekaert et al. (2001), and Beck and Levine (2004). Contradictory evidence also exists, as presented by Shen and Lee (2006), Liu and Hsu (2006), Frank (2007), and Naceur and Ghazouani (2007).[1]

However, traditional linear finance–growth specification implicitly assumes that the relationship between financial development and economic growth remains constant with different levels of financial development. This assumption overlooks the fact that financial development involves dynamic change. As countries grow, expectations of their banking sectors and stock markets develop, and even their financial structure can change. Patrick (1966) theorized that certain stages of financial development benefit economic growth. Bencivenga et al. (1995) contended that depending on the level of financial liquidity (transition costs), reduced transaction costs can boost, repress, or have no effect on economic growth. Therefore, it is essential not to turn a blind eye to the fact that the roles played by the banking sector and the stock market in the economy may vary depending on financial market activity and economic growth.

Recently, numerous economists have identified a nonlinear relationship between financial development and economic growth. For example, the negative nexus reported by Shen and Lee (2006) is rather robust in their various attempts except when a squared bank development variable is added. Once the positive coefficient is retrieved, the coefficient of the squared variable is negative. This inverted U-shaped relationship suggests that bank development positively influences economic growth up to a specific turning point, but subsequently the effect is negative. In fact, this argument is consistent with that of Khan and Senhadji (2003), who claimed that the reduced performance of bank development indicators in explaining growth could possibly exhibit an inverted U-shape. Minier (2003) applied the regression trees technique to endogenously divide 42 countries into two regimes based on stock market capitalization, and argued that, for countries with high stock market capitalization, a significant positive relationship exists between stock market development and economic growth. However, the relationship becomes significantly negative for low-capitalization subsamples. These evidences are consistent with the argument of Patrick (1966) that the effects of financial development on economic growth vary with financial development level.

Additionally, a threshold model is frequently adopted to capture nonlinear finance–growth relation.[2] For example, Rioja and Valev (2004) identified a threshold effect for financial development and economic growth. Specifically, they proposed that the relationship between financial development and economic growth may vary with regard to the level of economic development. In low-income regions, further development

[1] Note that another issue that discusses the causality and reverse causality between financial development and economic growth has also been a huge debate in empirical studies. See Patrick (1966), Shaw (1973), McKinnon (1973), Levine et al. (2000), Cálderón and Liu (2003), and Ang and McKibbin (2007).

[2] Berthelemy and Varoudakis (1996), Odedokun (1996), Deidda and Fattouh (2002), Graff and Karmann (2006), and Huang and Lin (2007, 2009).

of financial markets exerts an uncertain effect on growth. Meanwhile, in regions with intermediate incomes, financial development significantly and positively affects growth. Finally, in the high region, the effect is positive but smaller. Masten et al. (2008) demonstrated that the effects of financial development on growth are much stronger in developing European Economic and Monetary Union (EMU) countries than in developed EMU countries.

The previous literature contains the following major weaknesses. First, previous studies ignored the fact that the link between growth and financial development differs with the level of national financial development. Second, studies that adopting the quadratic form or threshold methods may overlook other possible nonlinear relationships between finance and growth. For example, an asymmetric finance–growth relation may suggest that a well-developed financial system enjoys superior economic growth to less developed countries or vice versa.

The aim of this paper is to investigate whether a nonlinear relationship exists between financial development and economic growth, and if so, whether their relationship exhibits a U-shaped or inverted U-shaped curve, or even some other nonlinear pattern. Next, to present an overall view of financial development, the proposed empirical model simultaneously considers two main financial sectors (the banking sector and stock market) and employs various indicators of financial development.[3] Additionally, based on the consideration of how financial system characteristics influence the economic growth equation, we further considered the stylized fact whether the finance–growth relationship differs between bank- and market-based economies. The study sample covers the period from 1976 to 2005, and examines a total of 46 countries.

Unlike previous studies that assumed the linear or nonlinear forms are known, we use a different approach to mitigate these weaknesses. This study implements the nonlinear model of Hamilton (2001) to make an additional contribution to this ongoing discussion of possible nonlinearity between financial system and economic growth. The flexible nonlinear model is a fully parametric model but has a nonparametric flavor because no functional form is assumed for the conditional mean. This assumption represents a more general approach to modeling the conditional mean of a random variable, and provides not only four valid tests of the null hypothesis of linearity against a broad range of alternative nonlinear models, but can also consistently estimate the appearance of the nonlinear finance–growth relation.

Flexible nonlinear estimation involves two components: linear estimates and nonlinear random field estimates that govern nonlinearity and curvature. The empirical results demonstrate that the banking industry development is negatively associated with economic growth, and furthermore that nonlinear behavior is successfully detected via

[3] As documented by Levine (2005), roles of bank and market simultaneously that play in economic growth can be discussed from different perspectives: (1) theory, such as Singh (1997), focuses one of the competing roles of banks and market in funding corporate expansion; (2) other theories, such as Merton (1992, 1995), Merton and Bodie (1995), and Levine (1997), emphasize that banks and markets may arise, coexist, and prosper by providing different financial functions to the economy; (3) still other theories, such as Smith and Boyd (1998) and Huybens and Smith (1999), stress complementarities between banks and markets. Therefore, in this study, we follow Levine and Zervos (1998) and simultaneously consider two main financial sectors, i.e., banking system and stock market, to study the relationship between financial development and economic growth.

nonlinear random field estimation. Specifically, a flexible nonlinear model can identify an inverted U-shaped relation between banking sector development and economic growth without specifying its functional form. Regarding stock market development, in situations that only involve linear estimates, no evidence is found to support a relationship between stock market development and economic growth. To re-estimate economic growth regression by adding nonlinear random field estimates, the nonlinear stock–growth effects are brought to light. The graphic results illustrate a positive relationship with asymmetric $\surd$-shape between stock market development and economic growth. Additionally, following the imposition of financial system characteristics, the empirical results demonstrate that nonlinear negative bank–growth and nonlinear positive stock–growth nexuses remain in both bank- and market-based countries, but the roles of bank and stock market development are significantly weakened in market-based countries.

The remainder of this paper is organized as follows. Section 2 introduces the flexible regression model while Sect. 3 details the source of the data and empirical models. Moreover, Sect. 4 lists the estimated results and their implications. Finally, Sect. 6 describes the study conclusions.

2 Flexible regression model

The flexible regression model was developed by Hamilton (2001) who employed the random field concept to reliably detect data nonlinearity. The model is

$$y_t = \mu(\boldsymbol{x}_t) + \varepsilon_t, \tag{1}$$

where

$$\mu(\boldsymbol{x}_t) = \alpha_0 + \boldsymbol{\alpha}'\boldsymbol{x}_t + \lambda m(\boldsymbol{g} \odot \boldsymbol{x}_t), \tag{2}$$

and where y_t and $\boldsymbol{x}_t$ are stationary and ergodic processes, respectively. In the proposed model, the symbol $\odot$ represents the element-by-element multiplication, whereas $m(\cdot)$ is the outcome of the random field. Equation 1 contains the linear component $\alpha_0 + \boldsymbol{\alpha}'\boldsymbol{x}_t$ and the nonlinear component $\lambda m(\boldsymbol{g} \odot \boldsymbol{x}_t)$, where $m(\cdot)$ is latent and unseen. Term λ contributes to nonlinearity, whereas $\boldsymbol{g}$ controls the curvature.

