IMF WORKING PAPER

WP/96/105

INTERNATIONAL MONETARY FUND

Western Hemisphere Department

Investment in Inflationary Economies

Prepared by Eduardo Levy Yeyati 1/

Authorized for distribution by Paulo Neuhaus

September 1996

Abstract

The paper presents a model of irreversible investment under uncertainty, where investment takes place whenever a threshold level of marginal returns is reached. The threshold depends positively on price volatility; a change from high to low inflation induces an upward capital stock adjustment. In economies that move in and out of temporary stabilizations, the observed effect is a negative inflation-investment correlation that replicates previous empirical findings, due to purely short-term dynamics. I study how this correlation is affected by the expected duration of each regime. Empirical evidence from ten inflationary economies confirms the predictions of the model.

JEL Classification Numbers:
E6, E22, E27

1/ This paper is broadly based on Chapter 2 of my doctoral dissertation. I would like to thank Andrew Abel, Fernando Alvarez, Andrew Atkeson, Gian Maria Milesi-Ferretti, Paulo Neuhaus, Carmen Reinhart, Miguel Savastano, Brian Stuart, and Nilson Teixeira for their valuable comments and suggestions, and Lita Ali, Hee Sue Koo, and Susan McCuskey for their helpful assistance. All the usual disclaimers apply.

Contents

Summary

The negative correlation between inflation and investment has often been used to suggest that price stability has a long-run beneficial effect on investment. This paper reviews the empirical evidence and shows that the findings can be accounted for by the short-term dynamics induced by frequent changes in average inflation levels and they do not necessarily imply a long-run link between the two variables. This paper departs from the previous related literature in focusing on the short-term dynamics and incorporating the investors' beliefs in the analytical presentation, allowing credibility issues to play an important role.

A model of irreversible investment under uncertainty is used to study how changes in inflation regimes affect investment decisions. The underlying assumption is that high inflation increases relative price volatility, which in turn translates into an increase in the volatility of the returns to capital, thus deterring new investment. Throughout the paper, a regime switch is understood as a change in policy that modifies the average inflation rate and the associated volatility of returns to investment.

The first part of the paper, using numerical simulations and Monte Carlo methods, derives the following analytical results from the model: the threshold effect induced by the frequent changes of regime results in an observed negative inflation-investment relation and firms' response to a change of regime is negatively affected by the probability of a future reversal to the previous regime. The second part of the paper shows that these results are consistent with empirical data from ten inflationary economies.

The paper suggests that a naive look at the standard empirical results might lead to an overstatement of the influence of current inflation level on investment. If frequent regime changes are an important factor behind the empirical correlation between inflation and investment, a relation between moderate but stable inflation and investment cannot be taken for granted.

I. Introduction

Conventional wisdom and several multicountry panel data studies support the belief in a positive relationship between macroeconomic stability and investment. 1/ One of the main findings in these works (and possibly the only statistically significant one) is a negative correlation between inflation and investment. These findings have often been used to suggest the existence of a beneficial effect of price stability on investment. The studies, however, do not go beyond the statistical results, and possible explanations of why inflation has effects on investment are only outlined. This paper provides an alternative explanation to the same findings. It shows that they can be accounted for by the short-term dynamics induced by frequent changes in inflation, and that they do not necessarily imply a long-run link between the two variables.

The interpretations of the empirical inflation-investment correlation proposed in the literature can be broadly classified in two groups, according to whether inflation affects the level or the volatility of the returns to investment. 2/ A typical argument of the first type tells us that, if money is complementary to production, a higher inflation tax implies higher operation costs for the firm and, in turn, lower returns. If inflation is believed to be highly persistent, at the beginning of an inflationary period the firm will find itself with more capital than optimal and the investment rate will be negatively affected. High inflation periods will then coincide with periods of downsizing or exit, a result broadly consistent with the empirical evidence. 3/ However, in an inflationary economy firms typically develop sophisticated ways of avoiding or passing on the burden of the tax to the final consumers or back to the Government, so that the implicit tax on investment arising from high inflation is extremely difficult to measure and possibly smaller than the one found in most empirical studies. 4/ On the other hand, due to the long horizon of most of the investment decisions, if the current inflation level is believed to be temporary, as is the case in most inflationary economies, a high tax on money holdings should not deter firms from following their long-run investment plans (likewise, temporarily low inflation should not induce a substantial upgrade of those plans).

1/ E.g., see the survey in Serven and Solimano (1992) and references therein.

2/ Inflation can also act indirectly through its depressing effect on consumption. Since this paper takes a partial equilibrium approach, this group of arguments is excluded from the discussion.

3/ E.g., see Rebelo and Vegh (1995) and Uribe (1994).

4/ E.g., see Laban-Sturzenegger (1994) for a model of financial adaptation in an inflationary economy. Uribe (1994) comes out with a substantial figure for the inflation tax for Argentina during the high inflation years. The model, though, treats the firm and the consumer identically when discussing the instruments used to minimize the tax burden.

The second group of explanations points to the role of inflation as a signal of current or upcoming uncertainty. Whether this uncertainty concerns a public sector deficit beyond control, unpredictable tax policy or disruption of the financial markets, the transmission mechanism between inflation and the investment decision process is always ambiguous. In order to test to what extent a particular model captures the empirical facts, a concrete assumption about this mechanism is needed. In this paper, I assume that inflation affects investment plans through its positive effect on relative price volatility, which translates into an increase in the volatility of the returns to investment.

There are a number of ways in which one can introduce relative price volatility as an increasing function of the inflation rate and, indeed, there is considerable empirical evidence on such a positive relationship. 1/ If high inflation leads to higher relative price volatility and, in turn, higher volatility of returns, the variable relevant to the investment decision is the level rather than the variance of inflation. This paper presents a model in which changes in the volatility of relative price that results from changes in inflation rates induce a threshold behavior, such that at the aggregate level inflation and investment are negatively correlated over time.

A model of irreversible investment under uncertainty is used to study the way in which investment decision rules are affected by different inflation levels. Throughout the paper, a regime switch will be understood as a change in policy that modifies the average inflation rate and the associated volatility of returns to investment. Following Dixit (1991) and Caballero and Pindyck (1994), uncertainty is modeled as a stochastic shift parameter in the demand function faced by a competitive industry. The firm's optimal investment rule is characterized by a threshold value of marginal returns to capital such that investment is positive only when this value is reached. I agree that a drop in volatility, by reducing the probability of large negative shocks, drives down the threshold level for the firm. After a switch from high to low volatility, a firm waiting to enter the industry may find that the current price level is above the new threshold and may thus decide to enter. New entry drives prices and returns down to the threshold level. Moreover, since right after the switch industry prices are mostly at the threshold, the probability that entry occurs in the following period is higher--adding some persistence to the response. A policy change in the other direction makes current profits look worse and helps investment postpone.

1/ E.g., see Blejer and Leiderman (1982), Marquez and Vining (1984) for studies at the cross-sectional level, and Domberger (1987) for analysis of intramarket volatility. Cukierman (1984) provides a comprehensive survey of both the theoretical and the empirical literature. See also the first chapters of Fischer (1986), and Fischer (1991).

