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FINANCIAL DEVELOPMENT AND GROWTH: A PANEL SMOOTH REGRESSION APPROACH

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In this paper, we propose an original framework to determine the relative influence of series of variables on the linkage between financial development and economic growth. Based on panel threshold regression models, we establish country-specific and time-specific finance-growth coefficients for 71 countries, both developed and developing, from 1960 to 2004. The results show that inflation rate, ratio of government consumption, degree of openness to trade and financial development affect the non-linearity between financial development and growth, and have the greatest influence on the relationship of two variables.

Keywords: Panel Smooth Regression Models, Financial Development, Growth
JEL classification: C23, F43, O16

1. INTRODUCTION

It is widely allowed in the contemporary economic literature, that financial development is positively associated with economic growth. However, empirical results often obtained through cross section analyses and dynamic panel techniques, whose robustness is not still verified, are based on two fundamental hypotheses. The first is the linearity of the relationship between finance and growth. The second is the constancy of finance-growth coefficient. The hypothesis of linearity has fundamental limits in that financial development does not affect economic growth in the same way in countries with different income levels. Khan and Senhadji (2000, 2003), Deidda and Fattouh (2002) and Favara (2003), among others obtained results along these lines. In the literature that supposes non-linearity between finance and growth, there are authors who find a negative or not significant relationship through a linear estimation of the finance-growth equation.

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The theoretical analysis of the non-linearity between finance and growth is based on the existence of multiple balances among both variables.[1] This situation bound to the existence of economies scale and lessening returns in banking sector, creates a poverty trap and is characteristic of weak financial and economic development. Furthermore, according to Berthélemy and Varoudakis (1995), the multiple equilibriums can appear because of a reciprocal externality between the financial and the real sectors. So, the existence of multitude equilibriums in the relationship between finance and growth suggests that the sensitivity of growth with regard to finance varies not only with time, but also according to the category of country.

Although the various works which analyze non-linearity between finance and growth are not precisely stratified, one can indeed remark that, whereas some authors suggest that financial development is the source of the nonlinear relationship between finance and growth, others think that the threshold variable could be an economic development indicator.

In the class of studies that supposes that financial development would settle non-linearity between finance and growth, Berthélemy and Varoudakis (1995, 1996), and Aghion *et al.* (2004) provide empirical evidence of multiple equilibriums between financial development and economic growth through the clubs of convergence. These studies were extended by Deidda and Fattouh (2008), who investigated the interaction between the banking sector and financial markets in regards to economic growth. They show that for highly developed financial markets, the effect of banking sector on growth is weak; for countries with a developed banking sector, the impact of financial markets on the growth is weak.

As regards the use of economic development indicators as transition variables, Deidda and Fattouh (2002) identify a nonlinear relationship between finance and growth by means of a panel smooth model (Hansen, 1999); the transition variable used is the income level. They found that financial development is significant only in countries which have high income level. So, Rousseau and Wachtel (2002) show the existence of the threshold effect in the nexus between finance and growth, but with the inflation rate as the transition variable from a sample of 84 countries between 1960 and 1995. Finally, from a quadratic nonlinear specification, Gaytan and Rancière (2004) show that there are three thresholds in the relationship between financial development and economic growth: indeed, the general outcome of Gaytan and Rancière (2004) paper is that the relationship between finance and growth is relatively weak in developed countries, whereas in developing countries, this relationship is strong.[2]

Stengos and Liang (2004) use a semi-parametric regressions approach to study non-linearity between financial development and economic growth. They confirm the

[1] Greenwood and Jovanovic (1990), Saint Paul (1992), Berthélemy and Varoudakis (1994, 1995, 1996) provide a strong explanation to this assertion.

[2] This results are opposed to those obtained by Deidda and Fattouh (2002) and Rioja and Valen (2004).

nonlinear linkage between finance and growth. On the other hand, Ketteni *et al.* (2007) found that the finance-growth relationship is linear when previously documented non-linearity between initial per capita income, human capital and economic growth is taken into account.

The alternative method adopted to analyze finance-growth relationship in this paper consists of using a Panel Smooth Threshold Regression (PSTR) model recently developed by Gonzàlez *et al.* (2005) and Fok *et al.* (2004). The PSTR model permits a smooth transition, as a weak number of thresholds, as for a *continuum* of regimes.

This approach presents two main advantages. First, PSTR specifications allow the finance-growth coefficient to vary not only between countries, but also with time. This provides a simple way to appraise the heterogeneous relationship between finance and growth with time and according to countries. The second advantage of this approach is that it permits a smooth change in country-specific correlation depending on the threshold variables. Consequently, we consider four threshold variables (inflation rate, government expenditure as ratio to GDP, degree of openness to trade, and financial development) which can potentially explain the heterogeneity in time and according to the country, between financial development and economic growth.

The rest of the paper is organized as follows. In the next section, we discuss the threshold specification regression and particularly, the cross-country heterogeneity and the time variability of finance-growth coefficients. The choice of transition variables and linearity tests are then presented in the third section. The fourth part of the paper is dedicated to the results obtained from various panel threshold models. The last section concludes.