For any choice of $\boldsymbol{x}$, $m(\boldsymbol{x})$ is a realization from the random field and is distributed in

$$m(\boldsymbol{x}) \sim \mathcal{N}(0, 1), \quad \mathrm{E}[m(\boldsymbol{x})m(\boldsymbol{z})] = H_k(h),$$

for

$$H_k(h) = \begin{cases} G_{k-1}(h, 1)/G_{k-1}(0, 1) & \text{if } h \leqslant 1, \\ 0 & \text{if } h > 1, \end{cases}$$

where, $0 < h \leqslant r$,

$$G_k(h, r) = \int_h^r (r^2 - z^2)^{k/2}\,\mathrm{d}z$$

for $h \equiv (1/2)[(\boldsymbol{x} - \boldsymbol{z})'(\boldsymbol{x} - \boldsymbol{z})]^{1/2}$ based on the Euclidean distance.

2.1 Estimation

Neither the conditional function $\mu(\boldsymbol{x}_t)$ nor the parameter vector $\boldsymbol{\vartheta} = (\alpha_0, \boldsymbol{\alpha}', \sigma, \boldsymbol{g}', \lambda)'$ provide any inference since $m(\cdot)$ is latent. Hamilton proposed that Eqs. 1 and 2 be represented in GLS form to enable the division of the unobserved part $m(\boldsymbol{x})$ into residuals. Hamilton rephrased the model as

$$\boldsymbol{y} = \boldsymbol{X\beta} + \boldsymbol{u},$$

where

$$\boldsymbol{y} = \begin{bmatrix} y_1 \\ y_2 \\ \vdots \\ y_T \end{bmatrix} \quad \boldsymbol{X} = \begin{bmatrix} 1 & \boldsymbol{x}_1' \\ 1 & \boldsymbol{x}_2' \\ \vdots & \vdots \\ 1 & \boldsymbol{x}_T' \end{bmatrix} \quad \boldsymbol{\beta} = \begin{bmatrix} \alpha_0 & \boldsymbol{\alpha}' \end{bmatrix} \quad \boldsymbol{u} = \begin{bmatrix} \lambda m(\boldsymbol{g} \odot \boldsymbol{x}_1) + \varepsilon_1 \\ \lambda m(\boldsymbol{g} \odot \boldsymbol{x}_2) + \varepsilon_2 \\ \vdots \\ \lambda m(\boldsymbol{g} \odot \boldsymbol{x}_T) + \varepsilon_T \end{bmatrix}.$$

Hamilton then suggested using the maximum likelihood estimation (MLE) with a recursive formulation, like the Kalman filter, to obtain the parameters of $\boldsymbol{\vartheta}$. Being conditional on an initial set of parameters, i.e., λ and $\boldsymbol{g}$, and defining $\zeta = \lambda/\sigma$ and $\boldsymbol{W}(\boldsymbol{X}; \boldsymbol{\theta}) = \zeta^2 \boldsymbol{H}(\boldsymbol{g}) + \boldsymbol{I}_T$, the parameters of the linear part, i.e., β and σ^2, can be calculated analytically as

$$\tilde{\boldsymbol{\beta}}(\boldsymbol{\theta}) = [\boldsymbol{X}'\boldsymbol{W}(\boldsymbol{X}; \boldsymbol{\theta})^{-1}\boldsymbol{X}]^{-1}[\boldsymbol{X}'\boldsymbol{W}(\boldsymbol{X}; \boldsymbol{\theta})^{-1}\boldsymbol{y}], \tag{3}$$

$$\tilde{\sigma}^2(\boldsymbol{\theta}) = [\boldsymbol{y} - \boldsymbol{X}\tilde{\boldsymbol{\beta}}(\boldsymbol{\theta})]'\boldsymbol{W}(\boldsymbol{X}; \boldsymbol{\theta})^{-1}[\boldsymbol{y} - \boldsymbol{X}\tilde{\boldsymbol{\beta}}(\boldsymbol{\theta})]/T, \tag{4}$$

where $\boldsymbol{H}(\boldsymbol{g})$ denotes the $T \times T$ matrix with a (t, s) element of $H_k(h_{ts}(\boldsymbol{g}))$, $\boldsymbol{I}_T$ is a $T \times T$ identity matrix, and $\boldsymbol{\theta} = (\boldsymbol{g}', \zeta)'$. Thus, we can write the concentrated log likelihood function as

$$\eta(\boldsymbol{\theta}; \boldsymbol{y}, \boldsymbol{X}) = -\frac{T}{2}\ln(2\pi) - \frac{T}{2}\ln\tilde{\sigma}^2(\boldsymbol{\theta}) - \frac{1}{2}\ln|\boldsymbol{W}(\boldsymbol{X}; \boldsymbol{\theta})| - \frac{T}{2}, \tag{5}$$

and subsequently obtain $\{\hat{\alpha}_0, \hat{\boldsymbol{\alpha}}', \hat{\sigma}^2, \hat{\boldsymbol{g}}', \hat{\zeta}'\}$ by maximizing Eq. 5.

2.2 Nonlinearity test

Given the framework of Eqs. 1 and 2, we can test linearity using either λ or the vector $\boldsymbol{g}$ where these two parameters dominate nonlinearity and curvature, respectively. If the null hypothesis $H_0 : \lambda^2 = 0$ is not rejected, the nonlinear component $\lambda m(\boldsymbol{g} \odot \boldsymbol{x}_t)$ in Eq. 2 disappears. On the other hand, if the null hypothesis $H_0 : \boldsymbol{g} = \boldsymbol{0}$ is rejected, this indicates that the individual variable contributes nonlinear properties to the model. Hamilton (2001) proposed a λ-test, called $\lambda_{\mathrm{H}}^{\mathrm{E}}(\boldsymbol{g})$, based on the Euclidean distance measure and Hessian-type information matrix. The LM statistic for the nonlinearity test can be calculated as

$$\lambda_{\mathrm{H}}^{\mathrm{E}}(\boldsymbol{g}) = \frac{\hat{\boldsymbol{u}}' \boldsymbol{H}_T \hat{\boldsymbol{u}} - \tilde{\sigma}_T^2 \mathrm{tr}(\boldsymbol{M}_T \boldsymbol{H}_T \boldsymbol{M}_T)}{\left(2\mathrm{tr}\left\{[\boldsymbol{M}_T \boldsymbol{H}_T \boldsymbol{M}_T - (T-k-1)^{-1} \boldsymbol{M}_T \mathrm{tr}(\boldsymbol{M}_T \boldsymbol{H}_T \boldsymbol{M}_T)]^2\right\}\right)^{1/2}} \sim \chi^2(1), \tag{6}$$

where $\boldsymbol{M} = \boldsymbol{I}_T - \boldsymbol{X}(\boldsymbol{X}'\boldsymbol{X})^{-1}\boldsymbol{X}'$.

However, the proposed $\lambda_{\mathrm{H}}^{\mathrm{E}}(\boldsymbol{g})$ statistic encounters a nuisance problem because the parameter vector $\boldsymbol{g}$ is not identified under the null. To this end, Dahl and Gonzále-Rivera (2003) proposed various nonlinear test statistics to circumvent the problem of unidentified parameters under the null hypothesis of linearity, and these statistics are robust to the specification of the covariance function that defines the random field.

