WP/01/44

IMF Working Paper

Inflation and Financial Depth

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INTERNATIONAL MONETARY FUND

 WP/01/44

IMF Working Paper

IMF Institute

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April 2001

Abstract

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 between 3 and 6 percent a year, depending on the specific measure of financial depth that is used.

JEL Classification Numbers: G2, G1, E31

Keywords: Inflation, Financial Depth

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I. INTRODUCTION

Conventional thinking in macroeconomics holds that permanent and predictable changes in the rate of inflation are neutral: they do not affect long-run real activity or real rates of return.[2] While 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.[3]

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. For example, Bullard and Keating (1995) find that the effects of a permanent increase in the rate of money growth depend on the initial rate of money creation. 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.

Going beyond the results of Bullard and Keating, there is now substantial work indicating that the empirical relationship between inflation and real activity, even in the long-run, is characterized by nonlinearities and by the existence of thresholds. Fischer (1993), for example, 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. For instance, Khan and Senhadji (2000a) find that for economies with initially low rates of inflation, modest increases in the rate of inflation are associated with higher 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. Furthermore, Khan and Senhadji find that the threshold rate of inflation is fairly low—around 1-3 percent for industrial countries, and 11-12 percent for developing countries. These results certainly have considerable significance for the conduct of economic policy. For instance, they suggest that great importance should be attached to the maintenance of long-run price stability.

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[2] Lucas (1980) refers to this as the empirically and theoretically best established proposition in macroeconomics.

[3] 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.

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.[4] And, the nature of these effects depends upon 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.[5] Thus, if changes in the rate of inflation do affect activity in financial markets, it is likely that such changes would also have implications for long-run real activity. Second, there is also 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. 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 long-run real performance. 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 look at several measures of financial market activity. These include bank lending to the private sector, measures of stock market capitalization and trading volume, 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 have positive real effects. However, for rates of inflation above the threshold level, further increases in the rate

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[4] 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.

[5] See the recent surveys of this literature by Levine (1997) and Khan and Senhadji (2000b).

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 3-6 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 very plausible explanation of the observed relationship between inflation and real growth.

The remainder of the paper proceeds as follows. Section II reviews the theoretical literature—as well as some existing empirical literature—on the interconnections between inflation, finance, and growth, Section III discusses data issues, Section IV describes the model specification and estimation method, Section V presents the estimation results, and Section VI concludes.

II. Inflation and Financial Depth: Some Theoretical Considerations

As we have argued, 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 Loyaza (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. While the direction of causation is difficult to establish, Beck, Levine, and Loyaza (2000) purport to find evidence that causality runs from financial development to real development. Finally, Khan and Senhadji (2000b), 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,

1998) demonstrate that secondary capital (equity) markets should also be expected to contribute to the growth process. As Hicks (1969) earlier argued, technological developments alone are inadequate to promote growth. Agents are willing to tie up resources in new technologies requiring large scale investments only if the 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. In this section we elaborate on 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 we review here 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 we will review 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.

A. Adverse Selection or Moral Hazard Problems in Credit Markets[6]

Consider an economy in which agents are heterogeneous. At each date some agents ("natural lenders") have funds available to invest, but lack projects in which these funds can be invested in a socially efficient way. Other agents ("natural borrowers") have access to projects that efficiently convert current resources into future capital, but lack the funds to operate these investments. The fundamental role of the financial system is to channel funds from natural lenders to natural borrowers.

Now suppose that the financial system must operate subject to an informational asymmetry, so that it is not freely and costlessly observable who is a natural lender and who is a natural borrower. In particular, imagine that each agent knows his own type (lender or borrower), but that this type is private information.[7] Then the efficient operation of the financial system implies that natural lenders must be given an incentive to lend, and natural borrowers must be

[6] This section is based on material in Azariadis and Smith (1996), Boyd, Choi, and Smith (1997), and Paal and Smith (2000).

[7] Note that we are formally describing an adverse selection problem in credit markets. See Gertler and Rogoff (1990) or Paal and Smith (2000) for settings with moral hazard problems in credit markets that deliver similar results.

given an incentive to borrow. Under certain circumstances, it will be necessary to ration credit in order to achieve this self-selection. In particular, intermediaries must limit the amount that any agent can borrow because, if they did not, natural lenders would be tempted to misrepresent their type, obtain borrowed funds, misallocate them, and default on loans with high probability. Doing so, of course, would undermine the efficient operation of the financial system.

What happens to the severity of the credit rationing required to induce borrowers and lenders to self-select as real rates of return fall in an economy? Clearly as real rates of return on savings fall, the incentive to borrow is increased, and the incentive to lend is reduced. Thus, lower real rates of return will exacerbate the severity of the adverse selection problem in this economy, and therefore will necessitate more widespread rationing of credit. As credit rationing becomes more severe, banks will lend less and fund less investment in physical and/or human capital. The consequence will be slower real rates of growth (in an endogenous growth model) and/or reduced long-run levels of real activity.

