INFLATION AND FINANCIAL DEPTH

MOHSIN S. KHAN
International Monetary Fund

ABDELHAK S. SENHADJI
International Monetary Fund

BRUCE D. SMITH
University of Texas at Austin

There is now a substantial theoretical literature arguing that inflation impedes financial deepening. Furthermore, it has been hypothesized that the relationship is a nonlinear one, in that there is a threshold level of inflation below which inflation has a positive effect on financial depth, but above which the effect turns negative. Using a large cross-country sample, empirical support is found for the existence of such a threshold. The estimates indicate that the threshold level of inflation is generally about 3–6 percent per annum, depending on the specific measure of financial depth that is utilized.

Keywords: Inflation, Financial Depth

1. INTRODUCTION

Although there are well-understood mechanisms by which permanent and perfectly understood changes in the rate of inflation can have real effects, most conventional thinking holds that these effects cannot plausibly be regarded as empirically very important.[1] Nonetheless, there is an expanding body of evidence showing that long-run changes in the rate of inflation do have real effects, and that these effects are not trivial. Barro (1995), for instance, finds that permanent increases in the rate of inflation have significant negative effects on long-run real growth rates. Furthermore, more recent evidence suggests that the consequences of a permanent change in the rate of inflation are much more complicated than Barro's results alone would indicate. Bullard and Keating (1995), using VAR analysis, find that the effects of a permanent increase in the rate of money growth depend on the initial rate of money creation. Permanent increases in the rate of money growth in economies that have initially low rates of money creation appear to increase the long-run level of real activity. But permanent increases in the rate of money growth in economies with initially high rates of money growth have detrimental consequences for long-run real activity.

165

Going beyond the results of Bullard and Keating, there is now substantial work indicating that the empirical relationship between inflation and real activity is characterized by nonlinearities and by the existence of thresholds. Using panel data, Fischer (1993) noted the existence of a positive relationship between long-run growth and inflation at low rates of inflation, and a negative one as inflation rose. Following Fischer (1993), there have been a number of formal empirical attempts to identify threshold effects in the inflation-growth relationship. These include, for example, papers by Sarel (1996), Ghosh and Phillips (1998), Bruno and Easterly (1998), and Khan and Senhadji (2001). These studies generally find that for economies with initially low rates of inflation, modest increases in the rate of inflation have little effect on long-run rates of real growth. But for economies with initially high rates of inflation, further increases in the inflation rate have adverse effects on real growth. In the most recent study of this issue, Khan and Senhadji (2001) find that the threshold rate of inflation is fairly low—around 1–3 percent for industrial countries, and 7–11 percent for developing countries. These results certainly have considerable significance for the conduct of economic policy. Basically, they suggest that governments should adopt a low positive inflation rate policy.

The empirical evidence, particularly that based on time-averaged data, seems to suggest that even permanent and predictable changes in the rate of inflation have real effects.[2] And the nature of these effects depends on how high the rate of inflation is. These observations then raise two obvious questions. First, what accounts for the apparently significant real effects of higher long-run rates of inflation? Second, why do the effects of higher rates of inflation change as the rate of inflation increases?

In this paper, we pursue the idea that the real effects of inflation derive from the consequences of inflation for financial market conditions. There are good reasons to think so. First, there is now both empirical and theoretical literature suggesting that financial markets play an important role in the growth process.[3] Thus, if changes in the rate of inflation do affect activity in financial markets, it is likely that such changes also would have implications for long-run real activity. Second, there also is both theoretical and empirical literature suggesting that increases in the rate of inflation can adversely affect financial market conditions. Moreover, this literature explains why the effects of increases in the rate of inflation might be very different at initially low versus initially high rates of inflation.

Although, as discussed earlier, there has been considerable theoretical analysis of the inflation and financial depth link, empirical evidence is remarkably scarce. Indeed, the only related empirical study is by Boyd, Levine, and Smith (2001), who examine time-averaged data on bank credit extension to the private sector, the volume of bank liabilities outstanding, stock market capitalization and trading volume (all as ratios to GDP), and inflation for a cross-country sample. The empirical model they specify relates the various measures of financial depth to inflation and a set of control variables. The authors find that, increases in the annual rate of inflation above 15 percent lead to markedly lower volumes of bank lending to the private sector, lower levels of bank liabilities outstanding, and significantly

reduced levels of stock market capitalization and trading volume. They also find that a given percentage point increase in the rate of inflation has a much larger effect on financial development at low than at high rates of inflation. In addition, they obtain similar results using nonoverlapping panels of data averaged over five-year intervals.

However, Boyd, Levine, and Smith do not explicitly test for the presence of threshold effects in the inflation-financial depth relationship. Nor do their results easily permit a comparison with the empirical findings on the links between long-run inflation and long-run growth. The purpose of this paper is to test for this nonlinear relationship between inflation and financial depth for a large cross-country sample utilizing new econometric methods for threshold estimation and inference developed recently by Chan and Tsay (1998) and Hansen (1999, 2000).

We start by reviewing briefly the theoretical literature on the relationship between inflation, financial depth, and growth. The remainder of the paper is then devoted to exploring the empirical plausibility of the inflation-financial market link as an explanation of the relationship between inflation and real activity. In order to explore this link, we consider several measures of financial market activity. These include bank lending to the private sector, measures that aggregate both bank lending and stock market activity, and measures that aggregate bank lending, stock markets, and bond markets.

With respect to all of these measures, we find that there are significant threshold effects in the relationship between inflation and financial market performance. For rates of inflation below the threshold, modest increases in the rate of inflation either have no significant effect on financial market conditions, or have small positive effects on the level of financial activity. The latter finding is consistent with two other results: that increases in financial depth have positive long-run real effects, and that—at low initial rates of inflation—modest increases in the rate of inflation can have positive real effects. However, for rates of inflation above the threshold level, further increases in the rate of inflation have strongly negative effects on financial development. Given what is known about the relationship between financial markets and growth, it is then not surprising that sufficiently high rates of inflation are detrimental to growth. Finally, we find that the thresholds in the inflation-financial depth relationship range from 3 to 6 percent. Such thresholds are quite consistent with existing estimates of thresholds in the inflation-growth relationship. Thus, the relationship between inflation and financial markets appears to provide an empirically plausible explanation of the observed relationship between inflation and real growth.