To solve the problem of the nuisance parameter vector $\boldsymbol{g}$, based on the Minkowski distance measure, Dahl and Gonzále-Rivera (2003) proposed two versions of modified λ-test. One way to avoid the identification problem is to fix $\boldsymbol{g}$. This method requires assuming complete knowledge of the covariance matrix, $\boldsymbol{H}(\boldsymbol{g})$, associated with the random field. This version of the $\lambda_{\mathrm{OP}}^{\mathrm{E}}$ statistic, which is based on known covariance functions, can be calculated as follows

$$\lambda_{\mathrm{OP}}^{\mathrm{E}}(\boldsymbol{g}) = \frac{T^2}{2} \frac{\boldsymbol{\kappa}' \tilde{\boldsymbol{x}}(\tilde{\boldsymbol{x}}'\tilde{\boldsymbol{x}})\tilde{\boldsymbol{x}}'\boldsymbol{\kappa}}{\boldsymbol{\kappa}'\boldsymbol{\kappa}} \sim \chi^2(1),$$

where $\boldsymbol{\kappa} = \mathrm{vec}(\boldsymbol{I}_T - \boldsymbol{u}\boldsymbol{u}'/\sigma^2)$.

Another approach to solving the identification problem is to use the technique of Taylor expansion and auxiliary regression to approximate the unknown covariance matrix. This version of the λ-test statistic, denoted as $\lambda_{\mathrm{OP}}^{\mathrm{A}}$, is not dependent on the nuisance parameters $\boldsymbol{g}$. The $\lambda_{\mathrm{OP}}^{\mathrm{A}}$ statistic, which is based on unknown covariance functions, can be calculated as

$$\lambda_{\mathrm{OP}}^{\mathrm{A}} = T^2 R^2 \sim \chi^2(q^*),$$

where $q^* = 1 + \sum_{j=1}^{2k+2} \binom{k+j-1}{k-1}$ and k denotes the number of the nonlinear variable.

Another type of nuisance problem occurs when λ can not be identified under the null hypothesis of $H_0 : \boldsymbol{g} = \boldsymbol{0}$. By fixing λ, Dahl and Gonzále-Rivera (2003) proposed the g-test, denoted as g_{OP}, which possesses the advantage of not suffering the nuisance problem involving the λ parameter under the null. The LM statistic can be expressed as:

$$g_{\mathrm{OP}} = T^2 R^2 \sim \chi^2(k).$$

3 Empirical model and data descriptions

The flexible regression model used in this study to examine the relationship between financial development and economic growth is[4]

$$\begin{aligned}\mathrm{GROWTH}_{it} = \alpha &+ \beta_1 \mathrm{BANK}_{it} + \beta_2 \mathrm{STOCK}_{it} + \beta_3 \mathrm{INFLA}_{it} \\ &+ \beta_4 \mathrm{GCON}_{it} + \beta_5 \mathrm{SCHOOL76}_i + \beta_6 \mathrm{Y76}_i \\ &+ \lambda[m(g_1 \mathrm{BANK}_{it}, g_2 \mathrm{STOCK}_{it})] + \nu_{it}, \end{aligned} \tag{7}$$

where BANK_{it} denotes the banking development proxies and STOCK_{it} represents the stock market development proxies. The significance of β_1 in Eq. 7 suggests a linear association between banking sector development and economic growth. Similarly, if the estimate of β_2 differs significantly from zero, stock market development is understandably related to economic growth.[5] In contrast to the linear relationship that exists between financial development and economic growth, this study further captures the nonlinear relationships using random field estimates, namely, g_1 and g_2.

This study uses data from 46 countries, over the period from 1976 to 2005, making our data be panel. Furthermore, this study uses 5-year averaged data to identify the effects of business cycles.[6] The dependent variable, GROWTH_{it}, is proxied by real per capita GDP growth. Meanwhile, the independent variables include banking industry depth (BANK_{it}), equity market depth (STOCK_{it}), and controlled variables.

The data sources for real per capita GDP growth (GROWTH_{it}) and macro variable inflation (INFLA_{it}), government consumption (GCON_{it}), and the logarithm of real GDP in 1976 ($\mathrm{Y76}_i$) are taken from the *International Financial Statistics* published by the IMF. The two bank development proxies ($\mathrm{LENDING}_{it}$ and $\mathrm{LIABILITY}_{it}$), and three stock market development proxies (MKTCAP_{it}, $\mathrm{STOCKTRA}_{it}$, and $\mathrm{TURNOVER}_{it}$)[7] are taken from the *Financial Structure and Economic Development*

[4] The approach of Hamilton (2001) is basically menu-driven. The advantage of this approach is that there is no need to know a parametric form a prior, providing increased flexibility to detect the relationship between economic growth and financial development; however, this method provides no structural form for the relationship. Consequently, the association between economic growth and development is at best a reduced form relation. Also, while Hamilton was originally used for price data, this study applies it for quantity data on economic development. We believe quantity data shed the same light on the information between the relationships. Past studies, such as Huang (2004, 2005), also applied Hamilton approach to quantity data.

[5] One caveat is necessary. This study is simply an associative investigation between economic growth and financial development. Though explanatory variables like financial development may lead economic growth, the evidence presented in this study is insufficient to make that assessment.

[6] See Rousseau and Wachtel (2000) and Beck et al. (2000).

[7] To conduct stock–growth investigation, we need measures of stock market development. Theory, however, does not provide a unique concept or measure of stock market development. Theory suggests that

Table 1 Summary of variables, descriptions, and data sources

Classification	Variable name	Description	Data source
Dependent variable	GROWTH	Growth rate of real per capita GDP	IFS
Bank development variables (BANK)	LENDING	Claims on the private sector by deposit money banks to nominal GDP	FSEDD
	LIABILITY	Liquidity liabilities to nominal GDP	FSEDD
Stock market development variables (STOCK)	MKTCAP	Stock market capitalization to nominal GDP	FSEDD
	STOCKTRA	Stock traded to nominal GDP	FSEDD
	TURNOVER	Turnover ratio (the ratio of stock market value traded to market capitalization)	FSEDD
Controlled variables	INFLA	Inflation rate, calculated from CPI	IFS
	GCON	Government consumption expenditures to nominal GDP	IFS
	SCHOOL76	Ratio of entering junior school in 1976	WDI
	Y76	The logarithm of Real GDP in 1976	IFS

FSEDD financial structure and economic development database, *IFS* international financial statistics, *WDI* world development indicators

Database.[8] Ratio of entering junior school in 1976 (SCHOOL76_i) is taken from the *World Development Indicators* published by the World Bank. See Table 1 for the variable definitions and sources, and see Table 2 for the descriptive statistics of the variables. Also, Table 3 reports the correlation matrix between variables. We find a positive correlation between both measures of bank development, as well as the three measures of stock market development. Furthermore, stock market development variables are more closely correlated with economic growth than with banking sector development. As listed in the Appendix, the 46 countries comprise 24 high-income countries, 16 middle-income countries, and 6 low-income countries.

3.1 Preliminary results of OLS

In order to compare the results with Shen and Lee (2006), we first implement the quadratic model (used by Shen and Lee 2006) to detect nonlinearity in the data. The

Footnote 7 Continued
stock market size and liquidity may affect economic growth. Stock market development is a complex and multi-faceted concept and no single measure will capture all aspects of stock market development. Thus, this paper uses variety of indicators that should provide a more accurate depiction of bank and stock market development. We use three variables, constructed by Demirguc-Kunt and Levine (1996) as proxies of stock market development.

[8] This database is recently updated in September 2006. See Levine's website, http://www.econ.brown.edu/fac/Ross_Levine/Publications.htm.

