Investment Choice and Inflation Uncertainty

Greg Fischer*

June 2016

Abstract

This paper investigates the relationship between inflation uncertainty and investment using a panel of loan-level data from small businesses. Micro-level data makes it possible to study phenomena that are obscured in country or industry aggregates. The data show that periods of increased inflation uncertainty are associated with substantial reductions in total investment. Moreover, there is a shift in the composition of investment away from fixed assets and towards working capital—the more flexible factor of production—and fixed asset investment exhibits periods of inaction consistent with real option models of investment under uncertainty.

JEL: E22, E31, D92, G21

Keywords: inflation, investment, uncertainty

---

*Contact information: London School of Economics, g.fischer@lse.ac.uk. I would like to thank Esther Duflo, Abhijit Banerjee, Oriana Bandiera, Tim Besley, Robin Burgess, Francesco Caselli, Victor Chernozhukov, Raymond Guiteras, Rick Hornbeck, Konrad Menzel, Trang Nguyen, Torsten Persson, Silvana Tenreyro, Tom Wilkening, and seminar participants at Columbia University, LSE, and the World Bank for many useful comments. The borrower data for this project were developed as part of joint research with Antoinette Schoar and Alejandro Drexler, for which Héber Delgado Medrano provided excellent research assistance. The management of ADOPEM in Santo Domingo, Dominican Republic, in particular Mercedes Canalda de Beras-Goico and Juan Francisco Terrero Silva, was incredibly helpful and patient in providing access to their data and an understanding of their business. I gratefully acknowledge the financial support of the National Science Foundation's Graduate Research Fellowship.

1 Introduction

There is a general presumption that inflation—and, in particular, uncertainty about future inflation—has negative consequences for economic growth. The theoretical literature provides a number of supporting arguments but perhaps none more intuitive than what Fischer and Modigliani (1978) describe as the focus of "practical men": uncertainty about future prices makes it difficult to plan. In the face of uncertainty, businesses may reduce or delay investment consistent with a real option model of firm investment behavior. The theoretical consequences of inflation uncertainty are not limited to investment levels alone. Uncertainty can also distort investment towards more flexible factors of production.[1] Aggregated across all firms, there is concern that these effects can reduce economy-wide investment and growth.

Owing to the fundamental importance of this issue, a wide range of theoretical work has explored the relationship between inflation uncertainty and investment. Theory, however, produces compelling but conflicting arguments for both a positive and negative relationship.[2] Ultimately the effects of inflation uncertainty on investment are an empirical question. Much of the empirical evidence points to a negative relationship;[3] however, while the bulk of theoretical mechanisms put

[1]Eberly and Van Mieghem (1997) show that with multiple factors of production differing in their adjustment costs investment is skewed towards the more flexible factor.

[2]Friedman (1977) argues that inflation volatility and uncertainty may "render market prices a less-efficient system for coordinating economic activity," thereby reducing allocative efficiency. When nominal rigidities are present, inflation uncertainty generates uncertainty about the relative price of final goods and input costs. Even without nominal rigidities, Lucas (1973) argues, increased inflation uncertainty accentuates firms' real responses to observed price variation and worsens the trade-off between output and inflation. Fischer and Modigliani (1978) taxonomy describes a number of potential channels from inflation to real outcomes. Most applicable in this context are the challenges for planning that are presented by uncertainty about future prices. Drawing on option pricing theory, Pindyck (1988; 1991) formalizes Fischer and Modigliani's observation to show that uncertainty increases the option value of delaying irreversible investment. Huizinga (1993) draws on this result to build a theoretical link between inflation uncertainty and reduced investment.

The theoretical work is not one sided. Hartman (1972) and Abel (1983) demonstrate that uncertainty increases investment when adjustment costs are convex and the profit function is convex in prices. Dotsey and Sarte (2000) show that precautionary savings can also produce a positive correlation between inflation variability and investment. In directly addresses the sign of the investment and uncertainty relationship Caballero (1991) demonstrates the importance of industry structure and highlights the limitations to finding a robust theoretical relationship between inflation uncertainty and investment.

[3]Holland (1993) surveys 18 studies of the empirical link between inflation uncertainty and real economic activity in the United States; one finds evidence of a positive relationship, fourteen find a negative relationship, and three find no evidence of a link.

Barro (1996) investigates the inflation and growth performance of 100 countries from 1960 to 1990, finding a link from higher long-term inflation to reduced growth and investment while stressing that clear evidence for adverse effects comes from experiences of high inflation. Using data from a similar period Fischer (1993) finds that inflation is negatively correlated with growth but cannot distinguish the effect of inflation levels and inflation volatility. Judson and Orphanides forward occur at the firm or plant level, empirical studies have tended to focus on country or industry aggregates.[4] This makes it difficult to identify the precise mechanisms through which inflation uncertainty operates. As a result, we know very little about firm-level behavior in the face of inflation and even less in low-income countries, where prices tend to be more volatile and the consequences commensurately larger.