2. INFLATION AND FINANCIAL DEPTH: SOME THEORETICAL CONSIDERATIONS

As we have said, there is now considerable evidence that inflation—even secular and, presumably, predictable inflation—has adverse effects on an economy's long-run level of real activity. But why should changes in the inflationary environment

that have come to be reflected in agents' expectations have any long-run real effects whatsoever? The purpose of this section is to review some theoretical answers that have been proposed to this question.

It is empirically well established that there are very strong correlations between various measures of an economy's financial depth and its long-run real activity, as reflected in either its long-run rate of growth or its level of production. This is true both for measures of banking activity, and for measures of stock market development. King and Levine (1993a,b) and Beck, Levine, and Loayza (2000), for example, demonstrate that measures of both bank lending to the private sector, and measures of bank liabilities outstanding, are strongly positively correlated with an economy's level of real production, and with its real rate of growth. Indeed, King and Levine (1993a,b) find that measures of banking activity are the only "robustly significant" predictors of future growth performance. Similarly, Levine and Zervos (1998) show that measures of stock market development are strongly associated with both higher levels of real activity and higher real growth rates. Although the direction of causation is difficult to establish, Beck, Levine, and Loayza (2000) purport to find evidence that causality runs from financial development to real development. Finally, Khan and Senhadji (2000), in the most recent study of this subject, find that the effect of financial development on growth is positive, although the size of the effect varies with different measures of financial development, estimation method, data frequency, and the functional form of the relationship.

In addition, there are a number of well-understood theoretical mechanisms by which financial development promotes growth. The earliest contributions (Greenwood and Jovanovic, 1990; Bencivenga and Smith, 1991) show how information acquisition by the financial system promotes the efficient allocation of investment capital, and how bank liquidity provision can alter the social composition of savings in a way that promotes both physical and human capital accumulation. Subsequent contributions (Huybens and Smith, 1999) demonstrate that secondary capital (equity) markets also should be expected to contribute to the growth process. As Hicks (1969) argued earlier, technological developments alone are inadequate to promote growth. Agents are willing to tie up resources in new technologies requiring large-scale investments only if capital markets exist that make these investments sufficiently liquid.

If inflation affects the development of the financial system, it will almost necessarily have long-run real effects. Here we briefly review some theoretical mechanisms demonstrating how even permanent and predictable changes in the rate of inflation affect the financial system and, through this channel, long-run real activity. Moreover, as we have shown, there is now considerable evidence that there are thresholds in the empirical relationship between inflation and real growth. The effects of an increase in the rate of inflation are potentially quite different depending on whether the rate of inflation is above or below some threshold level. The theories deliver the prediction that there are thresholds—possibly more than one—in the theoretical relationship between inflation and financial activity and, therefore, in the relationship between inflation and real activity.

The common theme in all of the theoretical literature is that financial market institutions arise to address endogenous frictions that are present in the process of allocating credit and investment capital. Indeed, such frictions seem essential in understanding the role of financial institutions in development: in the absence of such frictions the Modigliani-Miller Theorem would obtain, and the nature of finance would be irrelevant for allocations. Moreover, the severity of financial market frictions is itself endogenous in the models we describe. Inflation matters because it affects the severity of these frictions.

Among the frictions examined in the literature, *adverse selection* or *moral hazard* problems in credit markets have received the most attention.[4] In this literature, the transmission mechanism from inflation to financial depth works as follows: increases in inflation lower long-run real rates of return on a broad class of assets (through the inflation tax on nominal balances and the imposition of the nonarbitrage condition, which yields equalization of risk-adjusted rates of return), which leads to more severe rationing of credit, reductions in financial depth.[5]

In these models, threshold effects arise because at low enough rates of inflation the credit market operates in a totally Walrasian way with a Mundell-Tobin effect. If the initial rate of inflation is sufficiently low, and real rates of return are sufficiently high, an increase in the rate of inflation causes agents to substitute away from cash and into investments in physical or human capital. As a result, long-run growth or real activity is stimulated.

However, if the rate of inflation is increased excessively, real returns will be driven down to the point where credit market frictions become binding. Once the rate of inflation exceeds this threshold level, further increases in inflation will lead to credit rationing, and have negative consequences on the financial system and growth. Thus, there is a critical rate of inflation. Below this threshold rate, modest increases in inflation can stimulate real activity and promote financial depth. Above this threshold rate, increases in the rate of inflation interfere with the efficient allocation of investment capital, and consequently have negative growth consequences.

3. DATA ISSUES

The dataset utilized in this paper includes 168 countries (comprising both industrial and developing countries) and generally covers the period 1960–1999. Data for a number of developing countries, however, have a shorter span. Because of the uneven coverage, the analysis is conducted using unbalanced panels. The data come primarily from a new financial development dataset developed by Beck, Demirguc-Kunt, and Levine (1999) and the *International Financial Statistics* of the International Monetary Fund. Financial depth is measured by several alternative indicators: (i) fd_1: defined as domestic credit to the private sector as a share of GDP; (ii) fd_2: defined as fd_1 plus stock market capitalization as a share of GDP; and (iii) fd_3: defined as fd_2 plus private and public bond market capitalization as a share of GDP. By definition, fd_3 is the most exhaustive indicator of financial

depth, but is only available for advanced countries and for a shorter time span (starting 1975). By contrast, fd_1 is widely available, but is a more limited proxy for financial depth.