Pindyck and Solimano (1993) and Caballero and Pindyck (1994) use a similar model to obtain a threshold investment decision rule. Assuming that the attendant volatility parameter remains unchanged, there exists a threshold value for the industry price such that new firms enter the industry (investment occurs) as soon as this value is reached. In addition, it can be shown that the threshold depends negatively on the volatility parameter. On the empirical side, Pindyck and Solimano find that for a sample of Latin American and OECD countries, the volatility of returns is positively correlated with a number of variables, of which inflation is the only one that consistently has some significant explanatory power for investment. This is the more so for developing countries where inflation is high and one would expect the stability-investment relationship to be more pronounced. Although some kind of threshold behavior is suggested, the paper assumes a permanent regime and does not provide a clear story of why inflation affects investment beyond its correlation with their measure of volatility of returns. 1/

This paper departs from the previous literature in two ways. First, since the focus is on the threshold behavior arising from the succession of high and low inflation periods, the paper analyzes the transitional dynamics of the model rather than its steady state properties. 2/ The second and more important way in which this paper departs from previous models is by introducing a stochastic process for the timing of the switches. The reasons to do that are immediate. From a theoretical point of view, if a threshold behavior induced by frequent regime changes is postulated as an explanation of the empirical results, then rational investors have to take into account the probability of a regime switch in the future. Indeed, it is intuitive that the expected flow of marginal returns to capital, and in turn the optimal capital stock, depend nontrivially on the expected timing of the switches. On the other hand, the empirical data shows clearly that the response to a particular level of inflation varies across countries and over time. The introduction of expectations helps explain episodes where the agents--anticipating a reversal in the future--do not react to a regime switch even if it is in place for a long time, or situations where a peak of inflation is accompanied by a less than proportional decrease in investment.

The outline of the paper is as follows: in Section 2, I extend the Caballero and Pindyck (1994) model by introducing a simple two-state ergodic Poisson process for the timing of a switch. The transitional dynamics of

---

1/ Huizinga (1993) also studies the relative price volatility-investment relation for aggregate and disaggregate data on U.S. manufacturing firms. He finds that inflation volatility is positively correlated with relative price distortions and that both are negatively correlated with aggregate investment. At the disaggregate level, the results are mixed.

2/ In fact, there is no consensus in the literature about the long-run properties of the model. See Bertola and Caballero (1990, 1994) and Abel and Eberly (1995) on this point. Cecchetti (1993), in his comment to Huizinga (1993), raises the point of the ambiguity of the long-run results.

the model economy are studied in Section 3 with the help of numerical simulations and Monte Carlo methods. The main results obtained from the model are the following: a) the short-run threshold effect induced by the frequent changes of regime results in an observed negative inflation-investment relation; b) given a particular process for the timing of the switches, the magnitude of this effect depends both on the magnitude of the changes in the volatility parameter relative to the mean volatility and on the frequency of the switches; and c) the firms' response to a change of regime is negatively affected by the probability assigned to a reversal to the previous regime. In Section 4, the empirical evidence from ten inflationary economies is reviewed in light of these results. Section 5 presents some possible extensions as well as summary and conclusions.

II. The Model

The economy comprises a large number of identical industries, each consisting of a large number of identical competitive firms. The investment decision is binary: a firm has to decide whether or not to enter the industry at a fixed cost C. Exit is achieved by the natural death of units at a hazard rate δ. The size of the productive unit is fixed and normalized to one. Unit production Q_i is also one. The industry faces an isoelastic inverse demand function given by $P_t = Y_t N_t^{-\epsilon}$, where N is the number of operating units, ϵ the elasticity of the industry demand and Y is a demand shift parameter. Returns are denoted by z_t and, assuming no operating costs, are equal to the industry price P_t. Uncertainty is modeled simply as a geometric Brownian motion process for Y_t, i.e.,

$$\frac{dY_t}{Y_t} = \alpha_Y dt + \sigma dw \tag{1}$$

from which it follows that, in the absence of entry,

$$\frac{dz_t}{z_t} = \alpha dt + \sigma dw, \tag{2}$$

where dw is a standard Wiener process and

$$\alpha = \alpha_Y + \frac{\delta}{\epsilon}.$$

It can be proved that, whenever the regime--characterized by the drift α and the volatility σ--is believed to be permanent, the optimal rule is described by a threshold level z such that new firms enter when z_t hits the threshold. 1/ For each industry, the capital stock N_t decreases steadily at the rate δ as long as the price is below the entry threshold, and increases incrementally whenever it hits the threshold. In other words, given the current industry size, there is a price level such that any further increase in demand is perfectly compensated by the production supplied by new units. This is Dixit's (1991) "hysteresis" effect: when investment cannot be perfectly recouped and a positive demand shock that drives new entry is followed by a negative demand shock, the number of firms does not adjust instantaneously but remains relatively large.

Assume now that the regime, as characterized by the parameter σ, is not permanent. The simplest way to introduce this assumption is by postulating a two-stage ergodic Markov process in which σ can take on two values σ_1 and σ_2, with $\sigma_1 > \sigma_2$ and a transition matrix

$$\Gamma = \begin{pmatrix} 1 - \lambda_1 dt & \lambda_1 dt \\ \lambda_2 dt & 1 - \lambda_2 dt \end{pmatrix}$$

In words, if the current regime is characterized by a low (high) volatility, the probability of a switch to a high (low) volatility regime within an interval dt is $\lambda_2(\lambda_1)$. Denote $W^1(z_t) = W(z_t, \sigma_1)$ and $W^2(z_t) = W(z_t, \sigma_2)$, the value of the active firm at a time when volatility is high and low, respectively. To save notation, denote $\rho = \tau + \delta$, where τ is the firm's discount factor. 2/

It is easy to show that since no operating costs are involved, no exit occurs voluntarily. 3/ The value of the active firm for each regime is given by

$$W^1(z_t) = z_t dt + e^{-(\tau+\delta)dt}((\lambda_1 dt)W^2(z_{t+dt}) + (1-\lambda_1 dt)W^1(z_{t+dt})), \tag{3}$$

$$W^2(z_t) = z_t dt + e^{-(\tau+\delta)dt}((\lambda_2 dt)W^1(z_{t+dt}) + (1-\lambda_2 dt)W^2(z_{t+dt})), \tag{4}$$

1/ E.g., see Caballero and Pindyck (1994). For a general exposition of this type of models, see Harrison and Taksar (1983) and Dixit and Pindyck (1994).

2/ Throughout the paper, as it is standard in the irreversible investment literature, the discount rate is assumed to be constant. This is equivalent to assuming risk-neutral investors. If the discount rate is thought of as the subjective valuation of risk, then higher volatility will increase this rate and reinforce the qualitative results obtained under the risk neutrality assumption. I opted to ignore this point in what follows.

3/ The model can be extended to incorporate operating costs. The solution for this case involves an upper (entry) and a lower (exit) threshold level for each regime. Since this complicates the analysis at little additional gain in insight, I prefer to use the simpler version.

Maximization of the value functions (3)-(4) yields threshold rules such that new entry occurs under the high (low) volatility regime when the price level hits the regime threshold z_1 (z_2). 1/ Figures 1 to 4 show how the two threshold levels vary with some of the relevant parameters of the problem. 2/ In Figures 1 to 3 it can be seen how as the frequency of changes increases, the distance between thresholds shrinks and the threshold effect vanishes. In addition, both thresholds decrease with λ_1 and increase with λ_2, which makes intuitive sense since $E(\sigma) = (\lambda_2\sigma_1 + \lambda_1\sigma_2)/(\lambda_1 + \lambda_2)$ depends positively on λ_2 and negatively on λ_1.