Table 2 Descriptive satistics

	Average	Max	Min	Standard deviation
GROWTH	2.096	34.442	−40.074	5.635
LENDING	50.952	178.496	1.02E − 5	34.441
LIABILITY	55.609	263.778	8.21E − 6	37.587
STCAP	45.865	499.213	0.007	55.608
STOCKTRA	29.418	648.322	0.001	55.916
TURNOVER	53.146	989.639	0.171	71.323
INFLA	14.541	432.831	−27.275	33.592
GCON	15.688	105.539	0.049	8.923
SCHOOL76	50.891	101.859	5.244	26.837
Y76	3.984	8.661	−0.462	2.479

Note: Figures are presented in % except SCHOOL76 and Y76

OLS results are partially the same as in Shen and Lee (2006), showing that the second-order polynomial relationship exists for bank development and growth, but not for stock market development and growth.[9] In particular, the coefficients of the squared bank development variables are negative, indicating the bank–growth relation takes on an inverted U shape. However, the influence of stock market development on growth is statistically insignificant.

The advantage of the quadratic model is its simplicity, but this simplicity is under the assumption of a predetermined specification. For example, using the quadratic model we can at most find one turning point. The results might be biased if the true specification is not quadratic, but rather a cubic relation, because the model is usually simple and does not pay much attention to the diagnostic tests of whether the fitted model is appropriate for the observed data. By contrast, Hamilton (2001) flexible regression model does not presume any specification form. The advantage of this approach is that there is no need to know a parametric form a prior, which provides increased flexibility to detect the relationship between economic growth and financial development.[10]

4 Estimation results of flexible nonlinear inference

Because the data are presented in panel form, following Driscoll (2004), we demean data for each country to account for the individual effects of the panel data rather than including a dummy for each country. Because banking industry development is proxied by LENDING or LIABILITY, whereas stock market development is proxied by MKTCAP, STOCKTRA, or TURNOVER, which create six specifications. Table 4 lists

[9] Estimated results available upon request.

[10] However, this method provides no structural form for the relationship. Its estimation also involves more computation in the quadratic model. Because both approaches have their merits and disadvantages, our paper adopts the two approaches at the same time to make a comparison.

Table 3 Correlation matrix

	GROWTH	LENDING	LIABILITY	MKTCAP	STOCKTRA	TURNOVER	INFLA	GCON	SCHOOL76	Y76
GROWTH	1.000									
LENDING	0.042	1.000								
LIABILITY	0.017	0.801	1.000							
MKTCAP	0.094	0.601	0.707	1.000						
STOCKTRA	0.091	0.489	0.514	0.618	1.000					
TURNOVER	0.132	0.160	0.079	0.136	0.658	1.000				
INFLA	−0.273	−0.266	−0.254	−0.214	−0.168	−0.063	1.000			
GCON	−0.055	0.180	0.102	−0.006	−0.029	−0.033	−0.054	1.000		
SCHOOL76	−0.017	0.426	0.279	0.289	0.288	0.084	−0.224	0.329	1.000	
Y76	0.024	−0.047	0.063	−0.180	−0.095	0.033	0.261	−0.091	−0.192	1.000

Table 4 Estimated results of flexible nonlinear model: $\text{GROWTH}_{it} = \alpha + \beta_1\text{BANK}_{it} + \beta_2\text{STOCK}_{it} + \beta_3\text{INFLA}_{it} + \beta_4\text{GCON}_{it} + \beta_5\text{SCHOOL76}_i + \beta_6\text{Y76}_i + \sigma[\zeta m(g_1\text{BANK}_{it}, g_2\text{STOCK}_{it}) + \nu_{it}]$

	(1)	(2)	(3)	(4)	(5)	(6)
CONSTANT	−0.001 (0.006)	−0.001 (0.005)	1.14E−4 (0.006)	−0.002 (0.006)	−0.001 (0.006)	−0.001 (0.006)
LENDING (β_1)	−0.039*** (0.013)	−0.039*** (0.013)	−0.035*** (0.012)			
LIABILITY (β_1)				−0.059** (0.021)	−0.059*** (0.019)	−0.052*** (0.018)
MKTCAP (β_2)	0.006 (0.008)			0.009 (0.011)		
STOCKTRA (β_2)		0.007 (0.008)			0.008 (0.010)	
TURNOVER (β_2)			0.003 (0.005)			0.001 (0.006)
INFLA	−0.046*** (0.009)	−0.047*** (0.009)	−0.048*** (0.009)	−0.048*** (0.009)	−0.049*** (0.009)	−0.053*** (0.009)
GCON	−0.016 (0.029)	−0.017 (0.029)	−0.019 (0.029)	−0.099 (0.118)	−0.112 (0.118)	−0.112 (0.119)
SCHOOL76	8.89E−5 (7.65E−5)	7.90E−5 (7.40E−5)	6.49E−5 (7.57E−5)	6.24E−5 (8.97E−5)	5.65E−5 (8.97E−5)	3.27E−5 (9.01E−5)
Y76	−0.001 (0.001)	−0.001 (0.001)	−0.001 (0.001)	−3.21E−4 (0.001)	−3.80E−4 (0.001)	−3.49E−4 (0.001)
σ	0.024*** (0.002)	0.025*** (0.001)	0.025 (0.002)	0.023*** (0.003)	0.024*** (0.002)	0.020*** (0.004)
ζ	0.311 (0.227)	8.12E−5 (0.180)	0.192 (0.180)	0.603** (0.268)	−0.504** (0.216)	0.887** (0.447)
LENDING (g_1)	20.461** (7.216)	17.166 (689.985)	15.828*** (5.378)			
LIABILITY (g_1)				166.386*** (18.399)	161.164*** (31.631)	64.142*** (19.128)
MKTCAP (g_2)	24.048*** (6.445)			2.921 (2.800)		
STOCKTRA (g_2)		7.521 (191.470)			−2.323 (2.769)	
TURNOVER (g_2)			11.695*** (4.717)			33.600*** (8.442)
$\log L$	413.748	410.610	410.561	317.345	314.421	314.336
λ_H^E-test	0.063*	0.698	0.078*	0.039**	0.044**	0.017**
λ_{OP}^E-test	0.078*	0.748	0.093*	0.047**	0.084*	0.028**
λ_{OP}^A-test	0.047**	0.307	0.042**	0.028**	0.013**	0.007***
g_{OP}-test	0.005***	0.262	0.006***	0.046**	0.031**	0.015**

Notes: $\zeta = \lambda/\sigma$; The number in parentheses is the standard error; ***, **, and * denote rejection at the significance level of 1, 5, and 10%, respectively; The *p*-values are reported for , $\lambda_H^E, \lambda_{OP}^E, \lambda_{OP}^A$ and g_{OP}

the estimated results for Eq. 7 using demeaned data and presents several interesting results that deserve further discussion.

First, recall that if the null hypothesis $H_0 : \lambda^2 = 0$ is not rejected, the regression (7) turns out to be linear because the nonlinear part $\lambda m(g_1 \text{BANK}_{it}, g_2 \text{STOCK}_{it})$ disappears. The p-values of $\lambda_{\text{H}}^{\text{E}}$, $\lambda_{\text{OP}}^{\text{E}}$, and $\lambda_{\text{OP}}^{\text{A}}$ are below the 10% significance level except for specification (2), and thus the linear null hypothesis is rejected in favor of the nonlinear alternative.[11] Similarly, for the g-test of null hypothesis $H_0 : g_1 = g_2 = 0$, the p-value is below the 5% significance level, except for specification (2), indicating that the joint nonlinear components differ from zero. We thus conclude that there exists a nonlinear relationship between financial development and economic growth.