Suppose that higher rates of inflation are associated with lower long-run real rates of return on a broad class of assets. Then increases in inflation will be associated with more severe rationing of credit, reductions in financial depth, and lower levels of real activity. But why should higher rates of inflation reduce long-run real returns? The answer is that, in any economy, some agents hold real money balances either voluntarily or involuntarily. For instance, the banking system of virtually any economy holds a significant quantity of non-interest-bearing cash reserves. As is well-understood, higher rates of inflation act like a tax on real balances or bank reserves. And, if this tax is borne, at least in part, by bank depositors, higher inflation must lead to lower real returns on bank deposits. Since bank deposits compete with a variety of assets, it is plausible that reduced real returns on bank deposits will result in reduced real returns on a variety of assets. And, indeed, it is well-established that higher rates of inflation do *not* tend to be associated with higher *nominal* rates of return on equity.[8] Barnes, Boyd and Smith (1999) and Boyd, Levine, and Smith (2000) establish that this is, in fact, true for all but the highest inflation economies. Moreover, Barnes, Boyd, and Smith (1999) also show that higher rates of inflation are associated with lower real returns on short-term assets, government debt, and high grade bank loans.

Of course the mechanism just described explains why higher rates of inflation might reduce financial depth, with corresponding adverse consequences for growth. It does not yet explain why there might be threshold effects associated with the rate of inflation exceeding some critical level. In order to understand how threshold effects might arise, suppose that, if the rate of inflation is sufficiently low—and if real rates of return on savings are sufficiently high—the adverse selection problem in credit markets does not bind. Or, in other words, if real returns are high enough, credit rationing is not required to induce natural lenders to lend rather than borrow. If this transpires, then at low enough rates of inflation the credit market operates in a totally Walrasian way. Then, in a model that generates a Mundell-Tobin effect

[8] See, for instance, Nelson (1976), Fama and Schwert (1977), Gultekin (1983), Boudoukh and Richardson (1993), and Pennachi (1991).

in the absence of credit rationing, the following can occur. 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 and/or human capital. As a result, long-run growth and/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 the negative consequences described previously for the financial system and for real performance. Thus there is a critical rate of inflation. Below this rate modest increases in inflation can stimulate real activity and promote financial depth. Above this threshold increases in the rate of inflation interfere with the efficient allocation of investment capital, and consequently have negative growth consequences.

As Azariadis and Smith (1996) show, there may be an additional (that is, a second) inflation threshold in a model with adverse selection in credit markets. In particular, once the rate of inflation is high enough so that credit is rationed, rates of inflation that are sufficiently high will lead to perfect foresight dynamics that display endogenously arising volatility. This volatility will be manifested in all endogenous variables, including the rate of inflation. Thus models in this class suggest that economies exhibiting sufficiently high rates of inflation will also exhibit high inflation variability as well. Such a prediction is indeed in accordance with observation.

B. Costly State Verification Frictions in Credit Markets[9]

An alternative paradigm considers situations in which capital investment requires external finance, and in which external investors can observe the ex-post returns on the investments they have funded only by bearing some cost. This so-called costly state verification (CSV) friction, originally developed by Townsend (1979), has several implications. First, with risk neutral capital investors, the optimal method of providing external finance is for external investors to enter into debt contracts with the agents whose activities are being financed. Second, as pointed out by Diamond (1984) and Williamson (1986), it is often optimal for lending to be intermediated in the presence of a CSV problem. Third, as shown by Gale and Hellwig (1985) and Williamson (1986, 1987), the presence of a CSV problem can lead to credit being rationed. And fourth, as noted by Bernanke and Gertler (1989), in the presence of a CSV problem the composition of an agent's finances matters—the more internal finance any investor can provide, the less severe will be the CSV problem.

Boyd and Smith (1998) consider an otherwise standard monetary growth model in which some agents have access to capital investment projects and other agents do not. Agents who do have access to such projects combine their own income—thereby providing internal finance—with credit obtained externally in order to operate them. In addition, the provision of external finance is complicated by a CSV problem as just described. When credit rationing arises as a result of the CSV problem, Boyd and Smith show that the real rate of return received by external investors depends on two factors: the marginal product of capital (which

[9] This section is based on work by Boyd and Smith (1998) and Huybens and Smith (1999).

is a decreasing function of the aggregate capital-labor ratio) and the amount of internal finance provided by the operators of funded projects. This depends, in turn, on their income, which is an increasing function of the aggregate capital-labor ratio. Thus the expected rate of return received by agents who provide external funding for capital investments can be a non-monotonic function of the aggregate per capita capital stock. Moreover, loans to fund capital investments must compete with expected rates of return on other investments. Given a rate of return on other assets, loans to capital investors can earn a competitive return in either of two ways. One is that there can be a high marginal product of capital combined with a low level of internal finance (that is, the aggregate capital-labor ratio can be relatively low). The other is that there can be a low marginal product of capital combined with a high level of internal finance (that is, the aggregate capital-labor ratio can be relatively high).

The possibility that there is more than one capital-labor ratio consistent with a given rate of return on loans leads to the possibility that there is more than one steady-state equilibrium in an economy. For a given rate of return on alternative assets, there will typically be a steady-state equilibrium with a low per capita capital stock and a low long-run level of real activity, and there will be another steady state with a higher per capita capital stock and a higher long-run output level. Moreover, Boyd and Smith show that the low activity steady state can always be approached from some set of initial conditions. The high activity steady state, on the other hand, may be either stable or unstable. It will be stable if the steady-state rate of inflation is sufficiently low. On the other hand, it may become unstable if the steady-state rate of inflation is sufficiently high. When this occurs there is a critical or threshold rate of inflation: for long-run rates of inflation below the threshold, the high activity steady state can be approached. However, once the steady-state inflation rate exceeds the threshold level, there are no equilibrium paths that approach the high activity steady state.