2. FINANCE AND GROWTH: TOWARD A THRESHOLD SPECIFICATION

The basis of our model is exactly the same as the one used by many authors who have investigated finance-growth relationship on panel data. The corresponding equation is defined as follows:

$$g_{it} = \alpha_i + \beta f_{i,t-1} + \gamma z_{it} + \varepsilon_{it} , \tag{1}$$

where g_{it} is the GDP growth rate observed for the i^{th} country at time *t*, $f_{i,t-1}$ is the first lag of financial development indicator,[3] α_i denotes an individual fixed effect, z_{it} a vector of control variables. The residual ε_{it} is assumed to be $i.i.d.(0, \sigma_\varepsilon^2)$. This basic model, used in the first empirical estimations of finance-growth relationship realized in

[3] We use the lag of the financial development variable to treat the endogeneity problem between financial development and economic growth.

cross-country and on dynamic panel has been questioned by several authors. Deidda and Fattouh (2002), Favara (2003), then Rousseau and Wachtel (2002), think that there is a nonlinear relationship between finance and growth. Indeed, cross section and panel dynamic estimations of finance-growth nexus present two main drawbacks. First, they suppose the same finance-growth coefficient across all the country of the panel and with time. It is obvious that this assumption is unrealistic, because it does not take into account the effects of business cycles, which can affect the link between finance and growth, as countries react differently from different shocks to financial variables, according to their development level and their macroeconomic environment.

Secondly, this model implies that the finance-growth coefficient remains constant for a set time period. This seems unrealistic because the effect of the financial development on growth at the beginning of the 60s would be different from its effect in the 2000s. One possible solution is to suppose that the panel is heterogeneous and consequently, parameter (β_i) is random coefficient (random coefficient model of Swamy (1970)). However, this method also reveals its limits in that it only takes into account the difference of the elasticity between the countries, hiding the variability of the parameter with time.

One way to circumvent both these issues is to introduce threshold effects in a linear panel model. In this context, the first solution requires using the Panel Threshold Regression (PTR) model (Hansen, 1999) as suggested by Deidda and Fattouh (2002). In this case, the mechanism of transition proposed by Hansen (1999) between extreme regimes is very simple: at each date, if for a given country, the transition variable is lower than a given value, called the threshold parameter, the finance-growth model is defined by a particular regime; this regime is different from the model used if the transition variable is larger than the threshold parameter. For instance, let us consider a PTR model with two extreme regimes:

$$g_{it} = \alpha_i + \beta_0 f_{i,t-1} + \beta_1 f_{i,t-1}\Gamma(q_{it};c) + \delta z_{it} + \varepsilon_{it}\,, \tag{2}$$

where q_{it} is the threshold variable, c a threshold parameter and the transition function $\Gamma(q_{it};c)$ corresponds to the indicator function:

$$\Gamma(q_{it};c) = \begin{cases} 1 & if \quad q_{it} \geq c, \\ 0 & otherwise. \end{cases} \tag{3}$$

With such a model, the finance-growth coefficient is equal to (β_i) if the threshold variable is smaller than $c\,(q_{it} < c)$ and is equal to $(\beta_0 + \beta_1)$ if the threshold variable is larger than $c\,(q_{it} > c)$. This model can be extended to more general specification with r regimes. However, even in this case, the PTR model requires that the value of finance-growth coefficient can be divided into a small number of classes. Such an assumption is unrealistic for a sample of developed and developing countries. Because a model with few thresholds seems to be simple way to assess finance-growth linkage, one can assume that the consideration of an infinite number of thresholds could be a possible solution.

The conventional solution to this problem is the use of a model with a smooth transition function. This type of model, commonly used in time series analysis, has recently been extended to panel data with the Panel Smooth Threshold Regression (PSTR) model proposed by Gonzàlez *et al.* (2005) and Fok *et al*. (2004). Let us suppose then the simplest case of a PSTR with two extreme regimes and a single transition function, to illustrate relationship between finance and growth:

$$g_{it} = \alpha_i + \beta_0 f_{i,t-1} + \beta_1 f_{i,t-1}\Gamma(q_{it};\gamma,c) + \delta z_{it} + \varepsilon_{it}\,. \tag{4}$$

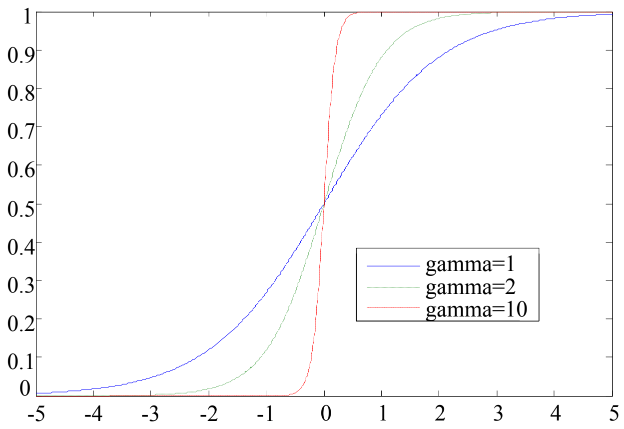
The transition function Γ is continuous and depends on the threshold variable q_{it}; $c = (c_1,...,c_m)'$ is a vector of parameters and the parameter γ determines the slope of the transition function. Following the work of Granger and Teräsvirta (1993) for the time series STAR models, González *et al*. (2005) used a logistic transition function:

$$\Gamma(q_{it};\gamma,c) = \left[1 + \exp\left(-\gamma \prod_{z=1}^{m}(q_{it} - c_z)\right)\right]^{-1},\ \gamma > 0,\ c_1 < ... < c_m\,. \tag{5}$$