Figure 4 shows threshold values for increasing σ_H and σ_L, keeping their ratio fixed. Note that this is equivalent to keeping fixed the ratios between the volatility parameters and the standard deviation of σ. As is apparent from Figure 4, both the thresholds and their means increase as volatility oscillates around a higher average level.

III. Numerical Simulations

The previous section presented the basic implications of the model. In particular, as long as a regime is in place, the number of firms decreases at a rate δ, except for a finite number of periods in which high values of the stochastic variable trigger entry, regulating the price process. On the other hand, as the economy goes from high to low volatility, the number of firms either remains the same or adjusts discretely depending on whether the industry price is below or above the new threshold level. When the switch is from low to high, there is no entry and in fact entry in the near future is made less likely. 3/ In this sense, independently of any long-run relation between volatility and investment, when different regimes alternate, on average the transitional dynamics will tend to show a negative correlation between volatility and investment. In this section, I examine in more detail some of the predictions of the model by simulating the model economy

---

1/ See Appendix I for a brief exposition of the solution method.

2/ Unless otherwise indicated, the parameter values used for the artificial economy in all the quantitative experiments are $\lambda_Y = .02$, $r = .05$, $\delta = .01$, $\epsilon = 1.5$, $\sigma_L = .15$, $\sigma_H = .30$, and $C = 20$. They were chosen arbitrarily, but all the qualitative results presented in the paper were tested against different values and proved to be robust to them.

3/ Since entry is an instantaneous incremental regulator, the path of industry size is continuous. However, it is not differentiable at the time of a switch.

Figure 1. Threshold Values as a Function of λ, for $\lambda_1 = \lambda_2$

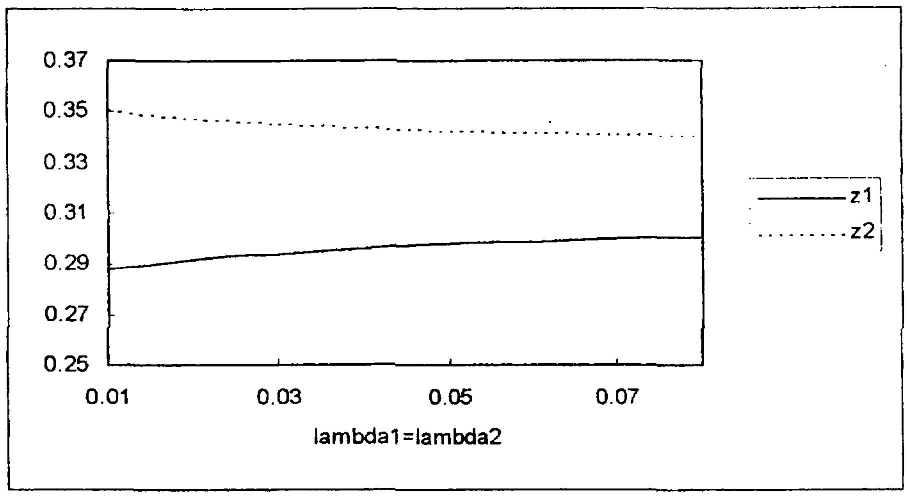


Figure 2. Threshold Values as a Function of λ_1, for λ_2 fixed

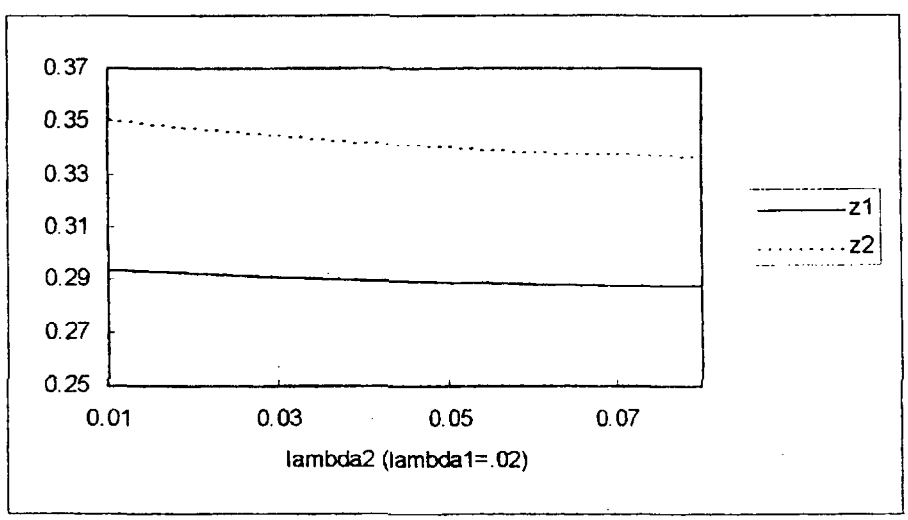


Figure 3. Threshold Values as a Function of λ_2, for λ_1 fixed

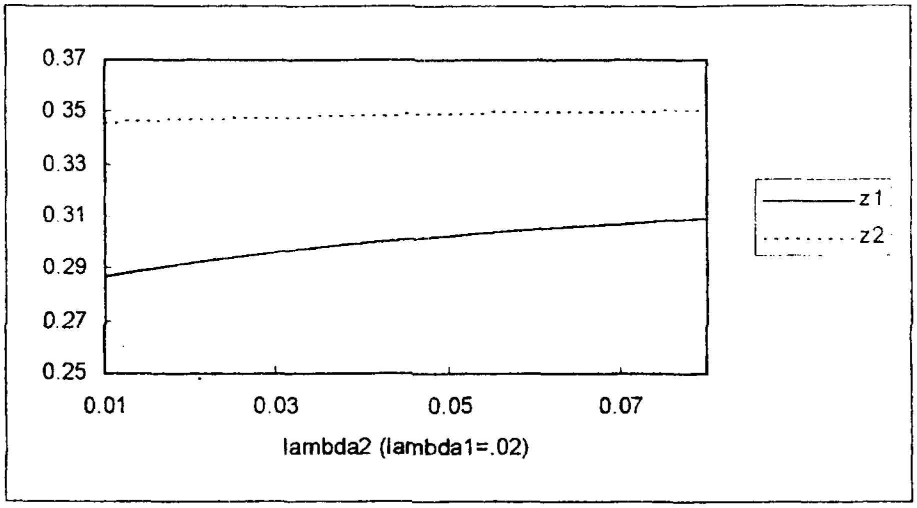
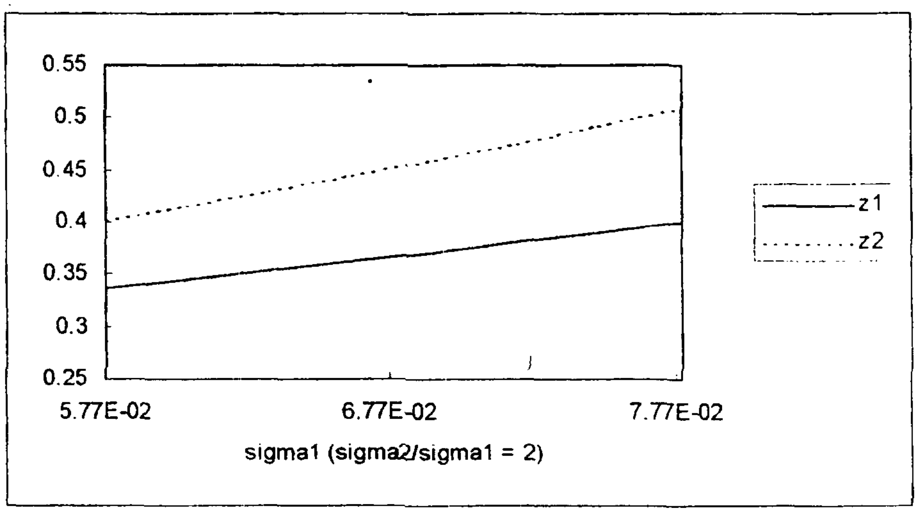