For initially sub-critical rates of inflation—that is, for rates of inflation below this threshold level—Boyd and Smith show that sufficiently small increases in the rate of inflation will reduce the capital-labor ratio and per capita output at the high activity steady state. Intuitively, higher rates of inflation drive down long-run real returns. The result is that credit rationing becomes more severe, banks lend less, and less capital investment is financed. In addition, Boyd and Smith demonstrate that there may be a second inflation threshold. In particular, there may be rates of inflation that are low enough so that the high activity steady state is stable, but beyond which perfect foresight dynamics approaching that steady state display endogenous oscillation. Just as is the case with an adverse selection problem in credit markets, sufficiently high rates of inflation will lead to inflation variability, as we observe. Thus, the presence of credit market frictions can explain not only the long-run relationship between inflation and growth, but also the relationship between the level of inflation and degree of inflation variability.

So far our discussion has entirely focused on the role of banks in the inflation-finance-development nexus. Huybens and Smith (1999) examine a version of the Boyd-Smith model in which there is long-lived physical capital whose ownership is traded in a set of secondary capital (equity) markets. Their modification of the Boyd-Smith model shares many of the features described above. Most prominently, it has the property that increases in the rate of inflation (for rates of inflation such that the high activity steady state is stable) reduce not only the volume of bank lending activity, but the volume of trade in equity markets relative to GDP.[10] Therefore, increases in the rate of inflation have adverse implications not just for credit extension, but for the liquidity of secondary capital markets as well.

C. Some Empirical Evidence

Boyd, Levine, and Smith (2000) 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. They find that, at low-to-moderate rates of inflation, increases in the rate of inflation 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 the relationship between inflation and financial market development becomes "flatter" as inflation increases: that is, 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 non-overlapping 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. We now turn our attention to that task.

III. Data Issues

The dataset utilized in this paper includes 168 countries (comprising both industrial and developing countries) and generally covers the period 1960–99. 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, Demirgüç-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.

It is recognized that the effect of inflation on stock markets may differ from that on the banking sector, or on the bond market. Consequently, the effect of inflation on the stock market alone is also estimated. Two indicators of the level of development of the stock

[10] Formally speaking, their result requires that the elasticity of substitution between capital and labor in production be sufficiently high. Duffy and Papageorgiou (2000) show that the elasticities of substitution required by Huybens and Smith for higher rates of inflation to reduce the volume of equity market trading relative to GDP are empirically plausible.

market are used. The first one is the stock market capitalization as a share of GDP (*stockc*), and the second is the stock market trading volume as a share of GDP (*stockv*). Note that the former measures the size of the market, while the second is a measure of liquidity and efficiency of the market.

The set of control variables includes: inflation computed as the growth rate of the CPI index, GDP per capita measured in 1987 PPP prices, the degree of openness defined as exports plus imports over GDP, and the share of public consumption in GDP. 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.[11] 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 10 observations. The latter are the arithmetic means of 10 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. Since 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).

IV. Model Specification and Estimation

To test for the existence of a threshold effect, the following model was estimated:

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

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

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

[11] See McKinnon (1973), Shaw (1973), and Bencivenga and Smith (1992).

which includes the log of income per capita (log*(pppgdp)*), the degree of openness (*open*), the share of public consumption in GDP (c_g), a time trend (*trend*) and three regional dummies, a dummy for Latin American countries (*d_la*), a dummy variable for Asian countries (*d_sa*), and a dummy variable for advanced countries (*d_adv*).[12] 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^*.[13] 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.[14]

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.[15] As mentioned in the previous section, different measures of financial depth will be used as dependent variable in equation (1). In order to keep the equation as parsimonious as possible, X_{it} contains only a few explanatory variables since income per capita (which is included in the equation) is a good proxy for a variety of other variables which may explain the level of development of the financial sector.

A. Estimation Method

If the threshold were known, the model could be estimated by ordinary least squares (OLS). Since 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). Furtheremore, since the regression is nonlinear and non-differentiable 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^*.

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

[13] 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.

[14] 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.

[15] 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 $1/(1+\exp(-\pi))$. Since both specifications yield results that are very close and since zero inflation is a rare phenomenon, the simpler functional form was retained.

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):

$$FD = X\beta_{\pi} + e \quad . \ \pi = \underline{\pi},...,\overline{\pi} \tag{2}$$

where FD is the vector of observations on fd_i, $\beta_{\pi}=(\gamma_1\ \gamma_2\ \theta')'$ is the vector of parameters and X 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 $\overline{\pi}$. Define $S_1(\pi)$ 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 $S_1(\pi)$ as follows:

$$\pi^* = \underset{\pi}{\operatorname{argmin}}\{S_1(\pi), \pi = \underline{\pi},\ldots,\overline{\pi}\} \tag{3}$$

B. 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.[16] 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 above) are asymptotically normally distributed:

[16] Hansen (2000) derives the asymptotic distribution for the discontinuous threshold model.