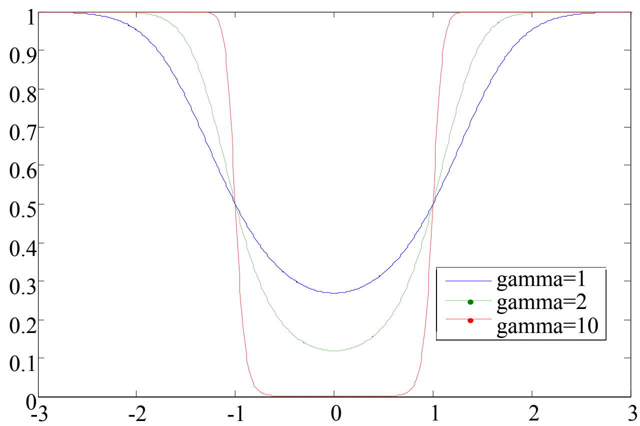
On Fig. 1, the transition function is displayed for various values of slope parameter γ. In the first case, we have functions with two regimes; while in the second case, transition functions have three regimes. For a high value of γ, the transition becomes rougher and the transition function $\Gamma(q_{it};\gamma,c)$ tends towards the indicator function $\Gamma(q_{it};c)$. Then, for every value of *m*, when γ tends towards infinite, the PSTR converges towards the PTR. In the opposite case, when γ is close to 0, the transition function $\Gamma(q_{it};\gamma,c)$ is constant and the PSTR estimation become a panel with fixed effects.

With regard to the previous specifications (panel analysis or PTR), the use of PSTR methodology presents some theoretical interests. The main advantage of the PSTR is that it allows the finance-growth coefficient to vary according to the country and with the time; it provides a parametric approach of the cross-country heterogeneity and of the time instability of the finance-growth coefficients, since these parameters change smoothly as a function of a threshold variable. For instance, if the transition variable q_{it} is different from the financial development indicator $f_{i,t-1}$, the sensitivity of growth to financial development variables for the i^{th} country at time *t* is defined as follows:

$$e_{it} = \frac{\partial g_{it}}{\partial f_{i,t-1}} = \beta_0 + \beta_1 \Gamma(q_{it};\gamma,c)\,. \tag{6}$$



Case 1: $m = 1$ and $c = 0$



Case 2: $m = 2$, $c_1 = 1$ and $c_2 = 0$

Figure 1. Transition Functions: Sensitivity Analysis to the Slope Parameter

According to the properties of the transition function, we have $\beta_0 \leq e_{it} \leq \beta_0 + \beta_1$ if $\beta_1 > 0$ or $\beta_0 + \beta_1 \leq e_{it} \leq \beta_0$ if $\beta_1 < 0$ because $0 \leq \Gamma(q_{it}; \gamma, c) \leq 1$. We notice that the finance-growth coefficient can be defined as a weighted average of parameters β_0 and β_1. Then, PSTR model allows a precious assessment of the impact of financial development on economic growth.

Another advantage of PSTR model is that the finance-growth coefficient can be different from the estimated parameters for extreme regimes, i.e., β_0 and β_1. As illustrated by Eq. (6), these parameters do not directly correspond to direct impact of financial development on growth. For instance, parameter β_0 corresponds to direct effect of finance on growth only when the transition function $\Gamma(q_{it};\gamma,c)$ tends towards 0. By opposite, when $\Gamma(q_{it};\gamma,c)$ tends towards 1, the finance-growth coefficient is equal to the sum of β_0 and β_1 parameters. Between these two extremes, there are an infinite number of finance-growth coefficients, which are defined as a weighted average of parameters β_0 and β_1. Therefore, it is important to remark that it is generally difficult to directly interpret the values of these parameters (as in a probit or logit model). It is generally preferable to interpret (*i*), the sign of these parameters, which indicates an increase or a decrease in the finance-growth coefficient according to the value of the threshold variable and (*ii*) the varying coefficient in the time and individual dimensions given by Eq. (6).

The PSTR model can be generalized to $r+1$ extreme regimes as follows:

$$g_{it} = \alpha_i + \beta_0 f_{i,t-1} + \sum_{j=1}^{r} \beta_j f_{i,t-1} \Gamma_j(q_{it};\gamma_j,c_j) + \delta z_{it} + \varepsilon_{it}\,, \tag{7}$$

where the *r* transition functions $\Gamma_j(q_{it};\gamma_j,c_j)$ depend on the slope parameters γ_j and on the location parameters c_j. In this specification, if the threshold variable q_{it} is different from the financial development indicator $f_{i,t-1}$, the finance-growth coefficient for the i^{th} country at time *t* is defined by weighted average of $r+1$ parameters β_j associated to $r+1$ extreme regimes:

$$e_{it} = \frac{\partial g_{it}}{\partial f_{i,t-1}} = \beta_0 + \sum_{j=1}^{r} \beta_j \Gamma_j(q_{it};\gamma_j,c_j),\ \forall i,\ \forall t\,. \tag{8}$$

When the transition variable is the same as exogenous variable, the elasticity expression is different. For instance, if $q_{it} = f_{i,t-1}$, the expression of finance-growth coefficient is then defined as:

$$e_{it} = \frac{\partial g_{it}}{\partial f_{i,t-1}} = \beta_0 + \sum_{j=1}^{r} \beta_j \Gamma_j(f_{i,t-1};\gamma_j,c_j) + \sum_{j=1}^{r} \beta_j \frac{\partial \Gamma(f_{i,t-1};\gamma_j,c_j)}{\partial f_{i,t-1}} f_{i,t-1},\ \forall i,\ \forall t\,. \tag{9}$$

Although those expressions of the elasticity allow some configurations for finance and growth relationship, several questions related to estimation and specification tests persist. The next section is devoted to answer them.[4]