The set of explanatory variables includes: inflation computed as the growth rate of the CPI index (π_{it}), GDP per capita measured in 1987 PPP prices (*pppgdp*), the degree of openness (*open*) defined as exports plus imports over GDP, and the share of public consumption in GDP (c_g). We include a measure of real activity to control for the fact that the level of economic development influences financial depth. Similarly, openness in goods trade may be related to openness to trade in financial services, thereby influencing the level of financial depth. And, finally, high levels of government expenditure (a variable more widely available than the government budget deficit) may affect the incentives of the government to "repress" the financial system.[6] It, therefore, also represents an appropriate right-hand side variable in the regressions.

Figure 1 plots the indicators fd_1, fd_2, and fd_3 against inflation. The data have been smoothed out by reducing the full sample to ten observations. The latter are the arithmetic means of ten equal subsamples corresponding to increasing levels of inflation. The relationship between inflation and all three indicators of financial depth are remarkably similar. There is in each case a very small region over which financial depth increases with inflation. Financial depth then declines as inflation rises and then flattens out strongly suggesting a nonlinear relationship between inflation and financial depth.

Further insights can be gathered by analyzing Figure 2 which gives the scatter plot of the three indicators of financial depth against inflation. Because very high inflation observations distort the scale of the graph and mask the most relevant range of the graph (most observations are below 100 percent), inflation rates above 100 percent have been excluded. All three plots show a clear relationship between inflation and financial depth. Furthermore, the relationship is clearly convex rather than linear (or piece-wise linear).

4. MODEL SPECIFICATION AND ESTIMATION

To test for the existence of a threshold effect, we utilized the empirical model utilized by Boyd, Levine, and Smith (2001), which can be written as follows:

$$fd_{it} = \gamma_1\big(1 - d_{it}^{\pi^*}\big)(1/\pi_{it} - 1/\pi^*) + \gamma_2 d_{it}^{\pi^*}(1/\pi_{it} - 1/\pi^*) + \theta'X_{it} + e_{it} \tag{1}$$

$$d_{it}^{\pi^*} = \begin{cases} 1 & if \ \pi_{it} > \pi^* \\ 0 & if \ \pi_{it} \le \pi^* \end{cases} \quad i = 1, \ldots, N; \quad t = 1, \ldots, T,$$

where fd_{it} is one of the indicators of financial depth, π_{it} is inflation based on the CPI index, π^* is the threshold level of inflation, $d_{it}^{\pi^*}$ is a dummy variable that takes a value of one for inflation levels greater than π^* percent and zero otherwise, X_{it} is a vector of control variables that includes the log of *pppgdp*, *open*, c_g, a time trend (*trend*) that captures a potential time trend in the financial development variable
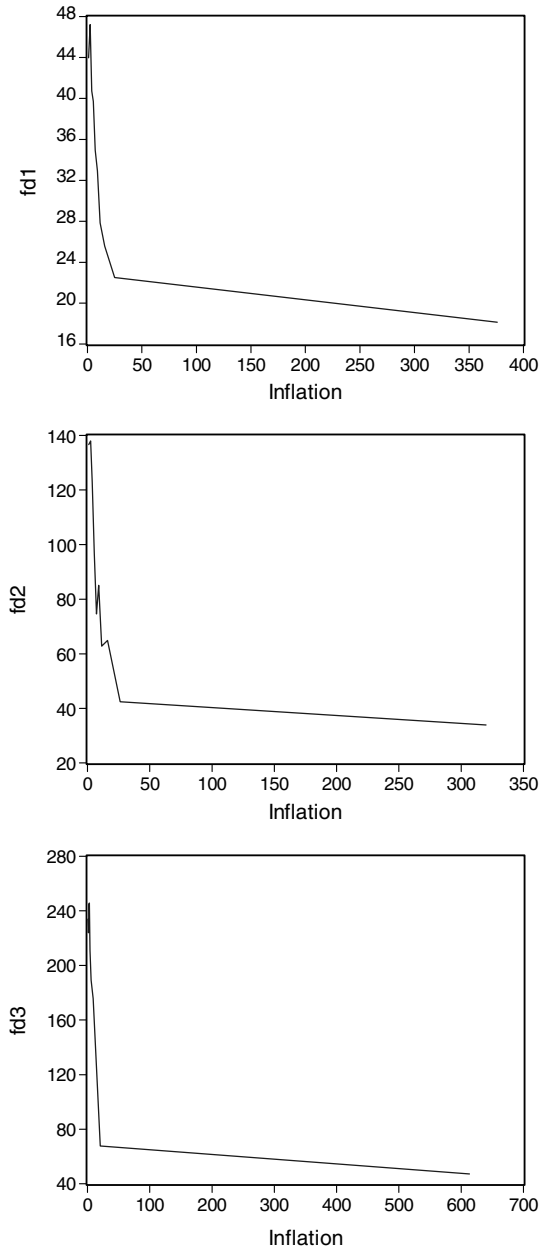
FIGURE 1. Averaged relationship between inflation and financial depth. *Note*: The relationship between three indicators of financial depth (fd_1, fd_2, and fd_3) and inflation. The data have been smoothed out by reducing the full sample to ten observations. The latter are the arithmetic means of five equal subsamples corresponding to increasing levels of inflation.
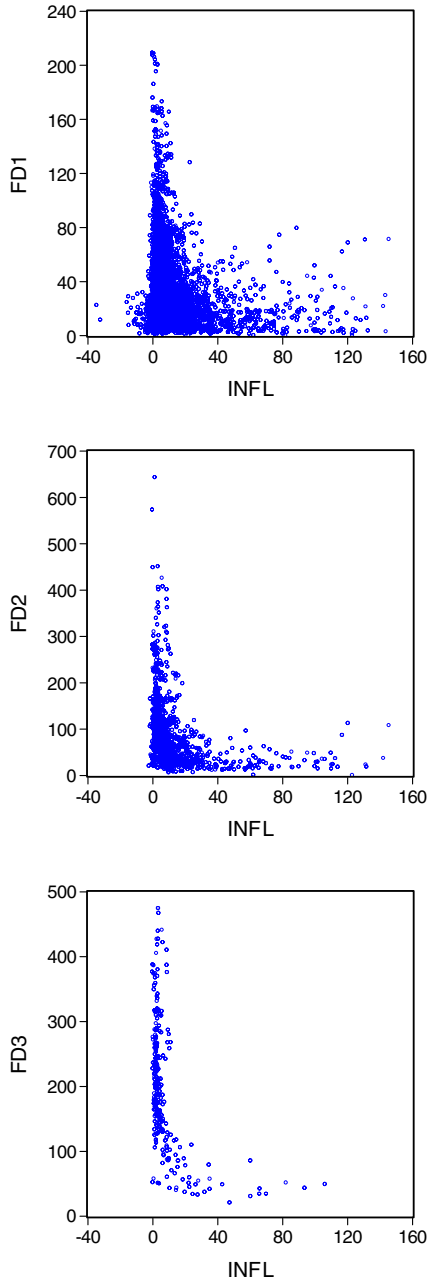
FIGURE 2. Scatter plot of inflation and financial depth. *Note*: The three panels show the scatter plot of financial depth indicators (*fd*₁, *fd*₂, *fd*₃) against inflation (*infl*) for annual inflation rates below 100 percent.