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

where $U = E(H_{it}H'_{it})$, $V = E(e^2_{it}H_{it}H'_{it})$, $H_{it} = (-\widetilde{X}_{it}, \gamma_1(1-d_{it}^{\pi^*}) + \gamma_2 d_{it}^{\pi^*})$, $\widetilde{X}_{it}$ 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 $\hat{V} = \sum_{i=1}^{N}\sum_{t=1}^{T}\hat{e}^2_{it}\hat{H}_{it}\hat{H}'_{it}/(NT)$, with $\hat{H}_{it} = (-\widetilde{X}_{it}, \hat{\gamma}_1(1-d_{it}^{\pi^*}) + \hat{\gamma}_2 d_{it}^{\pi^*})$.[17]

V. Estimation and Inference Results

A. 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 above. This implies estimating equation (1) and computing the residual sum of squares (RSS) for threshold levels of inflation ranging from $\underline{\pi}$ to $\overline{\pi}$. 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.

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.[18] 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.

B. 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

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[17] 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.

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

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.[19] Note though 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. This is consistent with empirical findings of Bullard and Keating (1995) and Khan and Senhadji (2000a) that show a similar relationship between inflation and growth. This is also consistent with recent theoretical work surveyed in Section II. However, none of these coefficients is statistically significant.

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 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 4 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

[19] Recall that inflation enters the specification in inverse form.

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 emphasis 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).

C. Correcting for the Potential Endogeneity of Inflation

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.[20]

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,[21] and the change in sign, while remaining statistically insignificant, on the first term when instrumental variables are used.

D. The Stock Market

An interesting question is whether inflation affects the different components of financial depth in a similar fashion. This section examines the effect of inflation on two indicators of stock market development: stock market capitalization and stock market trading volume. The estimation results in Table 4 show that inflation impedes stock market trading volume. For stock market capitalization, the first coefficient suggests that modest increases in inflation (while remaining below the threshold) promote increased stock market development. However, this coefficient is not statistically significant. And, as before, we continue to find strong evidence of threshold effects. Moreover, for rates of inflation above the threshold level, further increases in inflation have the strong negative effects on financial development that we have seen previously. The estimated threshold is 1 percent for market capitalization, and 3 percent for trading volume. Both PPP GDP and openness have a significant positive effect on stock market development while the size of the public sector, as measured by public consumption, has a significant negative effect.

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

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

Consistent with the findings for fd_1, fd_2, and fd_3, the confidence intervals around the threshold estimate for market capitalization and market volume are quite tight ([0,2.35], and [2.77,3.23], respectively). Figure 6 quantifies the effect of inflation on stock market capitalization and on trading volume. While they are both important, the effect on market capitalization is larger.

VI. Conclusions

The recent empirical growth literature has consistently found a negative 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.

The first part of the paper reviews the theoretical work on the relationship between inflation and financial development. The second part of the paper is devoted to the estimation of the relationship between inflation and financial development using a large panel dataset, which includes both banking and security market indicators of financial depth, and applying recent econometric techniques for estimating and drawing inference in models with threshold effects.

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 (2000a)). 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.

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,…,100}	6	246.95	5.93	0.000
fd_2	{1, 2,3,…,100}	3	50.20	14.49	0.000
fd_3	{1, 2,3,…,100}	5	34.38	13.00	0.000

Table 2. NLLS

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

Note: The panel covers the period 1960-99 (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.

Table 3. NLLS with Instrumental Variables

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

Note: The panel covers the period 1960-99 (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*.