3. ESTIMATION AND SPECIFICATION TESTS

The PSTR model estimation begins with the elimination of the individual fixed effects α_i by removing individual-specific means and then applying nonlinear least squares to the transformed model.[5] Gonzàlez *et al*. (2005) propose a testing procedure in following order: (*i*) test the linearity against the PSTR model, and (*ii*) determine the number *r*, of transition functions. The test of linearity in PSTR model (refer to Eq. (4)), can be done by testing: $H_0 : \gamma = 0$ or $H_0 : \beta_1 = 0$. But under the null hypothesis, the test will be non standard in both cases, and the PSTR model contains unidentified nuisance parameters. A possible solution is to replace the transition function $\Gamma(q_{it}; \gamma_j, c_j)$ by its first-order Taylor expression around $\gamma = 0$ and to test an equivalent hypothesis in an auxiliary regression. We then obtain:

$$g_{it} = \alpha_i + \theta_0 f_{i,t-1} + \theta_1 q_{it} f_{i,t-1} + \delta z_{it} + \varepsilon_{it}^{*}. \tag{10}$$

Since θ_i parameters are proportional to the slope parameter of transition function γ, testing the linearity of finance-growth model against PSTR consists of testing $H_0 : \theta_1 = 0$ versus $H_1 : \theta_1 \neq 0$. A generalization of the previous equation is proposed by González *et al*. (2005), then Colletaz and Hurlin (2006), who suppose the existence of *m* thresholds for each transition function. In this case, the model equation is:

$$g_{it} = \alpha_i + \theta_0 f_{i,t-1} + \theta_1 q_{it} f_{i,t-1} + \theta_2 q_{it}^2 f_{i,t-1} + \ldots + \theta_m q_{it}^m f_{i,t-1} + \delta z_{it} + \varepsilon_{it}^{*}. \tag{11}$$

The test consists as follows: $H_0 : \theta_1 = \ldots = \theta_m = 0$ versus $H_1 : \theta_i \neq 0$, $i = 1, \ldots, m$. Let us denote SSR_0, the panel sum of squared residuals under H_0, and SSR_1, the PSTR model with *m* regimes. The corresponding *F*-statistic is then defined by:

$$LM_F = \frac{(SSR_0 - SSR_1)/mK}{SSR_0/(TN - N - mk)} \sim F(mK, TN - N - mK), \tag{12}$$

where *T* is the number of years, *N* the number of countries, and *K* the number of

[4] For the analysis of the asymptotic behavior of PSTR estimator, refer to González *et al*. (2004, 2005) and Fok *et al*. (2005).

[5] See Gonzàlez *et al*. (2005) and Colletaz and Hurlin (2006), for more details.

exogenous variables. Once the linearity test is used, the problem is to identify the number of transition functions. The methodology of sequential tests is generally used. For instance, let us assume that we have rejected the linearity hypothesis. The issue is then to test whether there is one transition function $(H_0 : r = 1)$, or whether there are at least two transition functions $(H_1 : r = 2)$. Let us suppose a model with two transition functions $(r = 2)$:

$$g_{it} = \alpha_i + \beta_0 f_{i,t-1} + \beta_1 f_{i,t-1} \Gamma_1(q_{it};\gamma_1,c_1) + \beta_2 f_{i,t-1} \Gamma_2(q_{it};\gamma_2,c_2) + \delta z_{it} + \varepsilon_{it}^*, \tag{13}$$

$\Gamma_1(q_{it};\gamma_1,c_1)$ and $\Gamma_2(q_{it};\gamma_2,c_2)$ are two different transition functions. The logic of the test is the same and consists in replacing the second transition function by its first-order Taylor expression around $\gamma_2 = 0$, and then in testing linear constraints on the parameters. The model becomes:

$$g_{it} = \alpha_i + \beta_0 f_{i,t-1} + \beta_1 f_{i,t-1} \Gamma_1(q_{it};\gamma_1,c_1) + \theta_1 q_{it} f_{i,t-1} + \delta z_{it} + \varepsilon_{it}^*. \tag{14}$$

The test of no remaining non-linearity is simply defined by: $H_0 : \theta_1 = 0$. Let us denote SSR_0, the panel sum of squared residuals under H_0 (i.e., in a PSTR model with one transition function), and SSR_1, the sum of squared residuals of the transformed model (Eq. (14)). As in the previous case, the *F*-statistic LM_F can be calculated in the same way. Given a PSTR with r^* transition functions, we test the null hypothesis $H_0 : r = r^*$ against $H_1 : r = r^* + 1$. If H_0 is not rejected, the procedure ends. Otherwise, the null hypothesis $H_0 : r = r^* + 1$ is tested against $H_1 : r = r^* + 2$. The testing procedure continues until the first acceptance of H_0. Given the sequential aspect of this testing procedure, at each step of the procedure the significance level must be reduced by a constant factor τ, such as $0 < \tau < 1$, in order to avoid excessively large models. As suggested by González *et al.* (2005), we assume $\tau = 0.5$.

4. DATA AND PSTR RESULTS

Although some theoretical and empirical works prove that there are multiple equilibriums in the link between financial development and growth, the variables that determine these equilibriums remain to identify precisely. Previous literature states that financial development indicators or economic development variables affect the finance-growth link. In this paper, we suppose that the nonlinear relationship can depend on economic policy variables, such as the inflation rate (INFL), and the government expenditure as ratio to GDP (GOV), or structural variables like the degree of openness to trade (OPEN) and the financial development level. The financial development indicator used in this study is the Commercial-Central Bank ratio (BANK); it measures the degree to which commercial banks versus the central bank allocate society's savings. It equals the ratio of commercial bank assets divided by commercial banks plus central banks assets. The intuition underlying this measure is that banks are more likely to identify profitable investments, monitor managers, facilitate risk management, and mobilize savings than central banks. This variable presents the advantages available for several countries, over long a period. The present study covers the period from 1960 to 2004 and focuses on a sample of 71 countries both developed and developing.[6] Following the works of Levine *et al*. (2000) and Beck *et al*. (2000), we use a set of variables that controls for other factors associated with economic growth and for assessing the strength of an independent link between financial development and growth. We use the inflation rate and the ratio of government expenditure to GDP as indicators of macroeconomic stability, and the sum of exports and imports as a share of GDP to capture the degree of openness of an economy. Finally, the population growth rate (POP) allows us to appraise the impact of population dynamics on growth.