The key innovation of this paper is to expand on existing empirical results with micro-level data that allows us to identify the precise mechanisms through which inflation uncertainty affects investment. In doing so, this paper aims to provide direct evidence on the effects of inflation volatility at the unit of the investment decision maker, focusing on a real option model of investment as the conduit from inflation to real outcomes. In particular, I want to answer three questions. First, does increased inflation uncertainty reduce business investment? Second, does it generate periods of investment inactivity consistent with the real option model? Finally, does inflation uncertainty skew investment towards more flexible—and potentially less productive—factors of production?

To answer these questions, I utilize a unique panel of administrative loan data from a large and well-performing savings and loan bank based in the Dominican Republic. The unbalanced panel spans eight years from 2001 to 2008, with 47,443 observations representing 27,771 unique firms. I combine this with monthly data on price levels from the Dominican consumer price index and estimate inflation uncertainty by fitting a GARCH model to the monthly data.

There are a number of advantages to studying the link between inflation uncertainty and investment with micro-level data. The real option effect, by which uncertainty reduces investment, provides a central theoretical foundation for this link; yet the mechanisms it posits are unobservable

(1999) measure intra-year inflation volatility and find significant negative effects from both the level and volatility of inflation. Focusing on business cycle volatility rather than inflation per se, Ramey and Ramey (1995) also demonstrate a strong negative relationship between volatility and mean growth rates in OECD countries and suggestive evidence in a broader set of 92 countries. Pindyck and Solimano (1993) and Aghion et al. (2010) demonstrate that the negative relationship between volatility and growth is particularly strong in less developed countries, where prices also tend to be more volatile. The latter also develops a growth model in which volatility combined with imperfections in the credit market distorts investment from long-term productivity enhancements to short-term investments that generate a quicker return.

[4]Bloom et al. (2007) is a notable exception. They numerically solve a model of partially irreversible investment for the effects of uncertainty on short-run investment dynamics and test this model on a simulated panel of firm-level data. They then apply the same approach to study the investment behavior of 672 publically traded U.K. manufacturing companies over the period 1972-1991, finding evidence of more cautious investment behavior for firms subject to greater uncertainty, as measured by the volatility of the firms' equity returns.

in aggregated data. By using firm-level data, this paper can evaluate not only changes in the overall level of investment but also distortions in the type of investment that are predicted when capital differs in its degree of irreversibility. The small enterprise investment data used in this study provide another distinctive benefit. Real option models predict discreet decisions by individual production units with substantial periods of innaction, but even aggregation to the firm level can obscure this behavior (Doms and Dunne, 1998; Nilsen and Schiantarelli, 2003; Bloom et al., 2007). The firms in the study are small, with mean annual revenues of approximately $15,700, and should exhibit precisely the investment hysteresis predicted by the real option model. Moreover, they constitute a negligible share of aggregate investment, which mitigates concerns of reverse causality that would normally trouble efforts to assess the effect of aggregate volatility. In addition to providing an ideal setting in which to study effect of inflation uncertainty on real economic outcomes, the investment behavior of small firms has particular policy relevance. Across all levels of national income, the informal and small and medium enterprise (SME) sectors contribute approximately 65-70 percent of GDP (Ayyagari et al., 2003), and nevertheless little is known about their investment behavior.

The data show that periods of high inflation volatility are associated with substantial reductions in total investment. A 1% increase in inflation volatility (approximately 0.87 standard deviations of the historical mean), is associated with an 10% reduction in total business investment. Moreover, periods of high inflation are associated with a shift in the mix of investment away from fixed assets and towards working capital. Fixed asset investment falls by 15% to 37%, while the proportional change in working capital investment is less than 10%. The drop in fixed asset investment is driven primarily by a reduction in the likelihood of any fixed asset investment, which falls by 26%-46% for a 1% increase in inflation volatility. The observed changes in investment composition are robust to inclusion of other macro variables. The results are consistent with a link from inflation to real economic activity through a real option model of investment. Increased inflation uncertainty decreases total investment and distorts investment towards the more flexible factor of production.

The rest of the paper proceeds as follows. Section 2 discusses the theory of inflation uncertainty and investment behavior and presents a simple two-factor model of investment behavior. Section 3 estimates the behavior of inflation uncertainty in the Dominican Republic using a GARCH model and monthly price data. Section 4 summarizes the source of borrower data, and section 5 describes the empirical strategy for estimating the effect of inflation uncertainty on investment choices. Section 6 reports the results of this estimation, and the final section concludes.

2 A Model of Uncertainty and Investment Choice

This section summarizes some of the existing theory of uncertainty and investment, describes an example of a borrower's investment choice under uncertainty, and presents a simple two-factor model of investment behavior. As stated above, theory offers a number of competing perspectives on the issue. We will not resolve them here. Instead, the aim is to frame what is inherently an empirical question and provide a concrete, if stylized, example of how uncertainty can affect a firm's investment decisions.