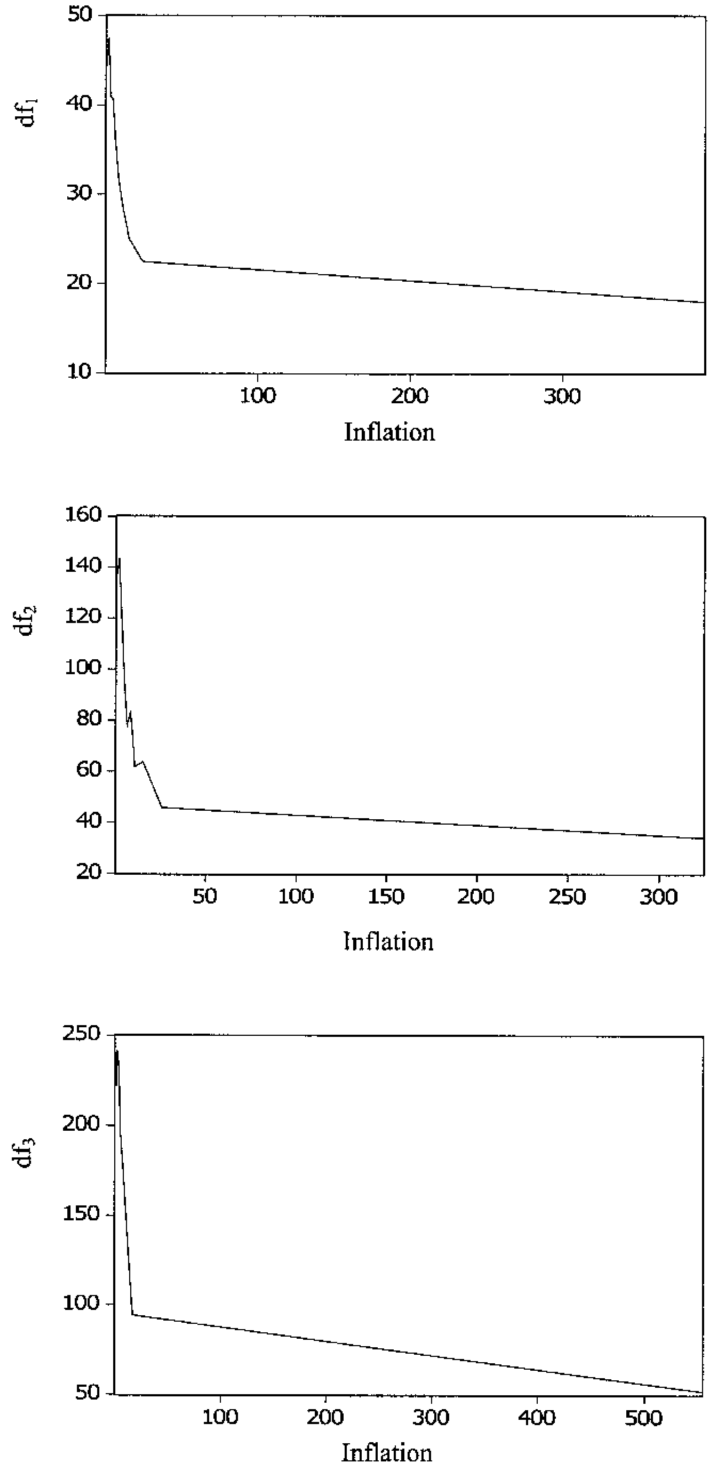
Instrumental variables were used for the first three variables. The dummy variable d^{π^*} takes one for inflation rates greater than the threshold estimate (π^*) and zero otherwise. The *t-statistics*, given between parentheses, are computed from White heteroskedasticity-consistent standard errors. The letters "a", "b", "c", indicate statistical significance at 1, 5, and 10 percent, respectively.

Table 4. Stock Market (NLLS)

Independent Variables	Dependent Variable: *Stock Market Capitalization*	Dependent Variable: *Stock Market Trading Volume*
$(1-d^{\pi^*})*(1/\pi-1/\pi^*)$	-2.1423 (-0.45)	1.8079 (2.14)b
$d^{\pi^*}*(1/\pi-1/\pi^*)$	18.0735 (1.90)c	34.0898 (2.72)a
log(pppgdp)	24.4713 (9.41)a	10.0450 (8.10)a
open	0.34370 (9.25)a	0.06020 (3.21)a
c_g	-1.3236 (-7.56)a	-0.85700 (-6.84)a
d_la	-20.5052 (-5.73)a	-9.7021 (-6.71)a
d_as	16.3673 (6.01)a	2.0886 (1.47)
d_adv	-18.6554 (-3.27)a	-5.5045 (-2.03)b
trend	-0.31490 (-1.59)	0.19260 (1.90)c
Threshold estimate (%)	1 (1.48)	3 (25.92)a
NxT	1120	1210
R^2	0.39	0.26

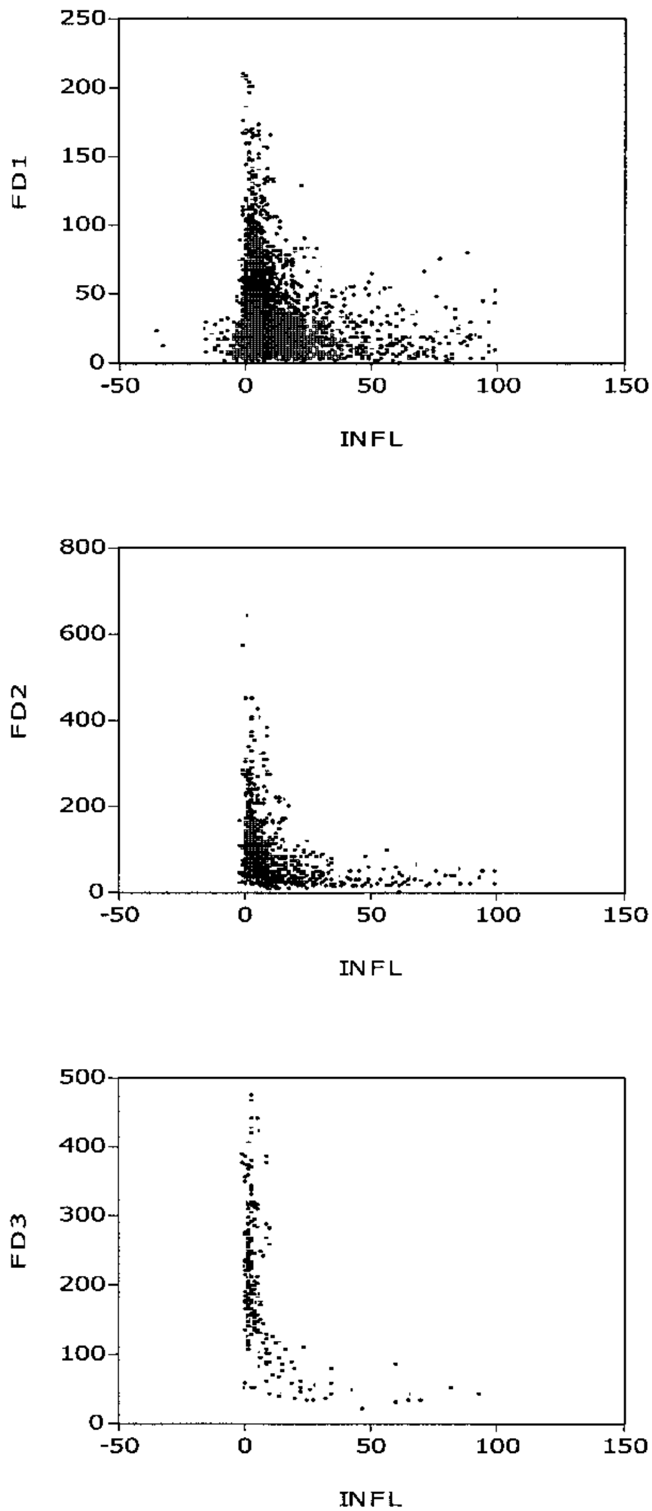
Note: The panel covers the period 1960-99 (T), for 168 countries (N). The dependent variable is an indicator of financial depth; fd_i, $i=1,2,3$. The independent variables are inflation, π; the log of PPP GDP, log*(pppgdp)*; degree of openness, *open*; public consumption as a share of GDP, c_g; a dummy 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.