Figure 4. Threshold Values as Functions of σ_L, for $\sigma_H/\sigma_L = 2$



to obtain realizations of the variables and using Monte Carlo methods to study their statistical properties. 1/

Figures 5 and 6 show the aggregate investment and the investment rate paths for one such experiment. Although they are not generalizable, they are representative of the qualitative pattern of the threshold behavior of investment which, at the aggregate level, showed considerable consistency across experiments. 2/

Tables 1 and 2 present a summary of the simulation results. 3/ First I examine the dynamics of the investment in the long run. I simulate investment for two economies with different volatilities and find that the relation between volatility and investment is not significant. This should not come so much as a surprise since, although some authors conjecture that irreversibility models lead to the negative link between investment and volatility, even for the simplest versions of these models there is still no analytical proof on this point. 4/

1/ Standard normal realizations for 480 periods are drawn to construct an approximation to a geometric Brownian motion with the volatility parameter following alternate periods of high and low values. For different sets of parameters, aggregate capital stock is the number of units operating at each period. The procedure is repeated for 200 different realizations of the stochastic variable representing different industries, keeping the driving process constant. Investment is aggregated over the 200 industries, the first 120 observations are discarded, and the aggregate investment rate is computed for the remaining 360 periods and averaged over nonoverlapping intervals. Averaged aggregate investment series are then regressed on its lagged values and the current level of volatility. The whole experiment is repeated 500 times to get averages of regression and correlation coefficients, standard errors, and R^2.

The only exception is the experiment for different long-run volatility parameters. Here investment is simulated for two sets of 200 units using different series of 480 realizations from low and high σ driving processes, respectively. After discarding the first 120 observations, the 12-period average of aggregate investment is computed for each group. We stack both groups and compute OLS, simulating a panel regression with two cross-section observations over 30 periods.

2/ In this sense, as the number of industries increases, the paths obtained from different experiments tend to converge.

3/ As in the rest of the tables, standard errors are shown in parentheses, and one and two stars denote significance at the 10 percent and 5 percent level, respectively.

4/ Abel and Eberly (1995) study a similar problem analytically and find that, depending on the way uncertainty is introduced in the model, the sign of the volatility-investment relation is either positive or ambiguous.

Figure 5. Total Numbers of Units - $\lambda_1 = \lambda_2 = .083$

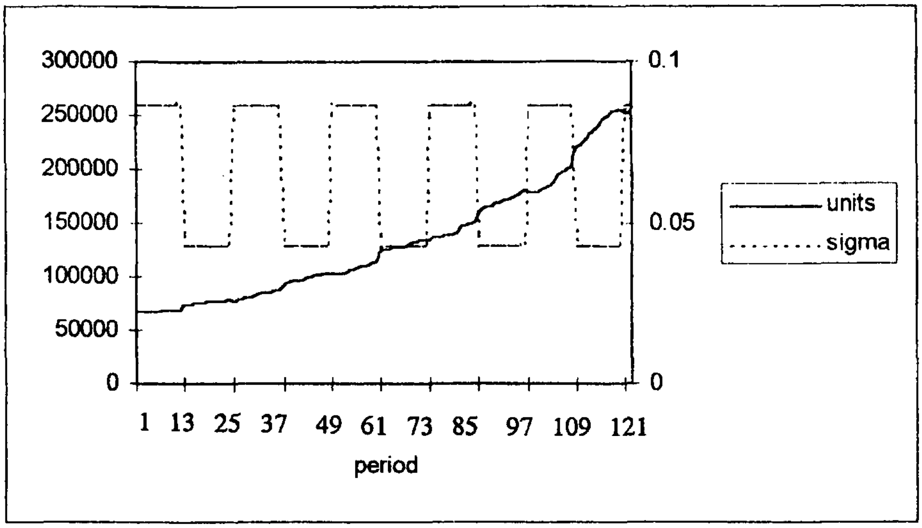


Figure 6. Investment Rate - $\lambda_1 = \lambda_2 = .083$

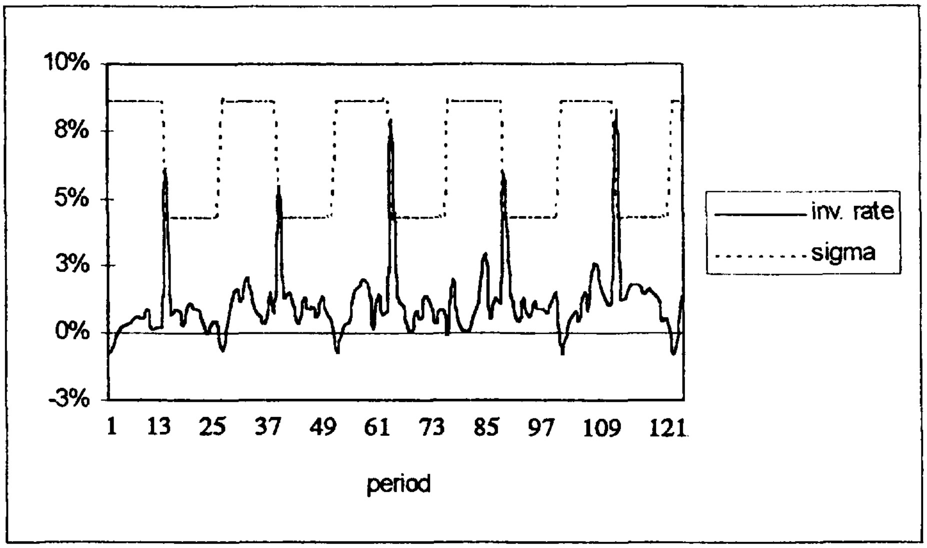


Table 1. Monte Carlo Experiments--Long-Run Properties--
$IR_t + c_0 + c_1 . \sigma_t + c_2 . IR_{t-1}$

Eqn.	σ_t	R^2	$\rho_{IR,\sigma}$
(1)	0.018 (0.032)	0.080	0.096

However, as shown by equation (1) in Table 2, the empirical negative inflation-investment link can be explained by focusing on the short-run dynamics implied by the model. Several experiments were conducted to explore this point in more detail. The results are presented in Table 2. First, I examined how the link is affected by the expected duration of a particular regime when the expectations are consistent with the process of the volatility parameter.