One strand of the theoretical literature has pointed towards a positive relationship between uncertainty and investment (Abel, 1983; Hartman, 1972). In both cases, the result proceeds from the realization that if the firm's profit function is convex in prices and capital adjustment costs are convex, a mean-preserving spread of prices increases the optimal level of investment. Caballero (1991) shows how this relationship depends on market structures. When markets are competitive, he shows that investment decisions depend almost entirely on the price of capital and its expected marginal profitability, which, as in Abel and Hartman, is convex with respect to prices. A Jensen's inequality argument shows that the optimal response to uncertainty is to increase investment. In contrast, when competition is imperfect, an increase in investment today makes it more likely that a firm will tomorrow have too much capital relative to its desired level. When adjustment costs are asymmetric (i.e., net of direct costs, it is more costly to reduce capital than to increase it) having too much capital is worse than having too little. Here, the uncertainty-investment relationship can turn negative.

Zeira (1990) notes that the fixed discount rate assumption of other studies is tantamount to risk-neutrality. He builds a model of investment that incorporates shareholder risk aversion and demonstrates that the uncertainty-investment relationship becomes indeterminate in this framework.

Pindyck (1991) looks at the case of irreversible investments (i.e., largely sunk costs that cannot be recovered), focusing on those for which delay is possible and allows the firm to gather new information about prices and other market conditions before making the investment. While firms do not always have the opportunity to delay investments—they may, for example, be subject to a short-lived strategic window—he argues that in most cases delay is feasible. In such case, the standard rule of investment decisions, which says that a firm should invest in a project when the present value of its expected net cash flows exceeds its cost, is no longer optimal. When investments are irreversible and decisions to invest can be postponed, increased uncertainty makes firms more reluctant to invest.

The reasoning behind this argument is instructive and builds on an analogy between real and financial investment decisions. The opportunity to make a real investment is like a call option on the underlying capital. Making the investment is like exercising the option with the cost of the investment the strike price of the option. Standard techniques of financial asset valuation tell us how to price the option and when to exercise it optimally.

2.1 A Stylized Example of an Investment Decision

Consider the following example, similar to ones used in Pindyck (1991) and Huizinga (1993). Suppose a small, credit-constrained business with a discount rate of 2% per month has access to an 8,000 peso loan. It can allocate the proceeds from this loan either to working capital (short-term assets such as inventory for a store) or to a long-term asset (e.g., a refrigerator that would allow the store to expand its product offerings). Assume short-term assets just break even, returning 2% (plus the entire original investment) after one month, and this amount can be reinvested in either asset each month.

First, consider a certain environment where the incremental profits from the long-term asset are 200 pesos per month in perpetuity. With certain investment returns, the firm's investment decision is straightforward and can be derived from the standard net present value calculation. The NPV of the long-term investment is 2,000 pesos, while the NPV of the short-term investment (assuming the firm reinvests in short-term assets every month) is 0.

Now consider the case of uncertainty of a very simple form: after one month, the firm will discover whether the monthly incremental profits from the long-term investment are 300 or 100. Each state occurs with equal probability, so that the expected profits remain the same as in the certain case, 200 pesos per month. For simplicity, assume that regardless of whether or not the business makes the investment, this uncertainty is resolved after one month and that once realized, profits will remain at this level forever.[5] If the firm is risk neutral, the net present value calculations are the same: 2,000 pesos for the long-term investment and 0 for the short-term investment. However, the borrower should not make the long-term investment now.

In the state of the world when profits are low, the business would have preferred not to make the long-term investment. The standard net present value calculations do not incorporate the possibility of waiting and preserving the option not to invest should profits obtain the lower value. Instead of investing today, the entrepreneur should wait one month until the uncertainty is resolved and invest only if profits attain the higher level. Table 1 presents these calculations.

The key insight here is that even for risk neutral businesses and positive NPV projects, firms should only invest today if the cost of delay exceeds the option value of waiting until uncertainty is resolved. Analogous to financial option theory, greater uncertainty increases the value of waiting, thus requiring a higher incremental profit for the firm to optimally invest today.[6]

This effect is potentially quite economically significant. Continuing with the stylized example from above, in the absence of uncertainty, the long-term asset need only match the return of the short-term asset (26.8% per year or 160 pesos per month) in order for the firm to invest today. In contrast, suppose revenues are uncertain such that prices either rise or fall by 1%—roughly the median monthly standard deviation of inflation in the Dominican Republic as described in section 3—with equal probability. Assuming a 10% profit margin after fixed costs, this small variation in prices generates 10% variation in profits, and the expected incremental income of the long-term

[5] Dixit (1989) extends the analysis to cases where uncertainty is resolved over time. For our purposes, there is no substantive difference.

[6] Aghion et al. (2010) consider an alternative mechanism where short-term investment takes little time to build and generates output quickly while long-term investment takes time to build but contributes more to productivity. With sufficiently imperfect credit markets, long-term investments can be interrupted by an idiosyncratic liquidity shock. In more volatile environments, entrepreneurs will reduce long-term investment. Their empirical predictions are similar to those motivated and found here.

asset would have to be 177 pesos per month (11% higher) in order for the firm to invest today. At 20% profit variability, the threshold level of expected monthly profits rises to 198 pesos, 24% higher than in the absence of uncertainty.

This example is perhaps overly stylized. Nevertheless, it draws in stark relief the potential magnitude of the uncertainty effect on investment decisions. Moreover, this effect results entirely from the option value of delaying uncertain, irreversible investments. It assumes risk neutrality or complete markets such that the firm can completely diversify away all income risk, i.e., the firm maximizes net present value but with the added possibility of delay. Neither of these assumptions are likely to hold among small businesses in less developed countries, for whom risk markets are incomplete and risk aversion is important. Together, these factors accentuate the distortion of price uncertainty on investment decisions.