Figure 1. Averaged Relationship Between Inflation and Financial Depth



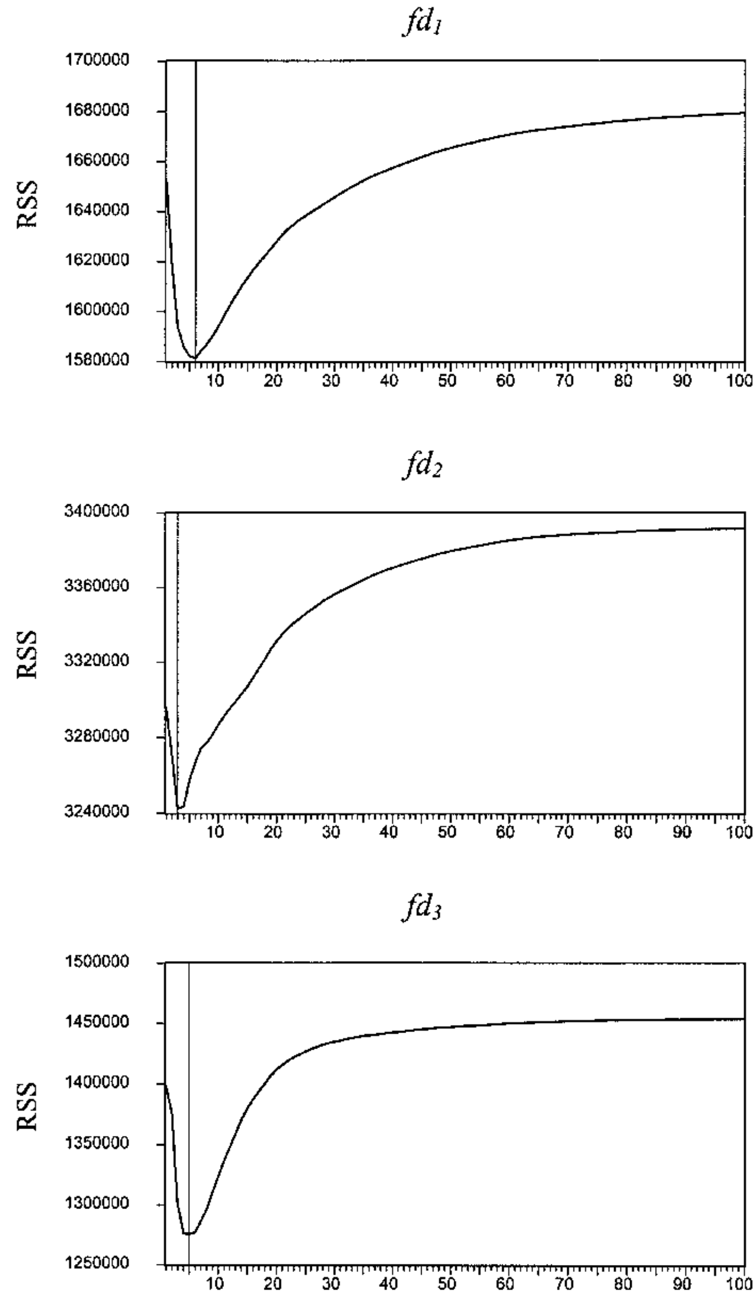
Note: Figure 1 shows the relationship between three indicators of financial depth (fd_1, fd_2, *and* fd_3) and inflation. The data have been smoothed out by reducing the full sample to 10 observations. The latter are the arithmetic means of five equal subsamples corresponding to increasing levels of inflation.