The second and equally significant finding of this study is that the linear estimates (β_1) of two BANK proxies in specifications (1)–(6) are all negative, strongly suggesting that banking industry development is negatively associated with economic growth. Furthermore, a nonlinear effect is ascertained as occurring when the nonlinear estimate of g_1 differs significantly from zero.

Third, unlike previous BANK results, to date no relationship has been found between stock market development and economic growth, since the linear estimates (β_2) for three STOCK variables are overwhelmingly not significantly different from zero. After applying random field estimates (g_2), nonlinear effects are revealed and successfully identified in specifications (1), (3), and (6).

4.1 Graphic results

As described by Hamilton (2001), with the values of $\boldsymbol{\vartheta} = \{\alpha, \beta_1, \ldots, \beta_6, \zeta, g_1, g_2, \sigma\}$, we are able to calculate a value for any z of interest, denoted as z^*. This calculation represents the inference of the econometrician as the value of the conditional mean $\mu(z^*)$ when the explanatory variables assume the value represented by z^*, and when the parameters are known to take on these specified values.

The upper panel of Fig. 1 illustrates the conditional expectation function against LENDING while the other independent variables are held constant. For example, Fig. 1a plots $\hat{\text{E}}[\mu(\text{LENDING}, \overline{\text{MKTCAP}})|\, \boldsymbol{Y}_T]$ against LENDING, where $\overline{\text{MKTCAP}}$, denotes the sample mean for variables MKTCAP and $\boldsymbol{Y}_T$. The solid line represents the posterior mean with $N = 10000$ Monte Carlo draws for each specification. Furthermore, the dashed lines denote the 95% confidence intervals.

Figure 1a–c represents the graphical relationship between LENDING and economic growth in accordance with specifications (1)–(3) in Table 4. The plots of (a) and (c) display a nonlinear inverted U-shaped pattern consistent with the highly significant nonlinear LENDING estimates (g_1) in specifications (1) and (3) in Table 4, whereas plot (b) exhibits an absolutely linear and negative relationship between LENDING and economic growth. The inverted U-shaped pattern indicates that the relationship between

[11] Since in most situations, the econometricians will not know the parametric form of the covariance, any specification will constitute only an approximation of the true covariance function. To this end, Dahl and Gonzále-Rivera (2003, p. 160) suggested "the $\lambda_{\text{OP}}^{\text{A}}$ tests, which do not require the explicit knowledge of the functional form of the covariance matrix, emerge as a powerful alternative across models." Therefore, $\lambda_{\text{OP}}^{\text{A}}$ which is based on unknown covariance matrix is more reliable than the other two λ-tests.

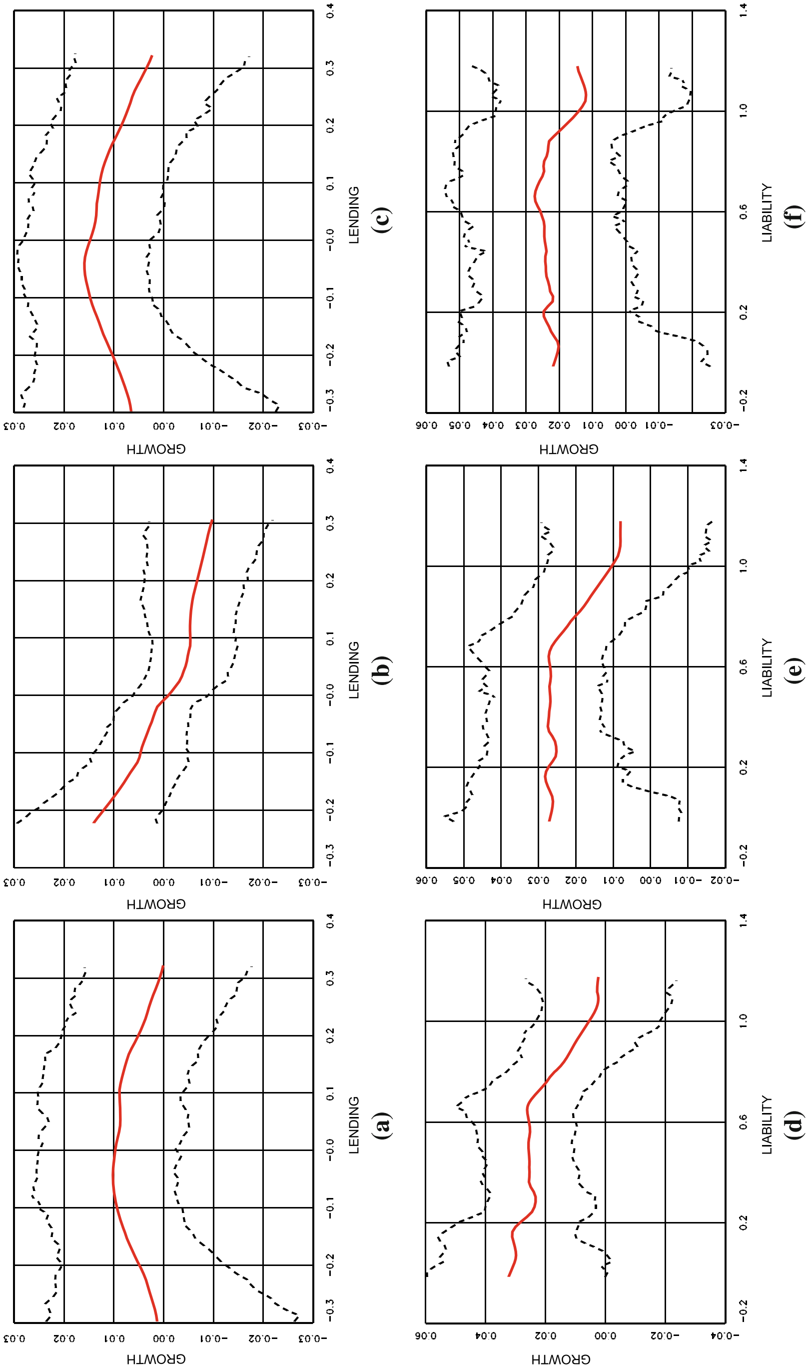

Fig. 1 Nonlinear relationship between bank development and economic growth. **a** Specification 1: LENDING. **b** Specification 2: LENDING. **c** Specification 3: LENDING. **d** Specification 4: LIABILITY. **e** Specification 5: LIABILITY. **f** Specification 6: LIABILITY

LENDING and growth is initially positive as LENDING increases, but becomes negative when LENDING exceeds −0.05. Similarly, Fig. 1d–f demonstrates the association among the second BANK proxy, LIABILITY, and economic growth. Clearly, the pattern displays a remarkably nonlinear shape. Particularly, the trend exhibits a negative slope, or even an inverted U-shape, but considerably flatter.

The statistical significance and graphical nonlinearity are worthy of further discussion. The effect of bank development on economic growth depends on β_1 and g_1, where the former contributes the linear slope of bank–growth pattern and the latter controls the curvature. Thus, comparing LENDING (specification (3) in Table 4 and Fig. 1c) and LIABILITY (specification (6) in Table 4 and Fig. 1f), the positive effect of LIABILITY on growth at low levels of bank development is much weaker than that of LENDING. The reason is that the negative linear effect of LIABILITY (−0.052) is greater than that of LENDING (−0.035), as even the curvature of LIABILITY (64.142) is highly nonlinear.