It is worth noting that these distortions do not necessarily imply a reduction in long-term capital stock. Bloom (2000) shows that while the real option effect of uncertainty can explain large elasticities of short-run investment, it does not affect long-term investment. He points out that while real option motives increase the investment threshold, reducing investment in times of strong demand, they also lower the disinvestment threshold, reducing the rate of disinvestment when demand is weak. In both cases, uncertainty has a cost—it pushes firms from their instantaneously optimal level of capital—but it does not reduce long-term investment through the real option effect. In the case of microenterprises, for which low levels of initial fixed assets limit the scope for downward adjustment, this reduced threshold for disinvestment may be less of a factor. As shown by a number of authors (e.g., Caballero, 1991; Lee and Shin, 2000; Pindyck, 1993; Sakellaris, 1994) when starting from a base of zero initial capital stock, the real option effect of uncertainty unambiguously reduces investment.

2.2 A Two-Factor Model of Investment Behavior

This section concludes by examining an investment model with two types of capital: long-term assets, which are partially irreversible; and working capital, which is freely adjustable. This model is common through the irreversible investment literature and represents a special case of those presented by Abel and Eberly (1996), Eberly and Van Mieghem (1997) and Dixit (1997), among others. The firm's revenue function takes the form

$$R(X,K,S) = X^{\gamma}K^{\alpha}S^{\beta}, \tag{1}$$

where K represents long-term capital, S represents short-term or working capital, and X represents an index of demand and productivity conditions. Assume labor is fixed and normalized to one. This revenue function can be derived from an underlying Cobb-Douglas production function and a constant elasticity demand function.[7] I assume, as is standard, that the productivity index evolves according to a geometric Brownian motion with positive drift μ and variance σ^2. The cost of each type of capital is r. However, long-term capital is costly to reverse, such that the proceeds from selling a unit of K are $r(1-\theta)$, where $\theta \in [0,1]$ represents adjustment frictions.[8]

The firm's optimization problem is

$$\begin{aligned} V(X_t,K_t,S_t) \quad = \quad & \max_{I_{Kt},I_{St}} R(X_t,K_t,S_t) - C(I_{Kt},I_{St}) \\ & + \frac{1}{1+\rho} E_t \left[V(X_{t+1},(K_t+I_{Kt})(1-\delta),(S_t+I_{St})(1-\delta) \right], \end{aligned}$$

where ρ is the discount rate, δ is the depreciation rate, I_{jt} is the investment in capital of type $j \in \{K,S\}$ at time t, and $C(I_K,I_S) = r\{I_S + I_K(1-\theta\ \mathbf{1}(I_K<0)\}$ is the investment cost function, where $I_K < 0$ implies disinvestment in the long-term asset. Both forms of capital evolve according to $j_{t+1} = (j_t + I_{jt})(1-\delta)$.

In continuous time, the Bellman equation associated with this optimization problem is

$$\rho V(X,K,S) = X^{\gamma}K^{\alpha}S^{\beta} - \delta(V_K K + V_S S) + \mu X V_X + \frac{1}{2}\sigma^2 X^2 V_{XX},$$

where V_j represents the partial derivative of V with respect to j.

As is well known, the general solution to this problem is characterized by a regions of inaction

[7] Following Eberly and Van Mieghem (1997), this is the same function used by Bertola (1998) and Dixit (1989).

[8] Note that the cases $\theta = 0$ and $\theta = 1$ represent full flexibility and complete irreversibility, respectively.

over which K does not change. Figure 1 shows the optimal policy in the space of two variables, (k,s), defined as

$$k = \log(K/X), \quad s = \log(S/X).$$

In the region of inaction, marked by the bold segment in Figure 1, the marginal gain to increasing K, $\partial V/\partial K$, is less than r, the unit cost of increasing K. Similarly, the marginal gain to decreasing K, $-\partial V/\partial K$, is less than $r(1-\theta)$. In this simple, two-factor model where only one of the capital inputs is subject to asymmetric adjustment costs, the optimal mix of capital will always reside along this bold segment. Abel and Eberly (1996) show that uncertainty increases the separation between the marginal product of capital that justifies investment and the marginal product of capital that justifies disinvestment. Graphically, this lengthens the region of inaction. In practice, increased uncertainty makes investment behavior in long-term assets more cautious. This implies that in periods of high uncertainty, we are likely to see fewer borrowers making *any* fixed asset investments.

As noted by Nilsen and Schiantarelli (2003) and Doms and Dunne (1998), empirical investigation of firm-level investment models under uncertainty are complicated by the rarity of observations with zero investment in any period. That is not the case for the loan level data used in this study. Only approximately 5% of borrowers report making a fixed asset investment during any loan cycle, and this allows one to observe periods of inactivity that would be predicted by a model of investment under uncertainty but which are obscured by aggregation across types of capital or production units. I can test directly the prediction that fewer firms will make any fixed asset investments in periods of heightened uncertainty.[9]

In a more general setting, Eberly and Van Mieghem (1997) demonstrate that in the presence of uncertainty, $S/(K+S)$, the share of total assets in working capital, will be bounded below by its optimal level in the absence of uncertainty. Firm prefers to use working capital, the flexible factor, when long-term assets are subject to asymmetric adjustment cost. This distorts investment from its optimal composition in the absence of uncertainty.