The probabilities of going from one regime to the other were assumed to be equal and, therefore, the expected duration of a particular regime is $1/\lambda$. Equations (1) and (8) reproduce the simulation results when the volatility path is consistent with the parameter λ, for expected durations of one and two years. 1/ It can be seen that the link generated by the model is weaker the less frequent the changes. This is consistent with the previous result: although the distance between thresholds increases with λ, the effect washes out as more periods are included in the average and the opposite long run effect tends to dominate.

For equations (5), (6), and (7), I assumed that the true probability of a switch is still .083 while the agents assign a different value to the probability parameter (λ = .042, .021, .010). While an arbitrary value of λ may seem inconsistent with rational behavior, in reality the formation of expectations over the future depends at least to some extent on a number of contemporaneous factors not captured by past observations. Not surprisingly, the results show that, as the assigned probability gets smaller, the investment-volatility relation is stronger, confirming the intuition that the sensitivity of investment to changes in volatility depends in an important way on the expectations of the agents about the duration of the current regime.

1/ Since the model simulates monthly data, λ is set to 1/12 and 1/24, respectively.

Table 2. Monte Carlo Experiments - $IR_t = c_o + c_t.\sigma_t + c_2.IR_{t-1}$

Eqn.			c_1	R_2	$\rho_{IR,\sigma}$
(1)	One-year averages	λ=0.083	-180 ** (0.45)	0.418	-0.580
(2)	σ_L=0.15, σ_H=0.25		-0.106 ** (0.050)	0.200	-0.357
(3)	σ_L=0.20, σ_H=0.40		-.0.173 ** (0.063)	0.295	-0.431
(4)	σ_L=0.25, σ_H=0.50		-0.159 ** (0.072)	0.243	-0.348
(5)		λ=0.042	0.313 ** (0.063)	0.599	-0.730
(6)		λ=0.021	-0.382 ** (0.076)	0.676	0.730
(7)		λ=0.010	-0.476 ** (0.087)	0.749	-0.845
(8)	Two-year averages	λ=0.042	-0.083 (0.053)	0.255	-0.393
(11)	Four-year averages	λ=0.021	-0.034 (0.051)	0.230	-0.213

I also examine how the link changes as the average level of volatility increases, keeping fixed the ratio between high and low volatility. Comparison of equations (1), (3), and (4) shows that, although the ratio z_2/z_1 is increasing in σ, the relation is slightly weaker for higher values of expected volatility. On the other hand, (1) and (2) tell us that, as σ_H increases from .25 to .30 keeping σL constant, there is a substantial improvement in the significance of the link. Although the combined effects of both increasing the σs and their ratio is ambiguous, it should be noted that it is not the absolute value of the difference between them that determines the overall effect.

IV. Empirical Analysis

This section studies the extent to which the proposed model captures the empirical behavior of investment in inflationary economies, by testing empirically the results obtained in the previous sections using data from ten inflationary countries. Before turning to the data, some comments regarding the interpretation of the empirical results are in order. First, in terms of the analytical model, a low inflation-low volatility regime is one in which inflation is low *on average*. Therefore, regime switches have to be understood as changes between regime averages rather than variations within a particular regime. Since the available investment and GDP data are annual, the observations correspond to high and low inflation *years*, and accordingly the coefficients and statistics obtained are biased downward.

A second point regards the treatment of hyperinflations. For several countries in the sample, inflation peaks dramatically over very short time spans (one or two months) after which it goes down dramatically, almost always following a stabilization experiment. Since these incidents have been historically short in duration, in terms of the model of Section 2 they should be associated with a very high probability of reversal. Therefore, the fact that investment reacts less than linearly to extremely high inflation is perfectly consistent with the result of the previous section that establishes a link between the importance of the threshold effect and the associated probability of a reversal. 1/ More importantly, the magnitude of the jump during hyperinflation years dominates the annual values even if the peak occurs near the end of the year, although lags in the investment response imply that the effect is captured in the following observation. Since the data was not corrected to mitigate this effect, some additional downward bias is introduced.

1. The data

In this section, I use data from ten inflationary economies: Argentina, Bolivia, Brazil, Chile, Ecuador, Israel, Mexico, Peru, Uruguay, and Venezuela. 2/ Data on real GDP and real investment were taken from the Penn World Table, version 5.6. Inflation rates series measured alternatively by the change in the Consumer Price Index (CPI) and the Wholesale Price Index (WPI), and real exchange rates deflated by the CPI and the WPI, were computed from the IMF International Financial Statistics monthly data. The information for Argentina and Brazil for recent years was complemented with data from the Instituto Nacional de Estadística y Censos of Argentina and the Fundaçao Getulio Vargas of Brazil. Since GDP and investment data are annual, all monthly series were averaged over the year. Similarly, whenever the standard deviation of a variable is included as a regressor, it is computed as the sample standard deviation for the corresponding year.

1/ Pindyck and Solimano (1993) suggest that high levels of inflation affect investment proportionally more than low levels. Although we believe that inflation starts to be a relevant explanatory factor at medium to high levels (and that is the reason why we focus on inflationary economies), we found that extremely high levels of inflation affect investment proportionally less than medium or high levels.

2/ This does not pretend to be an exhaustive sample. I tried to focus on countries that have gone through alternative periods of high and low inflation. Availability of reliable data was an additional concern. Some of the regressions were run for an extended sample that included Costa Rica and Colombia with basically similar results. These countries were finally excluded because I do not think they fit clearly in our definition of an inflationary economy.

The complete sample covers the period 1961-92 and includes 320 observations. All the results presented in the paper were found to be robust to changes in the sample range.

2. The inflation-investment relation

Table 3 presents some casual evidence of a positive relationship between inflation and relative price variability. 1/ RPD is the relative price dispersion, computed as the annual sample standard deviation from a monthly series of the ratio of the CPI to the WPI. INF, SINF, WPINF, and WPSINF are the average inflation rate and its annual sample standard deviation computed from the CPI and the WPI monthly series, respectively. The WPI series is not available for some of the countries in the sample. The number of available observations is 230.

Table 3. Correlation Between Inflation and Relative Price Dispersion

	INF	SINF	WPINF	WPSINF	RPD
INF	--				
SINF	.824	--			
WPINF	.975	.827	--		
WPSINF	.754	.892	.788	--	
RPF	.541	.623	.562	.568	--

As the above table shows, RPD is highly correlated with all four variables, the highest coefficient corresponding to SINF and the lowest to INF. In principle, it should be logical to look for a direct empirical relation between the relative price volatility proxy RPD and investment and to account for the inflation-investment result in terms of the high correlation between the two price variables. Moreover, the standard deviation of inflation should perform better than inflation in investment regressions. As in previous studies, the data tells a different story.