The results are presented in three sequences: first, non-linearity tests, then determination of the number of location parameters, and finally estimation outcomes and their analysis. Four models were estimated: models A, B, C and D use respectively inflation rate, government size, openness to trade and financial development indicators as the threshold variable. The table 1 presents the test of non-linearity results between the variable BANK and the economic growth.

The results of the non-linearity test reject the hypothesis of linearity for all transition variables. Table 1 shows the number of transition functions for each model. It would be interesting to notice that in most of the cases, the number of transition functions is lower or equal to two. This means that a weak number of transition functions are sufficient to assess the non-linearity between financial development and economic growth. However, some exceptional cases can be highlighted: for the transition variable (INFL), although it is possible to purge the non-linearity with three transition functions with one threshold each, it would be better to stop on two transitions, because using the third function

[6] The sample is the following: *18 low income countries* (Burkina Faso, Burundi, Ivory Coast, Ethiopia, Gambia, Ghana, Haiti, India, Kenya, Madagascar, Nepal, Niger, Nigeria, Pakistan, Rwanda, Senegal, Sierra Leone, Togo); *30 middle income countries* (South Africa, Argentina, Barbados, Bolivia, Chile, Colombia, Costa Rica, Egypt, El Salvador, Ecuador, Gabon, Guatemala, Honduras, Iran, Jamaica, Malaysia, Morocco, Mauritius, Panama, Dominican Republic, Paraguay, Peru, Philippines, Seychelles, Sri Lanka, Syria, Thailand, Trinidad and Tobago, Uruguay, Venezuela); *23 high income countries* (Australia, Austria, Belgium, Canada, Cyprus, Denmark, Finland, France, England, Greece, Iceland, Ireland, Israel, Italy, Japan, Norway, New Zealand, Netherlands, Portugal, Singapore, Sweden, Switzerland, USA). Our data are taken from the Penn World Table (PWT 6.2), and the financial database realized by Beck, Demirgüç-Kunt, and Levine (2005).

entails the degeneration of the first ones and the explosion of slope parameter. Moreover, the information criteria suggest that a model with two transition functions would be better than a model with three transition functions.

Table 1. LM_F Tests for Remaining Non-Linearity

Model	Model A		Model B		Model C		Model D	
q_{it}	INFL		GOV		OPEN		BANK	
N	m=1	m=2	m=1	m=2	m=1	m=2	m=1	m=2
H_0:r=0 vs H_1:r=1	15.92	9.282	46.41	23.74	7.301	3.614	5.018	0.927
	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.01]	[0.39]
H_0:r=1 vs H_1:r=2	11.12	0.336	0.099	0.160	0.013	0.020	1.476	-
	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.22]	
H_0:r=2 vs H_1:r=3	2.359	-	-	-	-	-	-	-
	[0.14]							

Notes: For each model, the testing procedure works as follows. First, the linear model (r=0) is tested against a model with one threshold (r=1). If the null hypothesis is rejected, the single threshold model is tested against a double threshold model (m=2). The procedure is continued until the hypothesis of no additional threshold is not rejected. The corresponding LM_F statistic has an asymptotic $F[mK, TN\text{-}N\text{-}(r+1)mK]$ distribution under H_0. m is the number of location parameters and K the number of explicative variables. The corresponding p-values are reported in brackets.

Once the non-linearity test is realized and the number of transition functions is identified, all that remains is to choose between a model with one threshold and a model with two thresholds, by transition function. The determination of the optimal number of thresholds in the transition function is presented in table 2.

To choose between a model with one threshold and a model with two thresholds, we present for each case the residual sum of squares and the criteria of information (AIC and Schwarz criteria). The choice of the "*optimal*" model is made according to Schwarz criterion in case of opposite results for the three statistics; most of the time the three criteria lead to the same result. The results reported on table 2 suggest that for the models B, C and D, one transition function with one threshold would be optimal ($m = 1$ and $r = 1$). For the model A, two transition functions with one threshold each is required ($m = 1$ and $r = 2$). Table 3 contains the parameters' estimates of the final PSTR models.

Table 2. Determination of the Number of Location Parameters

Model	Model A		Model B		Model C		Model D	
q_{it}	INFL		GOV		OPEN		BANK	
N	m=1	m=2	m=1	m=2	m=1	m=2	m=1	m=2
Opt. Number of Threshold	2	1	1	1	1	1	1	0
RSS	88202	88473	88135	88133	88287	88288	88289	-
AIC Criterion	3.345	3.349	3.344	3.344	3.345	3.346	3.346	-
Schwarz Criterion	3.361	3.369	3.357	3.360	3.359	3.362	3.362	-
Obs.	3053	3053	3053	3053	3053	3053	3053	3053

Notes: For each model, the optimal number of locations parameters used in the transitions functions can be determined as follows. For each value of m, the corresponding optimal number of thresholds, denoted $r(m^*)$, is determined according to a sequential procedure based on the LM_F statistics of the hypothesis of non remaining non-linearity. Thus for each couple (m,r^*), the value of AIC, and Schwarz criteria, and the RSS of the model are reported.