that is not adequately captured by the explanatory variables, and three regional dummies—a dummy for Latin American countries (d_la), a dummy variable for Asian countries (d_as), and a dummy variable for advanced countries (d_adv)—which capture cross-regional variations in financial depth that are not captured by the explanatory variables.[7] The subtraction of $1/\pi^*$ from $1/\pi_{it}$ in equation (1) makes the relationship between financial depth and inflation continuous at the threshold level π^*.[8] The first term in equation (1) gives the effect of inflation for inflation rates below or equal to the threshold. Similarly, the second term measures the effect of inflation on financial development for inflation rates above the threshold level.[9]

Note that inflation enters in its inverse form in order to capture the convex relationship between financial depth and inflation as highlighted by Figure 2.[10] As mentioned in the previous section, different measures of financial depth will be used as the dependent variable in equation (1). In order to keep the equation as parsimonious as possible, X_{it} contains only a few explanatory variables as income per capita (which is included in the equation) is a good proxy for a variety of other variables that may explain the level of development of the financial sector.

4.1. Estimation Method

If the threshold were known, the model could be estimated by ordinary least squares (OLS). Because π^* is unknown, it should be estimated along with the other regression parameters. The appropriate estimation method in this case is nonlinear least squares (NLLS). Furthermore, since the regression is nonlinear and nondifferentiable in π^*, conventional gradient search techniques to implement NLLS are inappropriate. Instead, estimation has been carried out with a method called *conditional least squares*, which can be described as follows. For any π^*, the model is estimated by OLS, yielding the sum of squared residuals as a function of π^*. The least squares estimate of π^* is found by selecting the value of π^*, which minimizes the sum of squared residuals. Stacking the observation in vectors yields the following compact notation for equation (1):

$$FD = Z\beta_\pi + e, \quad \pi = \underline{\pi}, \ldots, \bar{\pi}, \tag{2}$$

where FD is the vector of observations on fd_i, $\beta_\pi = (\gamma_1 \gamma_2 \theta')'$ is the vector of parameters and Z is the corresponding matrix of observations on the explanatory variables. The coefficient vector β is indexed by π to show its dependence on the threshold level of inflation, the range of which is given by $\underline{\pi}$ and $\bar{\pi}$. Define $S(\pi)$ as the residual sum of squares with the threshold level of inflation fixed at π. The threshold estimate level π^* is chosen so as to minimize $S(\pi)$ as follows:

$$\pi^* = \operatorname*{argmin}_{\pi}\{S(\pi), \pi = \underline{\pi}, \ldots, \bar{\pi}\}. \tag{3}$$

4.2. Inference

It is important to determine whether the threshold effect is statistically significant. In equation (1), to test for no threshold effects amounts simply to testing the null hypothesis $H_0: \gamma_1 = \gamma_2$. Under the null hypothesis, the threshold π^* is not identified, so classical tests, such as the *t test*, have nonstandard distributions. Hansen (1999) suggests a bootstrap method to simulate the empirical distribution of the following likelihood ratio test of H_0:

$$LR_0 = (S_0 - S_1)/\hat{\sigma}^2, \tag{4}$$

where S_0 and S_1 are the residual sum of squares under $H_0: \gamma_1 = \gamma_2$, and $H_1: \gamma_1 \neq \gamma_2$, respectively; and $\hat{\sigma}^2$ is the residual variance under H_1. In other words, S_0 and S_1 are the residual sum of squares for equation (1) without and with threshold effects, respectively. The asymptotic distribution of LR_0 is nonstandard and strictly dominates the χ^2 distribution. The distribution of LR_0 depends in general on the moments of the sample; thus critical values cannot be tabulated. Hansen (1999) shows how to bootstrap the distribution of LR_0 in the context of a panel.