Table 4 summarizes selected results obtained from panel regressions of real investment to GDP ratios on lagged values of the dependent variable, lagged growth rate, and combinations of price volatility proxies. Unless otherwise indicated, dummies where included to control for country specific fixed effects. AIC denotes the Akaike Information Criterion. In all

1/ See Footnote 1, Page 2.

regressions, the lagged dependent variable and the lagged GDP growth rate were significant at a 1 percent level. The coefficients and standard errors for these regressors are similar in all cases and are omitted in the tables. Heteroskedasticity--consistent standard errors are in parentheses. 1/

Table 4. Panel Regressions--Complete Sample

EQN.	INF	INF^2	SINF	$SINF^2$	R^2	AIC
(1)	-.035 (.023)				.827	1.862
(2)	-.099** (.036)		.063** (.029)		.829	1.857
(3)	-.177** (.052)	.004** (.002)	-.040 (.048)		.832	1.845
(4)	-.173** (.050)	.003** (.001)			.832	1.841
(5)			-.120** (.034)	.001** (.1113)	.830	1.851
(6)	-.139** (.069)	.0037* (.002)	-.083 (.069)	.001 (.0005)	.833	1.849

As is apparent from Table 4, the relation between inflation and the investment rate is nonlinear for the complete sample. The standard deviation regressor is significant only in the absence of a second order term, in which case it acts as a proxy to inflation squared, with which it is correlated. It is clear from equations (3) and (6) that it is the inflation level and not its standard deviation that explains investment. 2/

1/ Additional regressions were run using RPS, WPINF, WPSINF, and the standard deviation of the real exchange rate (deflated by both the CPI and the WPI). I found that neither of them provides significant additional information once the inflation variable is included although, given their high correlation with this variable, all of them perform fairly well when taken alone.

2/ These results were confirmed by using different interval lengths to average observations. The question about why the inflation level performs better than its standard deviation is addressed later in the paper.

Table 5 presents additional results for four-year averages. The lagged values of the dependent variable and the growth rate were excluded. To allow comparison, equation (4) in Table 5 shows the results for one-year averages excluding these two regressors. Whereas the main properties of the sample stay unchanged, as the interval gets larger the individual explanatory power of the inflation regressors decreases, in accordance with results obtained by simulating the artificial economy.

Table 5. Panel Regressions for Four Year Averages--Complete Sample

EQN.		INF	INF^2	SINF	$SINF^2$	R^2	AIC
(1)	Four-year average	-.257** (.113)				.519	2.941
(2)		-.896** (.215)	.024 (.007)			.565	2.864
(3)		-.656** (.310)	.028** (.010)	0.447 (.382)	.004 (.005)	.575	2.893
(4)	One-year average	-.456** (.073)	.007** (.002)			.451	3.012

It was argued above that the existence of peaks in the inflation rate series is the reason behind the empirical nonlinearity in the investment response to the inflation rate: since these inflation peaks correspond historically to episodes where extreme inflation was promptly followed by dramatic stabilizations, according to the model in Section 2 the probability of reversal assigned to these incidents by a rational investor has to be high, and their effect on investment low. Table 6 provides some preliminary support to the claim that the nonlinearity is related to hyperinflation episodes. The restricted sample is constructed excluding 26 observations for which the annual inflation rate corresponds to a monthly average inflation above 10 percent. By comparing the results with Table 4, it can be seen that the inflation rate improves its explanatory power while the inflation squared is not significant once inflation is included.

Table 6. Panel Regressions--Restricted Sample

Eqn.	INF	INF^2	R^2	AIC
(1)	-.023** (.076)		.832	1.837
(2)	-.032 (.224)	.011 (.022)	.832	1.843

3. Current inflation and future uncertainty

Why should inflation explain the investment behavior better than its standard deviation, if it is argued that, at least in part, the influence of the former comes from its effect on price level uncertainty to which the latter is more highly correlated? In this paper the following answer is proposed: the inflation rate acts as a visible indicator of current and future price volatility and, given that the investment horizon typically comprises more than the current year, it is in that role that it plays a part in the investment decision process. 1/ To examine this hypothesis, we first regressed the standard deviation of inflation on its own lagged value and on lagged inflation, both with and without country dummies. Table 7 shows that inflation seems to be a better one-year-ahead predictor of future volatility.

The fitted values from equation (2) in Table 7 were then used to construct one-year-ahead forecast of the inflation standard deviation (FORE), and the regressions of Table 4 were repeated substituting the forecast and its square for the inflation and square inflation regressors. Results are presented in Table 8. The sample comprises 310 observations. Comparison with Table 7 shows that the forecasts perform almost as well as the original variables, supporting the hypothesis that inflation works as a signal of future volatility. 2/

1/ Ball and Cecchetti (1990) present an empirical analysis of the level-uncertainty relationship over different horizons, suggesting that current levels of inflation are related with future volatility.

2/ The same experiment was run for the restricted sample, with similar results.

Table 7. Volatility Forecast--Complete Sample

Eqn.	INF_{-1}	$SINF_{-1}$	R^2	AIC
(1)	.582**		.284	3.898
	(.237)			
(2)	.599**			
No fixed effects	(.223)		.270	3.861
(3)	1.265**	-.673**	.389	3.690
No fixed effects	(.453)	(.307)		
(4)		.270**	.073	4.101
No fixed effects		(.155)		

Table 8. Panel Regressions with Forecast Variable--Complete Sample

Eqn.	$FORE_{+1}$	$FORE_{+1}^2$	SINF	$SINF^2$	R^2	AIC
(1)	-.243*	.010*	-.078	.001	.829	1.874
	(.126)	(.006)	(.076)	(.001)		
(2)	-.302**	.009**			.828	1.864
	(.089)	(.003)				

4. The influence of expectations

Section 3 showed that a large difference between low and high levels of volatility is not always associated with a stronger threshold effect. This is so because in countries where temporary stabilizations are followed by a reversal to extremely high inflation, firms discount the informational content of current inflation changes by factors that incorporate the temporariness and the magnitude of such changes. If the current regime is expected to be short-lived, the effect of today's switch on the discounted flow of marginal returns to capital is small. Likewise, if the difference between low and high inflation levels increases, the higher incentive to invest due to a more substantial reduction of inflation today is offset by the threat of higher potential losses after a reversal. In terms of the empirical tests, both factors imply that inflation rates are not directly comparable across countries, unless they are corrected to take into account their distribution over time.

A simple way to use the data to test whether inflation matters in absolute or relative terms is to normalize inflation values across countries, dividing them by the corresponding country standard deviation of the annual average inflation series. 1/ This is equivalent to measuring inflation in standard deviation units. A new series INFN was constructed dividing the original inflation series by the country standard deviations. 2/

Table 9 presents selected results. Comparing equation (1) with the results of Table 4, it can be seen that the new series performs better than INF alone. Equation (2) shows that, once INFN is included, inflation squared retains some explanatory power. 3/ This suggests that, even after normalizing the inflation values, there is still some nonlinearity in the response to very high levels of inflation.

Table 9. Panel Regressions--Normalized Inflation

Eqn.	INFN	INF^2	R^2	AIC
(1)	-.449** (.183)		.831	1.841
(2)	-657** (.237)	.001** (.001)	.833	1.835

V. Concluding Remarks

This paper examined the uncertainty effect on investment arising from frequent inflationary episodes. From the outset, the related and important question of whether a persistently high but stable inflation has any impact

1/ The standard deviation of the average inflation series increases with both the magnitude and the frequency of the changes in inflation.

2/ Additional experiments were run after dividing the inflation rate series into four regimes (low, moderate, high and very high inflation), defined using as cut-points the country mean and the mean minus and plus one standard deviation, and assigned the values 1, 2, 3, and 4, respectively. The same transformations were also applied to the detrended inflation series, to correct for the increase in average inflation over the years observed for most of the countries in the sample. For all three cases, the results were similar to those presented in the text.