Figure 2. Scatter Plot of Inflation and Financial Depth



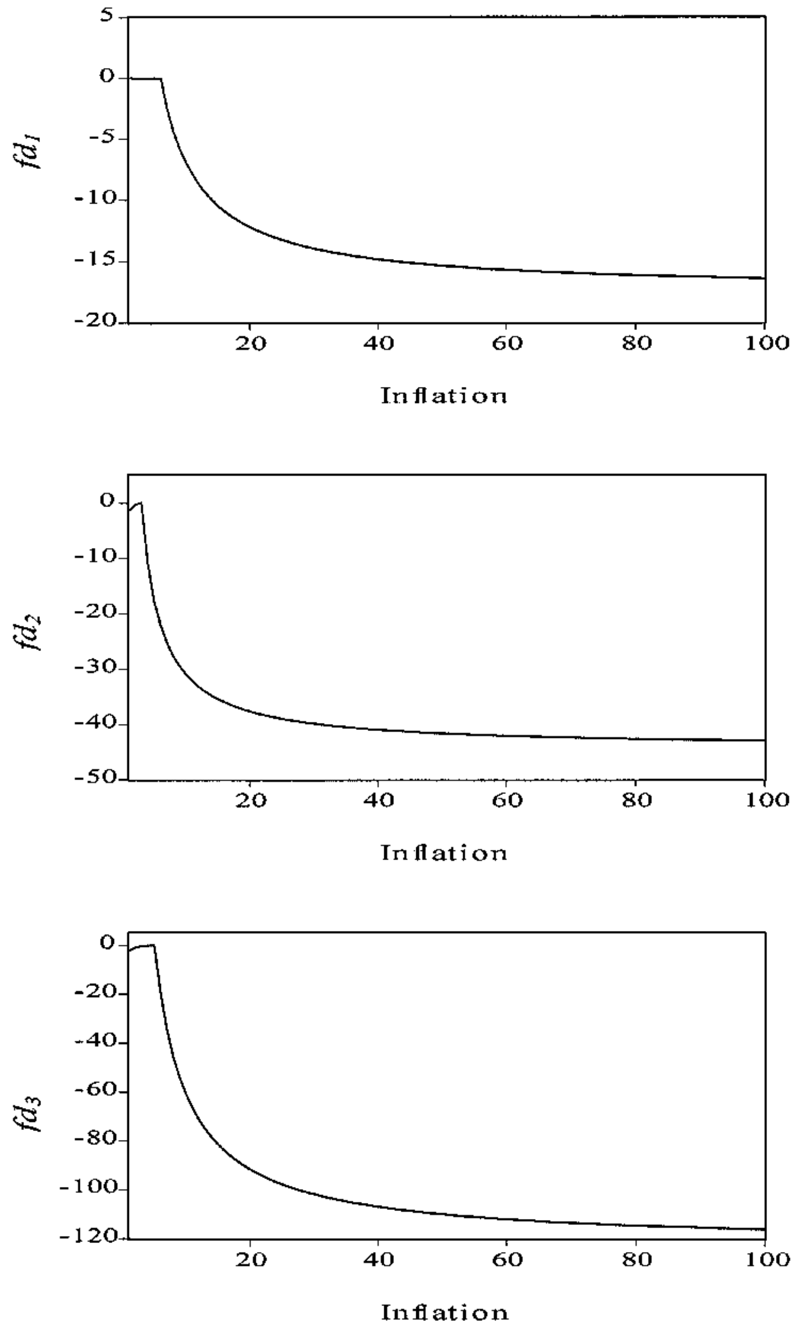
Note: The three panels show the scatter plot of financial depth indicators (fd_1, fd_2, fd_3) against inflation (*infl*) for annual inflation rates below 100 percent.

Figure 3. Residual Sum of Squares as a Function of the Threshold Level



Note: Figure 3 shows the residual sum of squares (RSS) from equation (1) as a function of the threshold level of inflation for the three samples. The minimum of the RSS sequence determines the threshold estimate, which occurs at 6 percent for fd_1, 3 percent for fd_2, and 5 percent for fd_3.

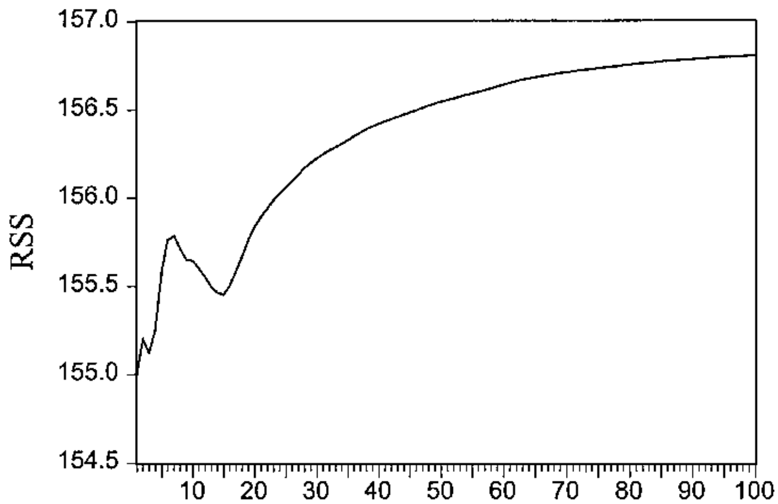
Figure 4. Effect of Inflation on Financial Depth