Regarding the stock–growth nexus, Fig. 2 shows relationships between three STOCK proxies and economic growth. First, plots of (c) and (d) exhibit absolutely linear and positive slope patterns, consistent with the insignificant estimate of STOCKTRA in Table 4. Second, as for the other two proxies, the link between stock market development and economic growth is totally different from that for the BANK case because it involves an asymmetric $\surd$-shaped relation rather than a symmetric inverted U-shaped relation. In the plots of (a) and (e), an asymmetric $\surd$-shaped curve is found in which the minimum point (i.e., turning point) is around −0.05. On the left-hand side of the turning point, it is termed the less-developed stock market; meanwhile, on the right-hand side of the turning point is termed the well-developed stock market. The two variables are negatively linked before the turning point, but positively linked after it. The $\surd$-shaped curve is asymmetric because the slope is steeper for the well-developed regime, suggesting that the two variables are strongly linked in the well-developed regime.

5 Discussion

The empirical results presented in this study indicate the existence of nonlinear relationships between financial development and economic growth. Namely, an inverted U-shaped bank–growth relation and a $\surd$-shaped stock–growth relation. $\surd$- or inverted U-shaped patterns imply that the process of financial development can be divided into two stages: namely the less-developed and well-developed stages. We discuss how the real economy benefits or suffers during each stage of financial development.

During the early stage of bank development, as noted by Diamond and Dybvig (1983), banks can provide individuals with insurance against idiosyncratic liquidity shocks by providing pools of liquidity or coalitions of depositors. That is, in their role as financial intermediaries, banks pool savings and lend firms investment funds and thus promote economic growth. Additionally, banks also play roles of delegated monitoring to reduce monitoring costs and prevent borrowers (firms) opportunism from causing economic inefficiency (Diamond 1984). However, with the maturation of the banking industry, the banking sector has begun to exert a significant influence

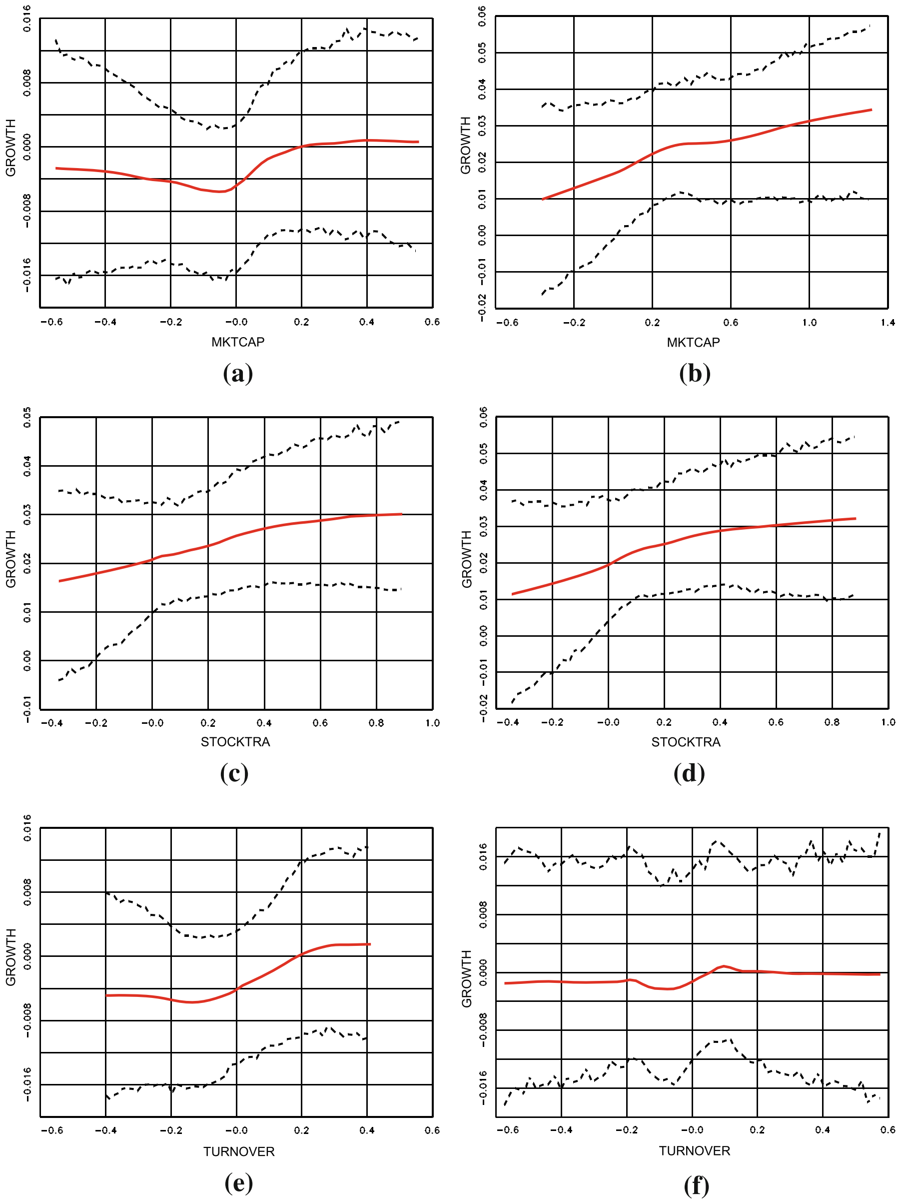

Fig. 2 Nonlinear relationship between stock market development and economic growth. **a** Specification 1: MKTCAP. **b** Specification 4: MKTCAP. **c** Specification 2: STOCKTRA. **d** Specification 5: STOCKTRA. **e** Specification 3: TURNOVER. **f** Specification 6: TURNOVER

over firms. This influence may manifest itself in negative ways. First, for example, given information asymmetry, Dewatripont and Maskin (1995) noted that both bad and good projects are undertaken and completed because lenders (bankers) fail to identify project quality before the intermediate stage and they are all worth continuing.[12] This condition worsens with banking sector domination of the financial system. Second, banks tend to exhibit an inherent bias toward prudence, implying that bank development may impede corporate innovation and growth. This phenomenon occurs because the capacity of banks is closely related to corporate governance (Levine 2002). Third, bankers may be preoccupied with the related firms, or may even collude with those firms against outside creditors, leading to influential banks preventing outsiders from removing inefficient managers if they are particularly generous to the banker (Black and Moersch 1998).

The process of stock market development is nonlinear, first occurring abruptly and rapidly, and subsequently continuing more gradually. Emerging stock markets are well known to be highly volatile, which makes it a poor guidance to an efficient investment and hence retards economic growth. Additionally, from the perspective of the competing relations between the banking sector and market, an initially growing stock market may undermine the existing group-bank systems (Singh 1997). As market develops and becomes more mature, a well-functioning stock market may promote economic growth via the following routes. First, a larger and liquid market provides a firm alternative vehicle for external financing, which is likely to be cheaper than borrowing via the banking system. Second, the numerous firms that are publicly listed and the SEC requirements that they release extensive accounting reports mean that considerable information is available. The wide availability of information helps (i) firms in making good investment decisions related to industry entry; (ii) people in undertaking research and checking managerial actions. Third, in well-developed stock markets, takeovers provide a mechanism for disciplining under-performing managers and promoting better corporate control by easing takeovers of poorly managed firms (Scharfstein 1988; Stein 1988).