3/ The inflation rate is not significant if INFN is included.

on investment was dismissed. 1/ The model presented in Section 2 has a number of implications concerning the link between investment and price volatility. First, whereas in the long run the link is not significant, a short-run threshold effect induced in the model economy by the frequent changes of regime volatility results in a negative volatility-investment correlation. In addition, the magnitude of this effect depends not only on the size of the changes, but also on the relation between them and the distribution of volatility values: the smaller and less frequent the volatility changes are, the more sensitive an economy is to a change of any given size. Finally, firms' response to a regime switch is affected by the expected duration assigned to the new regime.

The inflation rate was interpreted as a good proxy for the underlying volatility of relative prices, and some evidence was provided on this point. The underlying assumption is that CPI inflation rates are close to what a potential investor takes as a signal of the uncertainty he is facing in the near future. While the first implication of the model is consistent with the basic empirical findings, the last two help explain some specific cases. In particular, the dependence on the relative size of the change is consistent with the fact that investment was almost as responsive to inflation in Brazil as it was in Ecuador, although inflation rates have been much higher in the first country. The influence of expectations, in turn, explains for example why investment in Argentina did not react to the stabilization attempts of 1988, 1989, and 1990. In Section 4, a significantly negative relation between investment and inflation rates was found using data for a sample of inflationary economies. Evidence was also provided that measuring inflation in standard deviation units as a crude approximation to the relative magnitude of the changes in volatility improves the explanatory power of the inflation regressor.

[As usual, many things remain to be done. I will only mention those that I believe may yield additional insight on the subject.] A number of improvements or extensions come to mind: on the technical side, the measure of volatility may be improved substantially. If inflation acts as a proxy for relative price variability, alternative measures that capture more accurately this variability may do a better job at explaining investment behavior. Availability of disaggregated price data is an issue, but it is always possible to construct series for a smaller set of countries, and a shorter period of time. A measure of expectations in order to test directly how the expected duration affects the response to a regime switch is more problematic. The use of variables like the country risk premium or the

---

1/ A reason suggested earlier is that in a context of persistently high inflation one would expect that, since future inflation is mostly predictable, the economy can adapt to it at low cost by using more sophisticated financial and contractual instruments. A more pedestrian reason is that in most inflationary economies, high inflation is accompanied by increased variation, which makes disentangling the level effect from the volatility effect extremely difficult.

spread between interest rates for domestic and foreign currency-denominated loans seems promising, although availability of data is a potential problem.

On a more general level, one of the implications of the paper is that countries with moderate but stable inflation do not display a significant inflation-investment relation. A test of this proposition could be easily conducted and could shed some additional insight on the channel through which inflation affects investment. More importantly, several potentially relevant factors, notably those related to investment and production costs, were ignored in this paper for the sake of simplicity, but may play a decisive role in the behavior of investment during price stabilizations. The inclusion of these factors in the empirical tests are a natural next step.

The main conclusion that could be drawn from the paper is that the empirical finding of a negative correlation between inflation and investment can be accounted for by a purely short-run effect induced by the relation between inflation and relative price uncertainty in a context of irreversible investment. As should be clear from the previous discussion, this short-run effect does not require any long-run link between inflation and investment. In other words, the aforementioned empirical finding does not necessarily imply, as has been sometimes suggested, the existence of a long-run beneficial effect of price stability on capital accumulation. On the contrary, given that in the long run the nature of the relation is ambiguous, in the context of the model presented in this paper one would be tempted to conjecture that the investment boost often observed after a successful price stabilization may be a temporary phenomenon that tends to be reversed with time.

Working Equations

This section presents briefly the solution to the following investment problem: 1/

$$W^1(z_t) = z_t dt + e^{-(\tau+\delta)dt}\{(\lambda_1 dt)W^2(z_{t+dt}) + (1-\lambda_1 dt)W^1(z_{t+dt})\}, \quad (5)$$

$$W^2(z_t) = z_t dt + e^{-(\tau+\delta)dt}\{(\lambda_2 dt)W^1(z_{t+dt}) + (1-\lambda_2 dt)W^2(z_{t+dt})\}, \quad (6)$$

Expanding the right hand side of (5) and (6) using Ito's lema, dividing both sides by dt and letting $dt \to 0$:

$$\frac{1}{2}W^1_{zz}(\sigma_1 z)^2 + W^1_z \alpha z - (\rho+\lambda_1)\, W^1 + \lambda_1 W^2 = -z \quad (7)$$

$$\frac{1}{2}W^2_{zz}(\sigma_2 z)^2 + W^2_z \alpha z - (\rho+\lambda_2)\, W^2 + \lambda_2 W^1 = -z \quad (8)$$

The homogeneous solution of (7)-(8) is given by

$$W^1_H = D_1 z^{\beta_1} + D_2 z^{\beta_2} + \beta_1 z^{\beta_3} + B_2 z\beta^4,$$

$$W^2_H = D_3 z^{\beta_1} + D_4 z^{\beta_2} + \beta_3 z^{\beta_3} + B_4 z^{\beta_4} \quad (9)$$

where $\beta_{1,2,3,4}$ are the positive and negative roots of the characteristic equation:

$$\begin{vmatrix} \frac{(\sigma_1)^2}{2}\beta(\beta-1) + \alpha\beta - (\rho+\lambda_1) & \lambda_1 \\ \lambda_2 & \frac{(\sigma_2)^2}{2}\beta(\beta-1) + \alpha\beta - (\rho+\lambda_2) \end{vmatrix} = 0 \quad (11)$$

1/ See Levy Yeyati (1996) for a complete exposition of the solution.

In turn, (11) can be expressed as

$$Q_1(\beta).Q_2(\beta) = \lambda_1\lambda_2$$

where

$$Q_1(\beta) = \frac{\sigma_1{}^2}{2}\beta(\beta-1) + \alpha\beta - (\rho+\lambda_1)$$

$$Q_2(\beta) = \frac{\sigma_2{}^2}{2}\beta(\beta-1) + \alpha\beta - (\rho+\lambda_2)$$

If we denote $\upsilon_{1,2,3,4}$ the positive and negative roots of $Q_1(\beta)$ and $Q_2(\beta)$, respectively, it can be shown that the roots $\beta_{1,2,3,4}$ of the characteristic equation satisfy

$$\beta_1 > \max\{\upsilon_1, \upsilon_3\} > \min\{\upsilon_1, \upsilon_3\} > \beta_2 > 0$$

$$0 > \beta_3 > \max\{\upsilon_2, \upsilon_4\} > \min\{\upsilon_1, \upsilon_4\} > \beta_4$$