[9] Limitations on measurement of sales data and firm-level demand shocks prevent directly testing other predictions of this model, including convexity in response of investment to demand shocks.

3 Dominican Inflation Data

This section presents estimates of inflation uncertainty in the Dominican Republic. Inflation uncertainty is measured by the conditional variance of inflation, where inflation is modeled as an autoregressive conditional heteroskedastic (ARCH) process (Engle, 1982). The ARCH family of models has a number of virtues for estimating time-series models, but for our purposes their most important feature is that they provide estimates of the conditional variance in each period. It is these predicted values that will serve as our estimates of inflation uncertainty. The analysis of Dominican inflation follows closely a long line of similar work in the United States (Engle, 1983; Cosimano and Jansen, 1988; Huizinga, 1993; Jansen, 1989).

The basic structure of the univariate ARCH can be written as

$$\pi_t = \beta' \mathbf{x}_t + u_t, \tag{2}$$

with π_t as the dependent variable and $\mathbf{x}_t$ the vector of explanatory variables, which can include lagged values of π, and u_t, the stochastic disturbance term. Conditional on the information set, Ψ_{t-1}, this disturbance is distributed

$$u_t | \Psi_{t-1} \sim N(0, h_t^2). \tag{3}$$

Unlike standard models, the variance of the disturbance is allowed to evolve over time as a function of past realizations of variables, including disturbances. In the standard ARCH model introduced by Engle (1982), the conditional variance of the disturbance term follows an AR process such that

$$E(u_t^2 | \Psi_{t-1}) = h_t^2 = \eta_0 + \eta_1 u_{t-1}^2 + \eta_2 u_{t-2}^2 + \cdots + \eta_p u_{t-p}^2, \tag{4}$$

where the lag length, p, defines the order of the ARCH process. By allowing h_t^2, the variance of the disturbance in period t, to be a function of past realizations of the disturbance itself, this formulation can capture explicitly the observed phenomenon that large and small forecast errors tend to cluster together in the inflation time series. Once the equations (2) and (4) are specified, the model is easily estimated via maximum likelihood.

The generalized autoregressive conditional heteroskedastic (GARCH) model proposed by Bollerslev (2001) lets the conditional variance depend on an infinite number of lags of u_t^2 by amending equation (4) to include lags of the expected variance term itself,

$$h_t^2 = \eta_0 + \eta_1 u_{t-1}^2 + \eta_2 u_{t-2}^2 + \cdots + \eta_p u_{t-p}^2 + \xi_1 h_{t-1}^2 + \xi_2 h_{t-2}^2 + \cdots + \xi_q h_{t-q}^2. \quad (5)$$

Disturbance terms of this form are said to follow a GARCH(q,p) process. Bollerslev demonstrates that a GARCH model with a small number of terms performs as well or better than an ARCH model with many. As shown below, that is also the case for this analysis of Dominican inflation data.

To calculate the measure of monthly inflation uncertainty that will serve as the key explanatory variable in the analysis to follow, I estimate univariate ARCH and GARCH models of the form described in equation (2) where π_t is the monthly percentage change in the consumer price index for the Dominican Republic as reported by the Central Bank of the Dominican Republic, (*Indice de precios al consumidor.*) and $\mathbf{x}_t$ includes only lagged values of π_t. Figure 1 shows monthly and annual inflation levels over the period from January 1982 to February 2008.

I estimate both models with lag lengths of 1, 3, and 6 for the autoregressive terms of π in the main estimating equation. I consider ARCH processes (equation 4) of the same lag lengths as well as GARCH$(1,1)$ and GARCH$(1,3)$ processes (equation 5).

Table 2 presents the results of selected model specifications, including summary statistics evaluating the fit—the log likelihood along with the Akaike and Bayesian information criteria. Results are not sensitive to the model specification and so the remainder of the analysis will use the first-order GARCH model, which is preferred by both information criteria. The first-order GARCH model also achieves the best information criteria when the inflation process is estimated over the shorter period from January 1998 to February 2008, which overlaps with the period for which detailed loan data for Dominican microenterprises is available. Lagrange multiplier and l tests (Cumby and Huizinga, 1992) cannot reject the hypotheses that the remaining residuals in this specification are homoskedastic.

Figure 2 plots the estimated inflation uncertainty, i.e., $\hat{h}_t$, from January 1983 through February 2008.[10] There is substantial variation in inflation uncertainty over the period, ranging from a low of 0.73 percent in August 1998 to a high of 4.80 percent in April 2004. While the series is punctuated by periods of extreme volatility, such as seen in the first half of 2004, the level of uncertainty is consistently high throughout. The mean conditional standard deviation of inflation is 1.30 percent. The comparable value for U.S. inflation volatility is 0.25 percent, less than 20% of that experienced in the Dominican Republic. In fact, the lowest level of Dominican inflation volatility recorded over the sample period is more the 60% larger than the highest level experienced in the United States. This highlights the importance of understanding the effect of inflation uncertainty on investment behavior in less developed countries, where prices tend to be relatively unstable.