An interesting question is whether an inflation threshold, for example, of 10 percent is significantly different from a threshold of 8 percent or 15 percent. In other words, can the concept of confidence intervals be generalized to threshold estimates? Chan and Tsay (1998) show that in the case of a continuous threshold model studied here, the asymptotic distribution of all parameters, including the threshold level, have a *normal* distribution.[11] More precisely, define $\Phi = (\gamma_1 \gamma_2 \theta', \pi^*)$ to be the set of all parameters, including the threshold level. Chan and Tsay (1998) show that the NLLS estimates $\hat{\Phi}$ of Φ (described earlier) are asymptotically normally distributed:

$$\hat{\Phi} \sim N(\Phi U^{-1} V U^{-1}), \tag{5}$$

where $U = E(H_{it} H'_{it})$, $V = E(e_{it}^2 H_{it} H'_{it})$, $H_{it} = [-\tilde{X}_{it}, \gamma_1(1 - d_{it}^{\pi^*}) + \gamma_2 d_{it}^{\pi^*}]$, $\tilde{X}_{it}$ is the vector of all right-hand side variables in equation (1), and NT is the total number of observations. The estimates of U and V are given by $\hat{U} = \sum_{i=1}^{N} \sum_{t=1}^{T} \hat{H}_{it} \hat{H}'_{it}/(NT)$ and $\hat{V} = \sum_{i=1}^{N} \sum_{t=1}^{T} \hat{e}_{it}^2 \hat{H}_{it} \hat{H}'_{it}/(NT)$, with $\hat{H}_{it} = [-\tilde{X}_{it}, \hat{\gamma}_1(1 - d_{it}^{\pi^*}) + \hat{\gamma}_2 d_{it}^{\pi^*}]$.[12]

5. ESTIMATION AND INFERENCE RESULTS

5.1. Test for the Existence of Threshold Effects

The first step is to test for the existence of a threshold effect in the relationship between inflation and financial depth using the likelihood ratio, LR_0, discussed earlier. This implies estimating equation (1) and computing the residual sum of squares (RSS) for threshold levels of inflation ranging from $\underline{\pi}$ to $\bar{\pi}$. The threshold estimate is the one that minimizes the sequence of RSSs. The test for the existence of threshold effects has been conducted using the three selected indicators of financial depth. The results are summarized in Table 1.

TABLE 1. Test results of threshold effects

Dependent variable	Search range for thresholds	Estimate threshold (%)	LR_0	Critical value (1%)	Significance level
fd_1	$\{1, 2, 3, \ldots, 100\}$	6	246.95	5.93	0.000
fd_2	$\{1, 2, 3, \ldots, 100\}$	3	50.20	14.49	0.000
fd_3	$\{1, 2, 3, \ldots, 100\}$	5	34.38	13.00	0.000

The first column gives the range over which the search for the threshold effect is conducted, which is 1 percent to 100 percent with increments of 1 percent. This yields 100 panel regressions of equation (1). Using fd_1 as an indicator of financial depth, the minimization of the vector of 100 RSSs occurs at the inflation level of 6 percent. Repeating the same procedure for fd_2, and fd_3 yields threshold estimates of 3 percent and 5 percent, respectively. The column LR_0 in Table 1 gives the observed value of the likelihood ratio. The significance levels have been computed using the bootstrap distributions (corresponding to the three indicators of financial depth) of LR_0.[13] The null hypothesis of no threshold effects can be rejected at least at the 1 percent significance level for all three indicators of financial depth. Thus, the data strongly support the existence of threshold effects.

5.2. Estimation Results

Table 2 provides the estimation results of equation (1) for the three indicators of financial depth. The effect of inflation on financial development for inflation rates below or equal to (above) the threshold level is given by the first (second) coefficient. All three equations show a similar effect of inflation on financial depth. For fd_1, the first coefficient estimate suggests that a small increase in the rate of inflation (while remaining below the threshold) leads to a very modest reduction in financial depth.[14] Note, however, that the negative coefficients on the first term for fd_2 and fd_3 imply that for countries with low initial inflation (that is, countries with inflation below the threshold level), a moderate increase in inflation (that is, an increase inflation that does not bring the country's annual inflation rate above the threshold level) does not impede and can even slightly stimulate financial depth. However, this effect of inflation on financial depth is generally statistically insignificant. This is consistent with empirical findings of Bullard and Keating (1995) and Khan and Senhadji (2001) that show a similar relationship between inflation and growth. This is also consistent with recent theoretical work outlined in Section 2.

The coefficients on the second terms in the fd_1, fd_2, and fd_3 relationships are all large, positive, and highly statistically significant. Thus inflation has powerful negative effects on all measures of financial depth for rates of inflation above the threshold.

Having established the existence of a threshold for all three indicators of financial depth, the next important question is to see how precise these estimates

TABLE 2. NLLS estimates

Independent variables	Dependent variable		
	fd_1	fd_2	fd_3
$(1 - d^{\pi^*}) * (1/\pi - 1/\pi^*)$	0.03162	−2.1535	−2.8273
	(0.16)	(−0.38)	(−0.51)
$d^{\pi^*} * (1/\pi - 1/\pi^*)$	104.702	132.850	611.427
	(11.73)a	(4.80)a	(4.45)a
$log(pppgdp)$	9.2878	40.6773	43.3798
	(18.95)a	(10.88)a	(2.44)a
$open$	0.02995	0.36272	0.31164
	(3.04)a	(6.76)a	(3.17)a
c_g	−0.2908	−2.3867	−3.2073
	(−4.57)a	(−7.27)a	(−2.37)b
d_la	4.0939	−29.9007	−35.2277
	(5.22)a	(−5.50)a	(−1.94)c
d_as	−0.41178	11.2613	20.21247
	(−0.47)	(2.66)a	(0.65)
d_adv	28.6858	−8.69598	3.9033
	(18.55)a	(−1.08)	(0.16)
$trend$	0.16904	−0.83316	0.71076
	(3.68)a	(−2.85)a	(0.34)
Threshold estimate (%)	6	3	5
	(543.02)a	(45.78)a	(202.59)a
NxT	3606	1094	256
Below Threshold	2427	321	143
R^2	0.52	0.47	0.54

Note: The panel covers the period 1960–1999 (T), for 168 countries (N). The dependent variable is an indicator of financial depth; fd_i, $i = 1, 2, 3$. The independent variables are inflation, π, the log of PPP GDP, $log(pppgdp)$, degree of openness, $open$; public consumption as a share of GDP, c_g; a dummy for Latin American countries, d_la, a dummy for Asian countries, d_as; a dummy for advanced countries, d_adv; and a time trend, $trend$. The dummy variable d^{π^*} takes one for inflation rates greater than the threshold estimate (π^*) and zero otherwise. The *t-statistics*, given between parentheses, are computed from White heteroskedasticity-consistent standard errors. The letters "a," "b," "c," indicate statistical significance at 1, 5, and 10 percent, respectively.