To keep the value function finite for z arbitrarily small, the coefficients corresponding to the negative roots $\beta_{3.4}$ are set equal to zero. Therefore, we are left with the four coefficients D_i, i = 1, 2, 3, 4. By substituting (9)-(10) into the homogeneous part of (7)-(8), we reduce the set of unknown coefficients:

$$\left(\left[\beta_1(\beta_{-1})\sigma\frac{1^2}{2} + \beta_1\alpha - (\rho+\lambda_1)\right]D_1 + \lambda_1 D_3\right)z^{\beta_1} +$$

$$+ \left(\left[\beta_2(\beta_{-2})\sigma\frac{1^2}{2} + \beta_2\alpha - (\rho+\lambda_1)\right]D_2 + \lambda_1 D_4\right)z^{\beta_2} = 0$$

which gives

$$D_3 = \gamma_1 D_1$$

$$D_4 = \gamma_2 D_2$$

$$\gamma_1 = -\frac{1}{\lambda_1}\left[\ \beta_1(\beta_1-1)\frac{\sigma 1^2}{2}+\beta_1\alpha-(\rho+\lambda_1)\ \right]$$

$$\gamma_2 = -\frac{1}{\lambda_1}\left[\ \beta_2(\beta_2-1)\frac{\sigma 1^2}{2}+\beta_2\alpha-(\rho+\lambda_1)\ \right]$$

It is easy to check that $\gamma_1 < 0 < \gamma_2$ and that

$$W_p^1 = W_p^2 = \frac{z}{\rho-\alpha}$$

is a particular solution of (7)-(8). Now we are ready to characterize the complete solution,

$$W^1 = D_1 z^{\beta 1} + D_2 z^{\beta 2} + \frac{z}{\rho-\alpha}$$

$$W^2 = \gamma_1 D_1 z^{\beta 1} + \gamma_2 D_2 z^{\beta 2} + \frac{z}{\rho-\alpha}$$

It can be shown that, under the assumption of free entry, the value of the inactive firm is identically zero 1/ so that, at the threshold level, the value of the operating firm minus the entry cost C must also be zero. Formally, denoting z_1 and z_2 the threshold levels for the high and low volatility regimes, respectively:

1/ See Dixit and Pyndick, 1994, pp. 263-4.

$$W(z_1) = D_1 z_1^{\beta 1} + D_2 z_1^{\beta 2} + \frac{z_1}{\rho - \alpha} - C \qquad (11)$$

$$W^2(z_2) = \gamma_1 D_1 z_2^{\beta 1} + \gamma_2 D_2 z_2^{\beta 2} + \frac{z_2}{\rho - \alpha} - C \qquad (12)$$

The other two equations needed to solve the system come from the standard smooth pasting conditions at the thresholds. 1/

$$W_z^1(z_1) = \beta_1 D_1 z_1^{\beta_1 - 1} + \beta_2 D_2 z_1^{\beta_2 - 1} + \frac{1}{\rho - \alpha} = 0 \qquad (13)$$

$$W_z^2(z_1) = \beta_1 \gamma_1 D_1 z_2^{\beta_1 - 1} + \beta_2 \gamma_2 D_2 z_2^{\beta_2 - 1} + \frac{1}{\rho - \alpha} = 0 \qquad (14)$$

The system (11)-(14) can be solved numerically for the two thresholds z_1 and z_2, and the two unknown parameters D_1 and D_2.

1/ See Dumas (1991) for an exposition of how these conditions are derived.

References

Abel, Andrew B. and Janice C. Eberly "A Unified Model of Investment Under Uncertainty," American Economic Review, Vol. 84 (1994), pp. 1369-84.

_____, "The Effects of Irreversibility and Uncertainty on Capital Accumulation," American Economic Review, Vol. 84 (1995), pp. 1369-84.

Ball, Lawrence and Stephen G. Cecchetti "Inflation and Uncertainty at Short and Long Horizons," Brookings Papers on Economic Activity, (1990), pp. 215-245.

Bertola, Giuseppe and Ricardo J. Caballero "Kinked Adjustment Costs and Aggregate Dynamics," NBER Macroeconomics Annual 1990, ed. Olivier Blanchard and Stanley Fischer, (Cambridge: MIT Press 1990), pp. 237-295.

_____, "Irreversibility and Aggregate Investment," Review of Economic Studies, Vol. 61 (1994), pp. 223-246.

Blejer, Mario I. and Leonardo Leiderman, "Inflation and Relative-Price Variability in the Open Economy," European Economic Review, Vol. 18 (1982), pp. 387-402.

Caballero, Ricardo J. and Robert S. Pindyck, "Uncertainty, Investment and Industry Evolution," Mimeo, 1994.

Cecchetti, Stephen G. (1993), Comment to "Inflation Uncertainty, Relative Price Uncertainty, and Investment in U.S. Manufacturing," Journal of Money, Credit and Banking, Vol. 25 (1993), pp. 551-54.

Cukierman, Alex, "The Relationship between Relative Prices and the General Price Level: A Suggested Interpretation," American Economic Review, Vol. 69 (1979), pp. 444-47.

_____, Inflation, Stagflation, Relative Prices and Imperfect Information, (Cambridge University Press, 1984)

Dixit, Avinash K. and Robert S. Pindyck, Investment Under Uncertainty, (Princeton University Press, 1994)

Domberger, Simon, "Relative Price Variability and Inflation: A Disaggregated Analysis," Journal of Political Economy, Vol. 95 (1987), pp. 547-66.

Dumas, Bernard, "Super Contact and Related Optimality Conditions," Journal of Economic Dynamics and Control, Vol. 15 (1991), pp. 675-85.

Eberly, Janice, Comment to "Economic Instability and Aggregate Investment," NBER Macroeconomics Annual, Vol. 8 (1993), pp. 303-312.

Fischer, Stanley, Indexing, Inflation and Economic Policy, (Cambridge: MIT Press (1986).

_____, "Growth, Macroeconomics and Development," NBER Macroeconomics Annual, (1991), pp. 329-64.

Harrison, J. Michael and Michael I. Taksar, "Instantaneous Control of Brownian Motion," Mathematics of Operations Research, Vol. 8 (1983), pp. 439-53.

Huizinga, John, "Inflation Uncertainty, Relative Price Uncertainty, and Investment in U.S. Manufacturing," Journal of Money, Credit and Banking, Vol. 25 (1993), pp. 521-69.

Laban, Raúl and Federico Sturzenegger, "Distributional Conflict, Financial Adaptation and Delayed Stabilizations," Economic Politics, (1994) pp. 257-276.

Levy Yeyati, Eduardo, "Three Essays on Macroeconomic Finance," (doctoral Dissertation, Philadelphia: University of Pennsylvania, 1996).

Marquez, Jaime and Daniel Vinig, "Inflation and Relative Price Behavior: A Survey of the Literature, in M. Ballabou, ed., Economic Perspectives: An Annual Survey of Economics, Harwood, New York, Vol. 3 (1984).

Pindyck, Robert S. and Andrés Solimano, "Economic Instability and Aggregate Investment," NBER Macroeconomics Annual, Vol. 8 (1993), pp. 259-303.

Rebelo, Sergio, and Carlos Vegh, "Real Effects of Exchanged-Rate-Based Stabilization: An Analysis of Competing Theories," Mimeo 1995.

Serven, Luis and Andrés Solimano, "Private Investment and Macroeconomic Adjustment: A Survey", The World Bank Research Observer, Vol. 7 (1992), pp. 95-114.

Tommasi, Mariano, "The Consequences of Price Stability on Search Markets: Toward Understanding the Effects of Inflation", American Economic Review, Vol. 84 (1994), pp. 1385-96.

Uribe, Martin, "Exchange-Rate Based Inflation Stabilization: The Initial Real Effects of Credible Plans", Board of Governors of the Federal Reserve System, Mimeo (1994).