4 Dominican Microenterprise Data

The primary firm-level data used in this analysis are an unbalanced panel of loan administrative data from the clients of ADOPEM, a large and well-performing microfinance institution based in the Dominican Republic. ADOPEM is a savings and credit bank based in Santo Domingo, Dominican Republic and serves primarily low-income, urban individuals. Ninety percent of ADOPEM's loans during 2006 were for amounts between RD$2,500 and RD$50,000 ($70-$1,400), and approximately 77% of their 50,000 active clients are women.

ADOPEM routinely collects summary balance sheet and profit and loss account data from all individuals that borrow from it at the time of any new loan solicitation. The available data span from January 1998 through February 2008; however, as described below, data coverage varies throughout the sample. These data are quite rich and include information on business type, sales, defaults and late payment, fixed asset and working capital balances at the time the loan is made.[11] Of note and unusual for a microfinance institution, for slightly more than 10% of our sample they also include self-reported use of proceeds at the time of the loan. Such self-reported investment intentions cap-

[10]The first twelve months of data are used to "season" the estimation.

[11]All quantitative variables were truncated at the 1st and 99th percentiles in order to limit the effect of outliers and remaining errors in the data. All of the results presented below are robust to censoring rather than truncating these outliers.

ture exactly the behavior of interest: borrowers' planned investment allocation between short- and long-term assets. This data was collected by the microfinance institution for purely informational purposes and had no bearing on the lending decision.[12] Borrowers were free to use the funds for another purpose at any time during the life of the loan. Thus I presume that borrowers did not have an incentive to misrepresent their intentions. The full sample includes 47,443 firm-loan observations on 27,771 unique firms. Of these, 11,404 firms have more than one loan recorded in the data.[13]

Table 3 presents summary statistics at the firm-loan level for the entire sample and for just those reporting use of proceeds. The substantial majority of these firms operate in the service sector and with exclusively local customers. In real 2006 terms, the average loan size over the sample is RD$21,031, or approximately $600 at then-current exchange rates. Interest rates averaged 42.6% over the sample. The mean level of business fixed assets is RD$39,280; however, the distribution of assets is heavily right skewed, with a median of only RD$13,150. The median level of investment in additional business fixed assets is zero, with only 5% of borrowers investing in *any* fixed assets. This is consistent with the theory of optimal investment under uncertainty, discussed in section 2.2, in which investments in assets with asymmetric adjustment costs exhibit hysteresis.

5 Empirical Strategy

This sections describes the empirical strategy for linking inflation uncertainty with the investment behavior and business outcomes of Dominican microfinance borrowers. The investment behavior outcomes of interest are borrowers' total business investments, investments in long-term (fixed) assets, the share of loan proceeds they allocate to working capital, and whether a borrower makes *any* long-term investments. The key explanatory variable in each case is our measure of inflation uncertainty at the time of loan origination, obtained as described in section 3.

[12]ADOPEM employs a formula-based lending system under which the maximum borrowing amount is determined as a function of monthly repayment capacity. Self-reported use of proceeds does not enter into this calculation, and both credit officers and potential borrowers are aware of this fact.

[13]This includes all firms with a non-zero borrowing amount in ADOPEM's administrative loan database.

5.1 Uncertainty and investment choice

Denote y_{it} as the value of the outcome of interest (e.g., planned real investment in long-term assets) for individual i at time t and u_t as our measure of inflation uncertainty, obtained from the fitted GARCH residuals as described in section 3. The most basic specification simply considers the conditional mean of this outcome, y_{it}, with respect to inflation uncertainty, h_t, in regression form:

$$y_{it} = \alpha_1 + \beta_1 \hat{h}_t + \varepsilon_{it}. \tag{6}$$

The equation 6 can be augmented in a number of ways. First, we can take advantage of the detailed microdata and control for a vector of firm characteristics, **X**, including trailing sales, loan size, borrowing history and business type:[14]

$$y_{it} = \alpha_2 + \beta_2 \hat{h}_t + X_{it}\delta_2 + \varepsilon_{it}. \tag{7}$$

Repeat borrowers represent 41% of the unique firms in the data and 66% of all loan-borrower observations. For such borrowers we can also utilize the panel aspect of the data to control for unobserved borrower characteristics. The corresponding estimation equation that includes borrower-level fixed effects is

$$y_{it} = \alpha_3 + \beta_3 \hat{h}_t + \tilde{X}_{it}\delta_3 + \lambda_i + \varepsilon_{it}. \tag{8}$$

Controls for other measures of systemic risk and general economic activity, including inflation levels, exchange rate levels and volatility, and national income can be included in each of these specifications. In all of the regressions, standard errors are adjusted to account for the presence of the generated regressor, $\hat{h}_t$, as described in Appendix A. Following the same basic framework, I also estimate linear probability and probit models for the intention of borrowers to make *any* investment in fixed assets. As shown in section 2.2, increased uncertainty should be associated with a reduced probability of making any such investments.