are. This requires the computation of the confidence interval around the threshold estimates. If the confidence intervals are wide, that would imply that there is substantial uncertainty about the threshold level. The 95 percent confidence interval includes inflation rates in the [5.98, 6.02] interval for fd_1, in the [2.87, 3.13] interval for fd_2, and in the [4.95, 5.05] interval for fd_3. These extremely tight confidence intervals suggest that the threshold estimates are very precise. Combining the information given by these three confidence regions, the threshold value of inflation can be narrowed down to the 3–6 percent range, which is quite precise considering that this range is based on three different indicators of financial depth.

The log of income per capita [*log(pppgdp)*], which measures the level of economic development of a country, and hence proxies for a wide range of variables related to economic and financial development of a country, enters all of the financial development relationships with a positive and highly significant coefficient. A doubling of income per capita will increase fd_3 by approximately 45 percent of GDP. The degree of openness (*open*) is also positively and significantly related to financial depth, corroborating the view that international trade in goods and services may spur the development of financial markets. The size of the government as measured by the share of government consumption in GDP (c_g) has a negative effect on financial development. This may be because governments with weak fiscal positions are tempted to engage in financial repression, as argued above. The three regional dummies (*d_la* for Latin America, *d_as* for Asia, and *d_adv* for advanced countries) show a significantly higher level of fd_1 for advanced economies and a significantly lower level of fd_2 and fd_3 for Latin America, even after controlling for the level of income per capita. The fit is quite good for models estimated with annual panel data.

Figure 3 illustrates the economic significance of the regression coefficients estimated in Table 2. For each measure of financial depth, the three panels show the effect of inflation on financial depth as inflation increases from 1 percent to 100 percent. All three indicators of financial depth yield a similar pattern for the effect of inflation on financial depth. Below the threshold, an increase in inflation has a small positive but statistically insignificant effect on financial depth (except for fd_1, which shows a small negative but statistically insignificant effect). Above the threshold, increasing inflation significantly hampers financial depth. And, it bears emphasizing that the adverse effects of inflation for the financial system are particularly strong for economies with modest rates of inflation (but ones that exceed the threshold).

5.3. Correcting for the Potential Endogeneity of Inflation[15]

The NLLS estimates of equation (1) may be biased because of the potential endogeneity of inflation. Therefore, equation (1) was reestimated using NLLS with instrumental variables for all potential endogenous variables, including inflation, PPP GDP, and the degree of openness. The list of instruments for inflation includes its first two lags, the first two lags of real GDP growth, and a time trend. For PPP GDP and openness, the instruments are their respective first two lags and a time trend.[16]

Table 3 reports the estimation results which are very close to the NLLS results without instrumental variables in Table 2. The threshold estimates for fd_1, fd_2, and fd_3 are 4 percent (versus 6 percent), 4 percent (versus 3 percent), and 7 percent (versus 5 percent), respectively. The confidence intervals for fd_1, fd_2, and fd_3 are [3.89, 4.11], [3.88, 4.12], and [6.94, 7.06], respectively. The only significant differences between NLLS with and without instrumental variables is the weakening of the effect of inflation on financial depth,[17] and the change in sign,
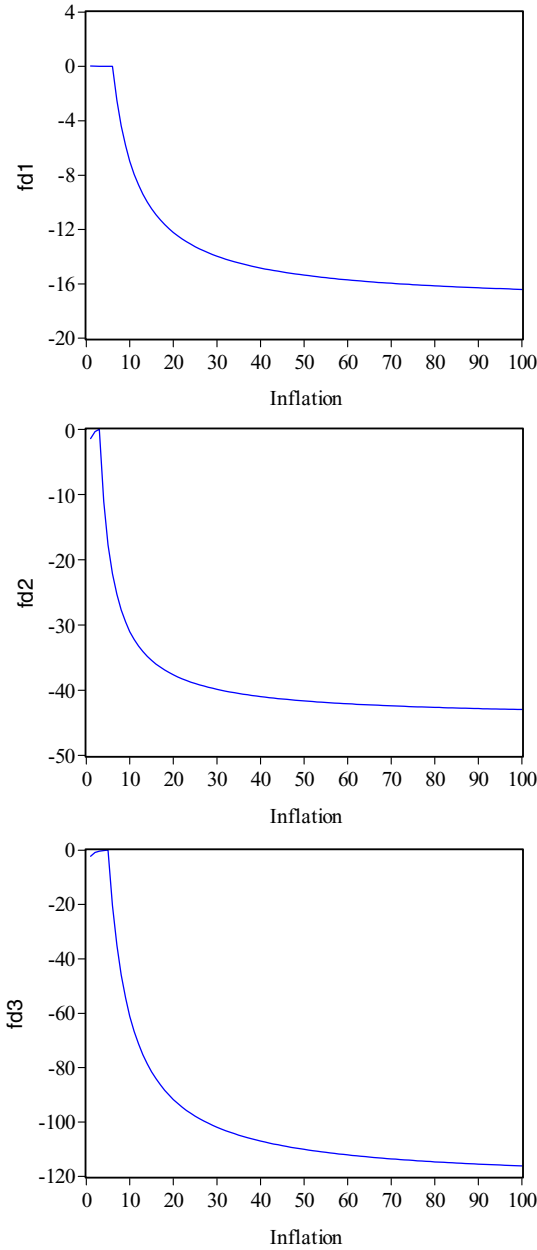
FIGURE 3. Effect of inflation on financial depth. *Note*: This graph shows the effect of inflation on financial depth (for inflation rates from 1 to 100 percent) using the coefficient estimates given in Table 2. Both inflation and financial depth are expressed in percentage terms.