The results highlight the influence of the four transition variables on finance-growth relationship. Remember that, the coefficient β_j cannot be directly interpreted as the finance-growth coefficient. Indeed, as in the logit or probit models, the value of the estimated parameters is not directly interpretable, but rather their sign. So, a negative sign (a positive sign respectively) of the parameter β_1 means that an increase of the transition variable involves a decrease (increase respectively) of the finance-growth coefficient. However, for the models with more than one transition function $(r > 1)$, the situation is slightly complicated: given the case of two transition functions where β_1 is positive and β_2 is negative, an increase in threshold variable has two opposite effects on the finance-growth coefficient; the scale of these two opposite effects depends on the location and slope parameters. On the other hand, if β_1 and β_2 have the same sign, a variation of threshold variable leads to two effects on the same direction of finance-growth coefficient.

If we go back to our estimates' parameters, we can indeed notice that for all transition variables, the finance-growth coefficient β_1 is negative and significant. For the model that has two transition functions, the coefficient β_2 is also negative. Thus, we can conclude that an increase of the transition variables (GOV), (OPEN) and (BANK), entails a decrease of finance-growth coefficient; this means a reduction of the direct effect of financial development on economic growth. These results have different interpretations depending on the transitional variable. For instance, in countries with high level of government consumption ratio, there is eviction (because the most part of productive resources are devoted to government consumption rather than private investment), that reduces the impact of financial development on growth. On the other hand, in countries characterized by high openness to trade and strong financial system, economic growth is less sensitive to financial development, because a large part of domestic investment is financed with foreign capital. Although these findings are counter-intuitive, they highlight the change in finance and growth relationship between low income countries (with low financial development and openness ratio) and high income countries (high financial development and openness ratio).

Table 3. Parameter's Estimates for Final PSTR Models

	Model A	Model B	Model C	Model D
Threshold variable	INFL	GOV	OPEN	BANK
(m, r^*)	(1, 2)	(1, 1)	(1, 1)	(1, 1)
Parameter β_0	1.837***	2.194***	1.812***	2.169***
	(0.458)	(0.469)	(0.478)	(0.744)
Parameter β_1	-0.122**	-1.182***	-0.596***	-0.161
	(0.062)	(0.164)	(0.211)	(0.157)
Parameter β_2	-0.168*	-	-	-
	(0.096)			
Location parameter c_j				
1st trans. function	9.494	2.723	4.042	4.211
2nd trans. function	24.028	-	-	-
Γ	[411.26 202.74]	2.989	2.153	10.524
Coefficients of control variables				
POP	-0.138	-0.163	-0.158	-0.154
	(0.122)	(0.122)	(0.122)	(0.122)
INFL	-3.700***	-3.747***	-3.571***	-3.601***
	(0.942)	(0.943)	(0.941)	(0.944)
GOV	-2.740***	-2.704***	-2.708***	-2.728***
	(0.407)	(0.416)	(0.407)	(0.407)
OPEN	-0.935**	-0.915**	-0.897***	-0.972***
	(0.375)	(0.375)	(0.398)	(0.375)

Notes: The standard errors in parentheses are corrected for heteroskedasticity. The values in brackets are the standard deviations. ***, **, * indicate the statistical significance and the rejection of null hypothesis at 1%, 5% and 10%.

Contrary to the previous cases, an increase of the transition variable (INFL) produces two negative effects on finance-growth coefficient. This suggests that an economic environment characterized by high inflation is not hospitable for a favorable impact of financial development policy on economic growth.

Globally, an increase in used transition variables, involves a negative impact of financial development on economic growth.

In regards to the slope of the transition functions, remember that when the slope parameter tends towards the infinity, the PSTR tends towards PTR; i.e., the transition function, instead of being smooth, is rather rough between the various regimes of financial development and economic growth nexus. As reported in Table 3, the framework of PSTR (smooth transition function) is well adapted for the models B and C, because the slopes of transition functions are low (respectively 2.98 and 2.15). It means that conditionally to the variables (GOV) and (OPEN), the relationship between finance and growth cannot be reduced to a limited number of regimes. On the other hand, for the model A (inflation rate as threshold variable), the transition is rather rough and the PTR framework is indicated to assess finance-growth nexus. As far as model D is concerned, the transition is not rough but lightly smooth, suggesting the use of PSTR specification.

The relative importance of the various threshold variables on the finance-growth relationship is underlined on Figure 2. Indeed, for each model, we represent the evolution of the elasticity of growth regard to finance according to transition variable (see Fig 2-1 to Fig 2-4); this elasticity is calculated from the Eq. (8) for all models, except the model D, where the Eq. (9) is used. These various figures illustrate clearly the non-linearity which exists between financial development and economic growth following the used threshold variables.

Fig 2-1 reveals that for inflation levels lower than 10%, the elasticity is 1.84; otherwise it is around 1.72. As for the threshold variables of the government consumption and the openness to trade, the transitions are smooth (see Fig 2-2 and Fig 2-3); so, for a ratio of government expenditure to GDP lower than 5%, the elasticity is equal to 2.2. This elasticity decreases gradually from 2.2 to 1 when this ratio ranges from 5% to 55%. Likewise, we notice for the openness to trade ratio that the elasticity falls slowly from 1.8 to 1.2. The weak relationship between financial development and economic growth in countries characterized by high level of openness to trade variable is proved by the reduction of the banking sector power and the preponderance of foreign and market financing, in countries with developed banking sector.

These findings suggest, contrary to previous studies, that either economic development variables or financial development indicators can affect the nonlinear relationship between financial development and economic growth.