[14] One would like to have cross-sectional variation in inflation uncertainty measures based on detailed price data for the specific market in which each firm operates, e.g., volatility in the price of refrigerators and retail food for *colmados*. Unfortunately, reliable, disaggregated price data for the Dominican Republic over this period are not available.

5.2 Instrumenting for endogenous timing of borrowing decisions

To the extent that we find a relationship between inflation uncertainty and investment behavior, selection may provide part of the explanation. For example, an inflation-sensitive borrower may postpone taking a loan during periods of high uncertainty. This would lead us to underestimate the effect of inflation uncertainty on investment choice as such borrowers would only reappear in our sample once uncertainty had fallen. Such timing changes may themselves have policy relevance; however, we are interested in the direct relationship between inflation uncertainty and investment choice.

The repeat nature of microfinance borrowing provides an instrument which we can use to overcome this potential selection effect. Sixty five percent of borrowers take out another loan within one month of the due date of their previous loans. Thus I repeat the above analysis instrumenting for the uncertainty level at the time of borrowing with the uncertainty level at the time each borrower's previous loan came due.[15]

5.3 Uncertainty and investment deferral

Finally, I look for evidence of deferred investment in response to past uncertainty. The combination of uncertainty and partially irreversible investment leads firms to be more cautions in their investment decisions. But if firms respond only by delaying investments until the uncertainty is resolved, investment levels would rebound in subsequent periods and the long-term level of investment would equal that when delay was not possible (Bloom, 2000). If such deferral is occurring, we would expect that, conditional on the current environment, higher levels of uncertainty at the time of a prior loan would predict increased long-term investment in the current period. Using the panel aspect of the data, I test for this by adding to the investment model specifications described above measures of lagged uncertainty, demand growth (as measured by GNP), and their interaction to investment

[15] The validity of this instrument relies on the identifying assumption that the uncertainty environment at the time of a borrower's previous loan affects her current investment decisions only through its effect on the timing of future borrowing. Under this assumption, the instrumental variables estimates provides an unbiased estimator for the effect of inflation uncertainty on investment decisions for those individuals who borrow again. It does not account for those borrowers who, in response to the uncertainty environment, never borrow again and hence do not reappear in the sample.

model specifications described above. I estimate models of the form

$$y_{it} = \alpha_5 + \beta_5 \hat{h}_t + \phi \hat{h}_{t-1} + X_{it}\delta_5 + \varepsilon_{it}, \tag{9}$$

where $\hat{h}_{t-1}$ represents the estimated level of inflation uncertainty over the the previous loan's term. If firms' long-term investments rebound after periods of uncertainty are resolved, we would expect $\phi > 0$.[16] I also estimate this specification for two lagged loan periods.

6 Results

This section explores the empirical relationship between inflation uncertainty and small firms' investment decisions. The results suggest that periods of high inflation volatility are associated with lower investment. Investment also shifts away from fixed assets and towards working capital—the more flexible factor of production—and fixed asset investment exhibits periods of inaction consistent with models of investment under uncertainty. These associations are robust to controlling for inflation levels, GNP growth, and exchange rates, as well as restricting our attention to within-borrower behavior and instrumenting for the possibly endogenous timing of borrowing decisions.

6.1 Uncertainty and investment choice

Table 4 presents the core results linking inflation uncertainty and investment behavior. As shown in panel A, total business investment (in real 2006 Dominican pesos) falls with increased inflation uncertainty. In the most basis specification, reported in column 1, a one percentage point increase in the standard deviation of inflation is associated with a RD$2,493 reduction in total business investment. The results are similar when I include firm fixed effects (column 4). Inclusion of other macro economic indicators–current and trailing inflation, GDP growth, and the US dollar exchange rate–reduces the coefficients substantially. The coefficients remain negative, but are not statistically significant in all specifications once standard errors are corrected for the presence of the generated

[16] Where the dependent variable is the share of loan intended for working capital or an indicator for any fixed asset investment, the deferral hypothesis would predict $\phi < 0$.

regressor.[17] This suggests that with respect to total business investment, inflation volatility may be in part capturing the effect of other macroeconomic factors.

The following two panels of Table 4 demonstrate the importance of looking at investment composition. Panels B demonstrates the effect of inflation uncertainty on investment in long-term assets (in real 2006 Dominican pesos). The first column presents the results from a regression that includes the level of inflation uncertainty (as measured by the estimated conditional standard deviation of inflation from the GARCH model described in section 3) and the inflation level in the month the loan originated. Consistent with the hypothesis that increased uncertainty distorts individuals' investment decisions away from long-term assets, the coefficient on inflation uncertainty is negative and significant. A one percentage point increase in the standard deviation of inflation ($\hat{h}_t$), approximately 0.87 standard deviations over the historical period, is associated with a reduction in fixed asset investment of RD$362. Column 2 presents results for a similar regression that extends the set of controls to include one-year trailing inflation and GNP growth as well as the current exchange rate and the level of exchange rate uncertainty (estimated using the same GARCH method employed for inflation uncertainty). Column 3 adds firm and loan characteristics including quintic polynomial for sales, an indicator for whether the loan was for a new or repeat borrower, and categorical variables for business type. Columns 4 and 5 report the results of panel data regressions that include firm fixed effects. In all specifications, the coefficient on inflation uncertainty is negative, ranging from a RD$181 to RD$362, relative to a mean investment of RD$990. These results are statistically significant at the 5%-level or better in all but the most demanding specification.