TABLE 3. NLLS estimates: instrumental variables

Independent variables	Dependent variable		
	fd_1	fd_2	fd_3
$(1 - d^{\pi^*}) * (1/\pi - 1/\pi^*)$	−0.00857	0.16146	0.17187
	(−0.04)	(0.03)	(0.03)
$d^{\pi^*} * (1/\pi - 1/\pi^*)$	22.4736	105.1931	694.017
	(3.92)a	(4.18)a	(3.20)a
$log(pppgdp)$	9.98988	45.6835	65.6259
	(19.54)a	(11.13)a	(3.02)a
$open$	0.04659	0.37634	0.30520
	(4.07)a	(7.02)a	(3.08)a
c_g	−0.32839	−2.3624	−2.3372
	(−4.24)a	(−7.51)a	(−2.14)b
d_la	2.22496	−36.9432	−49.7570
	(4.28)a	(−5.69)a	(−1.89)c
d_as	0.39001	13.0106	15.6443
	(0.86)	(2.60)a	(0.27)
d_adv	29.1170	−15.6133	−27.0580
	(19.86)a	(−1.00)	(−0.01)
$trend$	0.15245	−0.54792	2.4975
	(3.05)a	(−1.85)c	(1.10)
Threshold estimate (%)	4	4	7
	(70.39)a	(68.44)a	(242.37)a
NxT	3606	1094	256
Below Threshold	2427	321	143
R^2	0.52	0.47	0.54

Note: The panel covers the period 1960–1999 (T), for 168 countries (N). The dependent variable is an indicator of financial depth; fd_i, $i = 1, 2, 3$. The independent variables are inflation, π, the log of PPP GDP, log($pppgdp$); degree of openness, $open$; public consumption as a share of GDP, c_g; a dummy for Latin American countries, d_la; a dummy for Asian countries, d_as; a dummy for advanced countries, d_adv; and a time trend, $trend$. Instrumental variables were used for the first three variables. The dummy variable d^{π^*} takes one for inflation rates greater than the threshold estimate (π^*) and zero otherwise. The *t-statistics*, given between parentheses, are computed from White heteroskedasticity-consistent standard errors. The letters "a," "b," "c," indicate statistical significance at 1, 5, and 10 percent, respectively.

although remaining statistically insignificant, on the first term when instrumental variables are used.

6. CONCLUSIONS

The recent empirical growth literature has consistently found a negative but nonlinear relationship between inflation and growth. The nonlinearity in the relationship arises from the existence of threshold effects, that is, there is a threshold level of inflation below which inflation has no significant effect on growth, but beyond which inflation significantly hampers growth. These findings do not accord well with standard macroeconomic models. However, recent theoretical models provide

some interesting insights about this relationship. The main mechanism of transmission can be through financial markets. In the presence of frictions (arising from, for example, adverse selection, moral hazard, or costly state verification), inflation impedes financial development (and thus growth) by affecting the severity of these frictions. In particular, higher inflation leads to increased credit rationing and less extension of bank credit and therefore to lower investment and slower growth. These theoretical models further predict a nonlinear relationship between inflation and financial development, and thus between inflation and growth, that is similar to that uncovered in empirical work.

This paper finds that the relationship between inflation and financial depth is indeed nonlinear with threshold effects. The threshold level of inflation beyond which inflation significantly hinders growth is estimated to be in the 3–6 percent range. These estimates are quite precise and are robust with respect to the estimation method and to five alternative financial development indicators. The effect of inflation above the threshold is powerful. The combined effect on a broad financial development indicator fd_3, defined as the sum of domestic credit to the private sector, stock market capitalization, and bond market capitalization (private and public) over GDP, of moving from a 5 percent to a 20 percent annual inflation rate is around 90 percent of GDP.

Interestingly, the threshold estimates for the relationship between inflation and financial depth analyzed in this paper fall within the range of threshold estimates found in a recent paper where inflation is directly related to growth [see Khan and Senhadji (2001)]. These combined results provide strong support for the view that financial markets are an important channel through which inflation affects growth in a nonlinear fashion.

NOTES

1. For instance, the Mundell-Tobin effect provides a mechanism by which increases in the rate of inflation cause agents to shift their portfolio allocations away from holdings of real balances and into capital investments. This promotes long-run real activity. Alternatively, cash-in-advance models with variable labor supply (Cooley and Hansen, 1989), or with investment subject to a cash-in-advance constraint (Stockman, 1981), have the feature that inflation acts like a tax on labor supply, or investment, so that increases in inflation are detrimental to real activity. But it is commonly held that the effects generated via such mechanisms are relatively small.

2. Note, however, that it is difficult to disentangle the effects of the level of inflation from the effects of its variability, as they are highly correlated in the data. Indeed, for most samples, the correlation coefficient between the average rate of inflation and the standard deviation of inflation is quite high. This high correlation makes it virtually impossible to be sure whether it is the level of inflation, inflation variability, or some combination of the two that matters for growth performance.

3. See the recent surveys of this literature by Levine (1997) and Khan and Senhadji (2000).

4. See, for example, Azariadis and Smith (1996), and Paal and Smith (2000).

5. Khan, Senhadji, and Smith (2001) show that these theoretical predictions also can be derived using alternative frictions such as *costly state verification* frictions in credit markets.

6. See McKinnon (1973), Shaw (1973), and Bencivenga and Smith (1992).

7. Because the estimation method requires a large sample, individual equations for these (and other) group of countries cannot be estimated precisely.

8. Continuity of the relationship given in equation (1) is desirable, otherwise small changes in the inflation rate around the threshold level will yield different impacts on financial depth depending on whether inflation is increasing or decreasing.