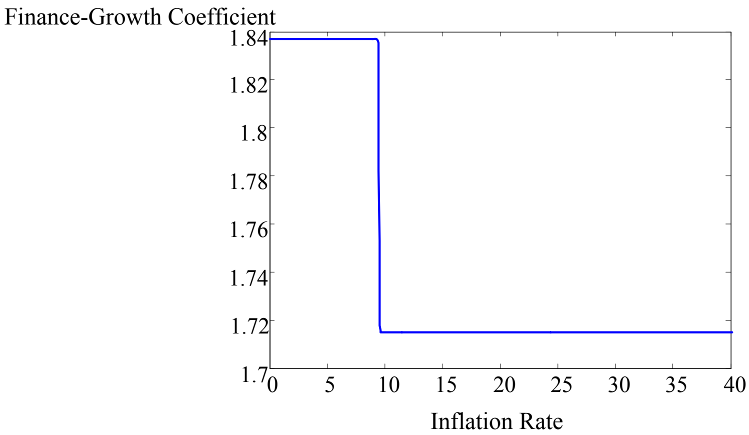


Fig 2-1. Model A

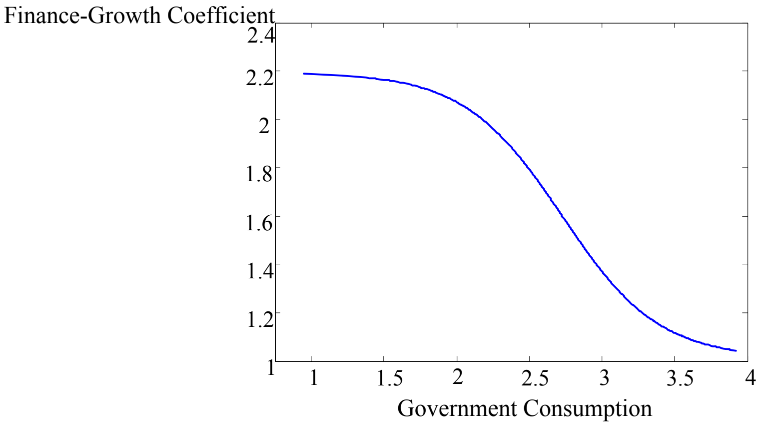


Fig 2-2. Model B

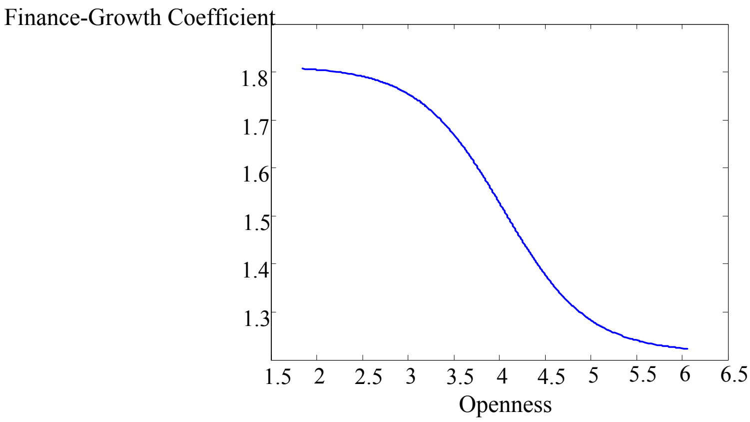


Fig 2-3. Model C

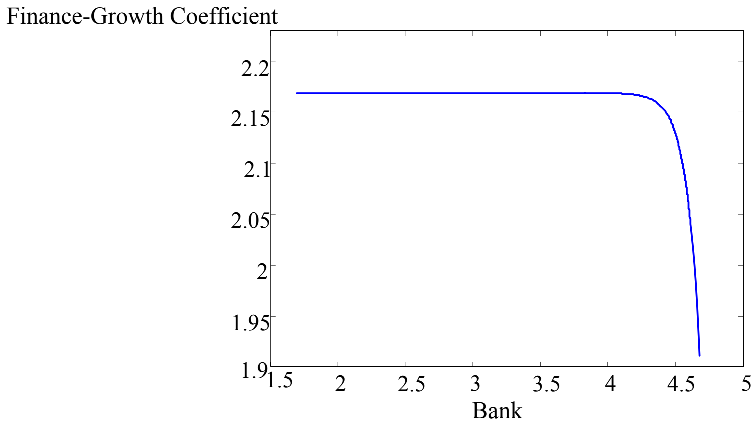


Fig 2-4. Model D

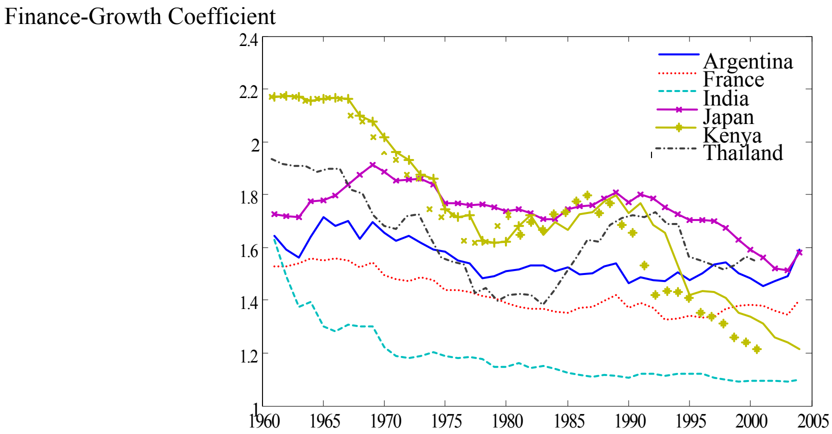


Fig 2-5. Estimated Finance-Growth Individual Coefficients for Selected Countries (Model B)

Figure 2. Estimated Finance-Growth Coefficients of PSTR Models

Finally, the evolution of the finance-growth coefficient related to model B (ratio of government expenditure as threshold variable),[7] is presented on the Fig 2-5. As we can indeed notice, finance-growth coefficients vary in time and according to country. This

[7] It would be interesting to point out that the evolution of the elasticity in the time can be represented for each model for all countries. The choice of the model and the countries here is random and attempts to represent of the general trend of data.

coefficient remains relatively more stable in developed countries than in developing countries.