The empirical results presented in this study indicate an inverted U-shaped bank–growth relation and a $\surd$-shaped stock–growth relation. Evidence of these nonlinearities is also provided by numerous studies. One possible explanation for the nonlinearity is that the relation may be dependent on the third factor. The first candidate for the third factor is probably the income level. Rioja and Valev (2004) took this one step further. They precisely explain the three distinct regions of financial development. In the low regions, which mostly contain very poor countries, advances in financial development are found to have had no statistically significant effect on growth. In the intermediate regions, changes in financial development are evidently the most effective in terms of advancing growth. In the high regions, additional financial development appears to have a positive, albeit smaller, effect. Jalilian and Kirkpatrick (2005) claim that the financial sector leads economic growth in low-income countries' data, but not in high-income countries. Xu (2000) finds that countries concentrated in the low or lower middle income group display negative cumulative effects of financial development in their GDP growth, but not in high income.

[12] If the project's funds are financed from market, lenders could precommit not to refinance bad projects at the interim date. As a results, only good projects are financed. The reason is that, in the market, new lenders must be brought-in in the interim date.

The second candidate for the third factor is financial development. For example, Shen and Lin (2009) argue that bank development is a blessing to economic growth for low bank development countries, but a curse for high bank development countries. Ketteni et al. (2007) also find an inverted U-shaped relation between bank development and economic growth. On the other hand, Minier (2003) identifies a $\surd$-shaped stock–growth relation in different levels of stock market capitalization countries. Shen and Lee (2006) present that the stage of bank development affects the relation between bank development and economic growth.

Theories explaining reasons for the (inverted) U-shaped finance–growth relation are also provided. Acemoglu and Zilibotti (1997) and Khan (2001) argue that the association between financial development and economic growth changes when endogenous changes in the extent of access to financial intermediaries and external finance. Bencivenga et al. (1995) offer that roles played by the banking sector and the stock market in the economy may vary when transition cost are reduced. Hung (2009) develops a standard model of asymmetric information that incorporates nonproductive consumption loans with productive investment loans to investigate the nonlinear relationship of finance–growth. He finds that the initial level of financial development plays a key role in determining the nonlinear relationships between financial development and economic growth.

5.1 Bank-based and market-based financial systems

It is interesting to examine how financial system characteristics influence the study results. Following Beck and Levine (2002), this investigation divides 46 countries into 23 bank-based countries and 18 market-based countries.[13] Tables 5 and 6 report the estimated results using samples from bank-based and market-based countries, respectively.

In case of the *bank-based* countries listed in Table 5, first, the *p*-value of two linear tests, the λ-test and the g-test, are all below 10%, confirming the existence of a nonlinear relationship between financial development and economic growth. Second, both the linear and nonlinear estimates of BANK variables differ significantly from zero, resulting in a nonlinear suggestion of a negative relationship between banking and growth. Regarding stock market development, the nonlinear effects of almost all STOCK variables are successfully identified although those of linear estimates are overwhelmingly insignificant. To summarize, using the sample from bank-based countries, the empirical results reveal much stronger evidence of a negative and nonlinear relationship between bank development and economic growth, as well as of a nonlin-

[13] Based on Beck and Levine (2002) classification: (1) 23 bank-based countries: Argentina, Austria, Bangladesh, Belgium, Colombia, Egypt, France, Finland, Germany, Greece, India, Indonesia, Israel, Italy, Japan, Jordan, New Zealand, Norway, Pakistan, Portugal, Spain, Venezuela, and Zimbabwe; (2) 18 market-based countries: Australia, Brazil, Canada, Chile, Hong Kong, Jamaica, South Korea, Malaysia, Mexico, the Netherlands, Peru, Philippines, Singapore, Sweden, Thailand, Turkey, the United Kingdom, and the United States; (3) The remaining five countries are not classified and included. They are Côte d'Ivoire, Denmark, Luxembourg, Morocco, and Nigeria.

Table 5 Estimated results of flexible nonlinear model using sample from bank-based countries: $\text{GROWTH}_{it} = \alpha + \beta_1 \text{BANK}_{it} + \beta_2 \text{STOCK}_{it} + \beta_3 \text{INFLA}_{it} + \beta_4 \text{GCON}_{it} + \beta_5 \text{SCHOOL76}_i + \beta_6 \text{Y76}_i + \sigma[\zeta m(g_1 \text{BANK}_{it}, g_2 \text{STOCK}_{it}) + \nu_{it}]$

	(1)	(2)	(3)	(4)	(5)	(6)
CONSTANT	0.005 (0.008)	0.005 (0.008)	−1.94E−4 (0.006)	0.005 (0.010)	0.001 (0.007)	−0.003 (0.006)
LENDING (β_1)	−0.053** (0.020)	−0.046** (0.019)	−0.040** (0.017)			
LIABILITY (β_1)				−0.028** (0.011)	−0.083*** (0.028)	−0.087*** (0.027)
MKTCAP (β_2)	0.007 (0.015)			0.015** (0.008)		
STOCKTRA (β_2)		0.004 (0.013)			0.015 (0.025)	
TURNOVER (β_2)			0.001 (0.005)			0.002 (0.006)
INFLA	−0.039*** (0.013)	−0.043*** (0.014)	−0.039** (0.014)	−0.045*** (0.015)	−0.050*** (0.015)	−0.045*** (0.015)
GCON	0.011 (0.027)	0.002 (0.026)	−0.004 (0.025)	0.005 (0.125)	0.046 (0.121)	−0.002 (0.135)
SCHOOL76	4.36E−5 (8.82E−5)	3.01E−5 (9.05E−5)	6.85E−5 (8.16E−5)	4.13E−5 (1.18E−4)	5.15E−5 (1.24E−4)	9.33E−5 (1.20E−4)
Y76	−0.001 (0.001)	−0.001 (0.001)	−0.001 (0.001)	−1.55E−4 (0.001)	−0.001 (0.001)	−9.38E−5 (0.001)
σ	0.018*** (0.002)	0.020*** (0.002)	0.019*** (0.003)	0.020*** (0.002)	0.017*** (0.003)	0.017*** (0.005)
ζ	0.609* (0.339)	0.323 (0.217)	0.428 (0.397)	−0.524 (0.475)	−0.798** (0.374)	0.817 (0.573)
LENDING (g_1)	11.790*** (3.181)	10.973*** (3.526)	38.802** (16.697)			
LIABILITY (g_1)				8.546*** (0.881)	4.774** (1.769)	33.950*** (6.216)
MKTCAP (g_2)	12.244*** (3.029)			0.010 (0.262)		
STOCKTRA (g_2)		6.056** (2.606)			86.745** (29.361)	
TURNOVER (g_2)			19.011* (11.304)			18.479** (7.227)
$\log L$	244.696	240.942	240.459	155.236	153.471	152.424
λ_{H}^{E}-test	0.063*	0.044**	0.063*	0.061*	0.016**	0.031**
λ_{OP}^{E}-test	0.093*	0.057*	0.074*	0.071*	0.036**	0.051**
λ_{OP}^{A}-test	0.047**	0.036**	0.015**	0.025**	0.001***	0.015**
g_{OP}-test	0.038**	0.015**	0.018**	0.036**	0.001***	0.016**

Notes: $\zeta = \lambda/\sigma$; The number in parentheses is the standard error; ***, **, and * denote rejection at the significance level of 1, 5, and 10%, respectively; The p-values are reported for , λ_{H}^{E}, λ_{OP}^{E}, λ_{OP}^{A} and g_{OP}