9. Theoretically, the relationship between financial depth and inflation may be characterized by multiple thresholds. However, as it is very difficult to estimate multiple thresholds, equation (1) only considers the single-threshold case.

10. There is a discontinuity at an inflation rate of zero in equation (1). However, the observations included in the sample are mostly positive with very few negative inflation rates. There are ways of circumventing this problem. For example, one may postulate a logistic relationship (which is continuous everywhere) between financial depth and inflation in which case inflation would enter as $1/[1 + \exp(-\pi)]$. Because both specifications yield results that are very close and because zero inflation is a rare phenomenon, the simpler functional form was retained.

11. Hansen (2000) derives the asymptotic distribution for the discontinuous threshold model.

12. An alternative, and perhaps more accurate, method of computing the standard errors of the coefficients and threshold estimates is by a bootstrap method. However, this method is computationally more costly. Furthermore, the sample size used here is large enough for the asymptotic distribution to yield a reasonably accurate approximation.

13. For a more detailed discussion on the computation of the bootstrap distribution of LR_0, see Hansen (1999).

14. Recall that inflation enters the specification in inverse form.

15. As it is well known, the problem of simultaneity bias is a tricky one and very difficult to resolve using econometrics alone. This section should be interpreted in light of Section 2 highlighting theoretical arguments supporting the specification in equation (1) and the direction of causality it implies.

16. Data availability restricted our choice of instruments, and thus no experimentation with alternative instruments was undertaken.

17. This is reflected in a decline in the coefficient on the second term for fd_1 and fd_2.

REFERENCES

Azariadis, Costas and Bruce D. Smith (1996) Private information, money, and growth: indeterminacy, fluctuations, and the Mundell–Tobin effect. *Journal of Economic Growth* 1, 309–332.

Barro, Robert J. (1995) Inflation and economic growth. *Bank of England Quarterly Bulletin*, 166–176.

Beck, Thorsten, Asli Demirguc-Kunt, and Ross Levine (1999) A New Database on Financial Development and Structure. New York: Cambridge University Press.

Beck, Thorsten, Ross Levine, and Norman Loayza (2000) Financial intermediation and growth: causality and causes. *Journal of Monetary Economics* 46, 31–77.

Bencivenga, Valerie R. and Bruce D. Smith (1991) Financial Intermediation and Endogenous Growth. *Review of Economic Studies* 58, 195–209.

Bencivenga, Valerie R. and Bruce D. Smith (1992) Deficits, inflation and the banking system in developing countries: the optimal degree of financial repression. *Oxford Economic Papers* 44, 767–790.

Boyd, John H., Ross Levine, and Bruce D. Smith (2001) The impact of inflation on financial sector performance. *Journal of Monetary Economics* 47, 221–248.

Bruno, Michael and William Easterly (1998) Inflation crises and long-run growth. *Journal of Monetary Economics* 41, 3–26.

Bullard, James and John Keating (1995) The long-run relationship between inflation and output in postwar economies. *Journal of Monetary Economics* 36, 477–496.

Chan, Kung-Sig and Ruey S. Tsay (1998) Limiting properties of the least squares estimator of a continuous threshold autoregressive model. *Biometrica* 85(2), 413–426.

Cooley, Thomas F. and Gary D. Hansen (1989) The inflation tax in a real business cycle model. *American Economic Review* 79, 733–748.

Fischer, Stanley (1993) The role of macroeconomic factors in growth. *Journal of Monetary Economics* 32, 485–512.

Ghosh, Atish and Steven Phillips (1998) Warning: inflation may be harmful to your growth. *IMF Staff Papers* 45(4), 672–710.

Greenwood, Jeremy and Boyan Jovanovic (1990) Financial development, growth, and the distribution of income. *Journal of Political Economy* 98, 1076–1107.

Hansen, Bruce (1999) Threshold effects in non-dynamic panels: estimation, testing, and inference. *Journal of Econometrics* 93(2), 345–368.

Hansen, Bruce (2000) Sample splitting and threshold estimation. *Econometrica* 68(3), 575–605.

Hicks, John (1969) *A Theory of Economic History*. Oxford: Clarendon Press.

Huybens, Elisabeth and Bruce D. Smith (1999) Inflation, financial markets, and long-run real activity. *Journal of Monetary Economics* 43, 283–315.

Khan, Mohsin S. and Abdelhak Senhadji (2000) Financial Development and Economic Growth. IMF working paper WP/00/209.

Khan, Mohsin S. and Abdelhak Senhadji (2001) Threshold effects in the relationship between inflation and growth. *IMF Staff Papers* 48(1), 1–21.

Khan, Mohsin S. Abdelhak Senhadji, and Bruce Smith (2001) Inflation and Financial Depth. IMF working paper WP/01/44.

King, Robert G. and Ross Levine (1993a) Finance and growth: schumpeter might be right. *Quarterly Journal of Economics* 108, 717–738.

King, Robert G. and Ross Levine (1993b) Finance, entrepreneurship, and growth: theory and evidence. *Journal of Monetary Economics* 32, 513–542.

Levine, Ross (1997) Financial development and economic growth: views and agenda. *Journal of Economic Literature* 35(2), 688–726.

Levine, Ross and Sara Zervos (1998) Stock markets, banks, and economic growth. *American Economic Review* 88, 537–558.

McKinnon, Ronald I. (1973) *Money and Capital in Economic Development*. Washington DC: Brookings Institution.

Paal, Beatrix and Bruce D. Smith (2000) The Sub-Optimality of the Friedman Rule, and the Optimum Quantity of Money. Mimeograph.

Sarel, Michael (1996) Nonlinear effects of inflation on economic growth. *IMF Staff Papers* 43, 199–215.

Shaw, Edward S. (1973) *Financial Deepening in Economic Development*. New York: Oxford University Press.

Stockman, Alan (1981) Anticipated inflation and the capital stock in a cash-in-advance economy. *Journal of Monetary Economics* 8, 387–393.