5. CONCLUSION

In this paper, we put forward an empirical evaluation of the influence of various threshold variables on the financial development and growth nexus. This assessment is based on a Panel Smooth Threshold Regression specification, and investigated the non-linearity between financial development and growth. Our main results can be summed up as follows: first, we found that the relationship between financial development and economic growth is nonlinear. This non-linearity is robust to several specifications using different threshold variables. Indeed, inflation rate, ratio of government expenditure, degree of openness to trade, and financial development greatly influence the finance-growth coefficient. Moreover, the ratio of government expenditure and degree of openness to trade allow a *continuum* of regimes between financial development and economic growth. We conclude that the nonlinearity between finance and growth can be bound by economic development variables as well as financial development indicators. This study can be extended through the use of more varied financial development indicators.

REFERENCES

Aghion, P., P. Howitt, and D. Mayer-Foulkes (2005), "The Effect of Financial Development on Convergence: Theory and Evidence," *The Quarterly Journal of Economics*, 120(1), 173-222.

Berthelemy, J-C., and A. Varoudakis (1995), "Clubs de Convergence et Croissance. Le Rôle du Développement Financier et du Capital Humain, " *Revue Economique*, 46(2), 217-235.

_____ (1998), "Développement Financier, Réformes Financières et Croissance. Une Approche en Données de Panel," *Revue Economique*, 49(1), 195-206.

_____ (1996), "Economic Growth, Convergence Clubs and the Role of Financial Development," *Oxford Economic Papers*, 48, 70-84.

Colletaz, G., and C. Hurlin (2006), "Threshold Effects of the Public Capital Productivity: An International Panel Smooth Transition Approach," Working Paper, 1/2006, LEO, Université d'Orléans.

Chan, K., and H. Tong (1986), "On Estimating Thresholds in Autoregressive Models," *Journal of Time Series Analysis*, 7, 178-190.

Deidda, L. (2006), "Interaction between Economic and Financial Development,"

Journal of Monetary Economics, 53, 233-248.
Deidda, L., and B. Fattouh (2002), "Non-linearity between Finance and Growth," *Economics Letters*, 74, 339-345.
_____ (2008), "Banks, Financial Markets and Growth," *Journal of Financial Intermediation*, 17, 6-36.
Eggoh, J. (2009), "Développement Financier et Croissance Economique: Eléments d'Analyse Théorique et Empirique," University of Orleans, 412.
Favara, G. (2003), "An Empirical Reassessment of the Relationship between Finance and Growth," IMF Working Paper, 03/123, European I Department.
Fok, D., D. van Dijk, and P. Franses (2004), "A Multi-Level Panel STAR Model for US Manufacturing Sectors," Working Paper, University of Rotterdam.
Fouquau, J., C. Hurlin, and I. Rabaud (2008), "The Feldstein-Horioka Puzzle: A Panel Smooth Transition Regression Approach," *Economic Modelling*, 25, 284-299.
Gaytan, A., and R. Ranciere (2004), "Wealth, Financial Intermediation and Growth," Available at SSRN: http://ssrn.com/abstract=860925.
Gonzàlez, A., T. Terasvirta, and D. van Dijk (2005), "Panel Smooth Transition Regression Models, Series in Economics and Finance," Working Paper, 604, Stockholm School of Economics, Government Finance Statistics.
Granger, C., and T. Terasvirta (1993), *Modelling Nonlinear Economic Relationships*, Oxford University Press.
Hansen, B. (1999), "Threshold Effects in Non-Dynamic Panels: Estimation, Testing, and Inference," *Journal of Econometrics*, 93, 345-368.
Ketteni, E., T. Mamuneas, A. Savvides, and T. Stengos (2007), "Is the Financial Development and Economic Growth Relationship Nonlinear?" *Economics Bulletin*, 15(14), 1-12.
Khan, M., and S. Senhadji (2000), "Threshold Effects in the Relationship between Inflation and Growth," IMF Working Paper, 00/110.
_____ (2003), "Financial Development and Economic Growth: A Review and a New Evidence," *Journal of African Economies*, 12, AERC, Supplement 2, ii89-ii110.
Minea, A., and P. Villieu (2008), "Un réexamen de la relation non-linéaire entre déficits budgétaires et croissance économique," *Revue Economique*, 59(3), 561-570.
Rioja, F., and N. Valev (2004), "Finance and the Sources of Growth at Various Stages of Economic Development," *Economic Inquiry*, 42, 127-140.
Rousseau, P., and P. Wachtel (2002), "Inflation Thresholds and the Finance-Growth Nexus," *Journal of International Money and Finance*, 21, 777-793.
Stengos, T., and Z. Liang (2004), *Financial Intermediation and Economic Growth: A Semiparametric Approach*, in S.B. Heidelberg ed., New Trends in Macroeconomics, 39-52.

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