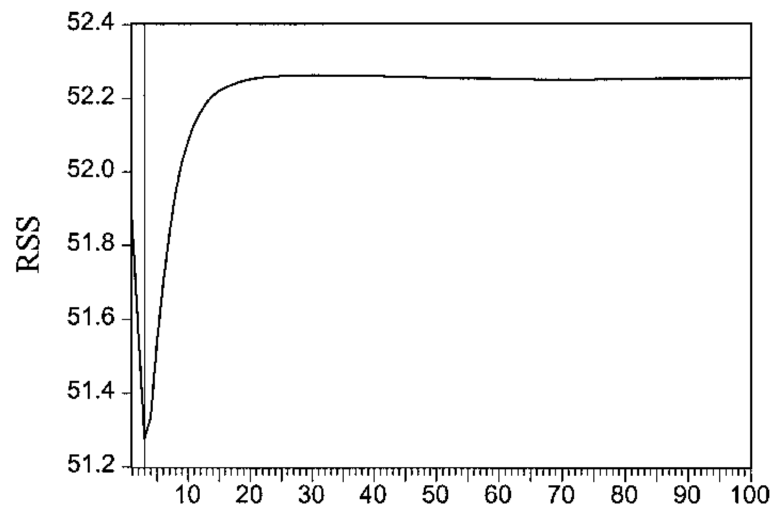
Note: This graph shows the effect of inflation on financial depth (for inflation rates from 1 to 100 percent) using the coefficient estimates given in Table 2. Both inflation and financial depth are expressed in percentage terms.

Figure 5. Residual Sum of Squares as a Function of the Threshold Level for the Stock Market

stockc

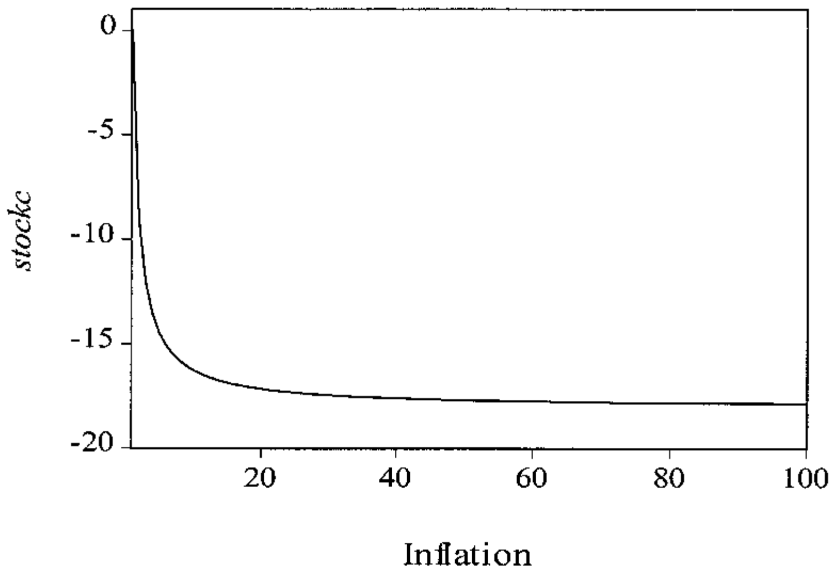


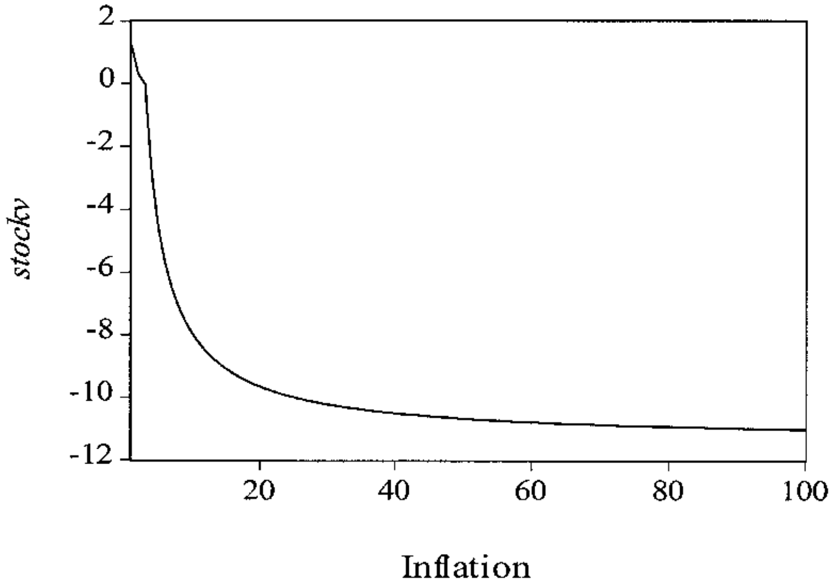
stockv



Note: Figure 5 shows the residual sum of squares (RSS) from equation (1) as a function of the threshold level of inflation for the three samples. The minimum of the RSS sequence determines the threshold estimate, which occurs at 1 percent for *stockc*, and 3 percent for *stockv*.

Figure 6. Effect of Inflation on Financial Depth for the Stock Market





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 4. Both inflation and financial depth are expressed in percentage terms.

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