Table 6 Estimated results of flexible nonlinear model using sample from market-based countries: $\text{GROWTH}_{it} = \alpha + \beta_1 \text{BANK}_{it} + \beta_2 \text{STOCK}_{it} + \beta_3 \text{INFLA}_{it} + \beta_4 \text{GCON}_{it} + \beta_5 \text{SCHOOL76}_i + \beta_6 \text{Y76}_i + \sigma[\zeta m(g_1 \text{BANK}_{it}, g_2 \text{STOCK}_{it}) + \nu_{it}]$

	(1)	(2)	(3)	(4)	(5)	(6)
CONSTANT	0.004 (0.014)	−0.006 (0.013)	−0.004 (0.013)	0.001 (0.013)	0.001 (0.013)	−0.004(0.013)
LENDING (β_1)	−0.062** (0.023)	−0.064** (0.023)	−0.060** (0.022)			
LIABILITY (β_1)				−0.026 (0.030)	−0.031 (0.027)	−0.035 (0.023)
MKTCAP (β_2)	0.004 (0.011)			−0.001 (0.013)		
STOCKTRA (β_2)		0.011 (0.012)			0.002 (0.011)	
TURNOVER (β_2)			0.012 (0.012)			0.003 (0.012)
INFLA	−0.053*** (0.011)	−0.057*** (0.011)	−0.058*** (0.012)	−0.043*** (0.012)	−0.043*** (0.012)	−0.052*** (0.012)
GCON	−0.307* (0.174)	−0.247 (0.180)	−0.261 (0.181)	−0.108 (0.237)	−0.103 (0.233)	−0.168 (0.249)
SCHOOL76	1.18E−4 (1.71E−4)	1.59E−4 (1.69E−4)	1.17E−4 (1.69E−4)	−5.46E−5 (1.74E−4)	−4.60E−5 (1.73E−4)	6.28E−5 (1.78E−4)
Y76	−0.002 (0.002)	−1.83E−4 (0.002)	−8.71E−5 (0.002)	2.58E−4 (0.002)	2.14E−4 (0.002)	−1.01E−4 (0.002)
σ	0.011 (0.009)	0.016 (0.010)	0.021* (0.011)	0.023*** (0.003)	0.023*** (0.003)	0.030*** (0.002)
ζ	2.527 (2.592)	1.395 (1.363)	0.916 (1.053)	0.820** (0.319)	0.818** (0.311)	5.78E−5 (0.254)
LENDING (g_1)	29.575*** (9.840)	27.920** (12.681)	83.415 (53.114)			
LIABILITY (g_1)				94.192*** (17.652)	95.199*** (17.161)	13.490 (484.841)
MKTCAP (g_2)	29.578*** (4.350)			−0.336 (1.655)		
STOCKTRA (g_2)		65.268*** (6.265)			0.376 (1.330)	
TURNOVER (g_2)			36.157 (31.552)			25.809 (927.574)
$\log L$	161.617	160.654	160.133	149.448	149.491	147.150
$\lambda_{\text{H}}^{\text{E}}$-test	0.083*	0.069*	0.430	0.048**	0.061*	0.568
$\lambda_{\text{OP}}^{\text{E}}$-test	0.138	0.093*	0.838	0.072*	0.073*	0.831
$\lambda_{\text{OP}}^{\text{A}}$-test	0.042**	0.046**	0.257	0.034**	0.041**	0.349
g_{OP}-test	0.024**	0.035**	0.354	0.063*	0.031**	0.644

Notes: $\zeta = \lambda/\sigma$; The number in parentheses is the standard error; ***, **, and * denote rejection at the significance level of 1, 5, and 10%, respectively; The p values are reported for, $\lambda_{\text{H}}^{\text{E}}$, $\lambda_{\text{OP}}^{\text{E}}$, $\lambda_{\text{OP}}^{\text{A}}$ and g_{OP}

ear relationship between stock market development and economic growth compared to the full-sample countries.

Table 6 lists estimated results employing the sample from *market-based* countries, and shows that the empirical evidence weakens regardless of bank sector or stock market development. For example, the linear and nonlinear estimates of BANK variables remain significantly negative but at the lesser significance level. Also, stock market development is weakly linked with economic growth since the linear and nonlinear estimates of three STOCK proxies differ only insignificantly from zero.

In sum, considering whether financial system characteristics affect analytical results, the empirical evidence shows that, in bank-based countries, financial development is closely associated with economic growth but the link weakens in market-based countries. As we know, financial development often begins with the banking sector and then gradually shifts to market.[14] For that reason, in market-based financial systems, both the banking sector and stock market have generally undergone extensive development. Therefore, the marginal effect of financial development on economic growth in market-based countries is weaker than that in banked-based countries.

6 Concluding remarks and future work

This study re-investigates the relationship of financial development and economic growth, where financial development is measured by either banking sector development or stock market development. Meanwhile, the banking sector is proxied by LENDING or LIABILITY. Moreover, the stock market is proxied by MKTCAP, STOCKTRA, or TURNOVER. This study adopts Hamilton (2001) flexible nonlinear model which helps detect nonlinear finance–growth relation without pre-specifying any functional form.

This study reaches the following key conclusions. First, based on determining four types of nonlinear test, we reject the null hypothesis of linearity regardless of the measures of financial development. Next, an inverted U-shaped bank–growth relation is identified. Therefore, bank development is positively related to economic growth below a specific threshold, but becomes negatively related after the threshold. Finally, in contrast to the inverted U-shaped curve for bank–growth relation, an asymmetric $\surd$-shaped relationship is observed between stock market development and economic growth. Consequently, stock market development is negatively but weakly related to economic growth before a threshold but becomes positively related after the threshold. The conclusion of this study thus indicates that earlier studies that did not consider these nonlinear relations might have made misleading inferences.

Although this study investigates the nonlinear relation between financial development (banking sector and stock market development) and economic growth, a potential interaction between stock market and banking sector development should also be considered. As argued by Smith and Boyd (1998) and Huybens and Smith (1999), there

[14] As noted in Allen and Santomero (2001), as financial market becomes increasingly more competitive, traditional commercial banks are forced to move away their traditional intermediation business. Instead, they are forced to develop alternative business involved using instruments such as options and swaps and dynamic trading strategies to compete with markets.

are reasons to believe that bank and stock market development are not just only independently influential for economic development, but also likely to exhibit codependencies, complementaries, and possible interaction. The approach of Hamilton (2001) provides no structural form for variables. Consequently, the association between economic growth and financial development is at best a reduced-form relation. Therefore, Hamilton (2001) reduced-form regression fails to model potential dynamics and interaction between bank development and stock market development. In this respect, we hope future studies on the finance–growth nexus could adopt a structured-form regression in order to capture the finance dependence and dynamics between bank and stock market development.

Acknowledgements We thank James Hamilton for providing us with Gauss code to compute his estimator.

Appendix

Categorized by *Financial Structure and Economic Development Database*, 46 countries are listed follows.

High-income OECD countries: Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Italy, Japan, Luxembourg, the Netherlands, New Zealand, Norway, Portugal, South Korea, Spain, Sweden, the United Kingdom, and the United States.
High-income nonOECD countries: Hong Kong, Israel, and Singapore.
Upper middle income countries: Argentina, Chile, Malaysia, Mexico, Turkey, and Venezuela.
Lower middle income countries: Brazil, Colombia, Egypt, Indonesia, Jamaica, Jordan, Morocco, Peru, Philippines, and Thailand.
Low-income countries: Bangladesh, Côte d'Ivoire, India, Nigeria, Pakistan, and Zimbabwe.

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