Panel C focuses on another measure of investment composition, reporting the effects on the share of loan proceeds used for working capital. The same pattern is evident. In all specifications, increased inflation uncertainty is associated with an increased share of loan proceeds for working capital and a corresponding decrease in the share for fixed assets. A one percentage point increase in the standard deviation of inflation increases the share of investment in working capital by 0.73

[17]The reported standard errors in all regressions are calculated according the bootstrap procedure described in Appendix A in order to account for the presence of the generated regressor. Failure to account for the generated regressor would underestimate the standard error of the coefficient on $\hat{h}_t$ by 29% to 77% across all regressions. The effect on other estimated coefficients is substantially smaller, with bootstrapped errors generally within 10% of those estimated ignoring the presence of the generated regressor.

to 1.25 percentage points, with coefficients significant at the 1%-level in all specifications. These results support the predictions of the real option model: increased inflation uncertainty distorts firms' investments towards the more flexible factor.

The real option model also predicts that we should observe periods of inactivity with respect to investment in the irreversible asset. Table 5 presents the results of probit and linear probability model specifications of this hypothesis using the same set of explanatory variables described above. In each specification, the coefficient on inflation uncertainty is negative and significant. A one percentage point increase in the standard deviation of inflation is associated with a reduction of 0.7 to 1.7 percentage points in the probability a borrower makes any long-term investment. This effect is large relative to the mean value of 3.7%. These results strongly support the predictions of the real option model linking inflation uncertainty and investment. In periods of high inflation uncertainty, observations with *any* investment in fixed assets are less likely.

As described above, observed reductions in long-term investments could be the result of both distortions to the investment choices of individuals who borrow regardless the level of uncertainty and distortions in the timing of borrowing decisions. Table 6 reports the results from the instrumental variables specification, instrumenting for inflation uncertainty and the other included macro-level explanatory variables with the corresponding values at the time a borrower's previous loan came due. In all specifications, the coefficients on inflation volatility in the month of borrowing suggest reduced investment in long-term assets in periods of high uncertainty. The parameter estimates are broadly in line with those from the comparable OLS specifications, although they are no longer significant in the more demanding specifications.

6.2 Uncertainty and investment deferral

Finally, I look for evidence of deferred investment in response to past uncertainty, estimating equation 9 with total fixed asset investment, share of investment for working capital, and the probability of any fixed asset investment as the dependent variables. If firms' long-term investments rebound after periods of uncertainty are resolved, we should observe that conditional on the current inflation environment, high levels of past uncertainty are associated with higher levels of current fixed asset investment. As shown in Table 7, I do not find any evidence for such deferral. In every specification and for each dependent variable, the coefficients for inflation uncertainty lagged one loan cycle point in the same direction and are of a similar magnitude to those for the contemporaneous level of inflation uncertainty. Columns 4 to 6 of Table 7 include two loan period lags of inflation uncertainty. The other coefficients are robust to including these lags, and the lagged coefficients themselves show no evidence of deferral.[18]

These results suggest that inflation uncertainty may have persistent consequences; however, they should not be taken as a rejection of the deferred investment prediction from some real options investment models. The period between loan cycles may be too short to capture any deferrals, and further research is required to fully test this hypothesis.

6.3 Loans sizes and the demand channel

This subsection provides evidence for the importance of the demand channel in determining investment behavior. As noted above, observed declines in investment during periods of high inflation uncertainty could occur either because businesses request smaller loans or because financing is harder to obtain. Table 8 demonstrates that in this context, the demand channel plays an important role. As shown in columns 5 and 6, the mean loan size falls in periods of high inflation uncertainty, but the bank does not reduce overall lending. Regressions of total monthly loan volumes against inflation uncertainty and other macroeconomic indicators (shown in columns 1 and 2) are imprecisely estimated, but in no specification do they demonstrate a significant negative response to inflation uncertainty. In fact, in the more parsimonious specification, total loan volumes increase somewhat. Furthermore, in periods of high uncertainty, borrowers' requested loan amounts fall more than actual loan disbursements. The difference is RD$519 (bootstrapped p-value: < 0.01) in the basic specification of columns 3 and 5 and RD$121 (bootstrapped p-value: 0.33) when including controls for other measures of the macroeconomic environment. In both specifications we can reject at any conventional significance level the hypothesis that loan sizes are falling faster than requested bor-

[18]The correlation between current inflation uncertainty and the first and second loan cycle lags is 0.137 and -0.1934, respectively.

rowing amounts. While borrowers may be anticipating cutbacks, taken together with the observed distortion towards the more flexible factor of production, these facts support the importance of the demand channel.

7 Conclusion

This paper presents micro-level evidence for the mechanisms behind an important macroeconomic relationship: the link between inflation and investment. In periods of high inflation uncertainty, small businesses reduce their total investment. Periods of high inflation uncertainty are also associated with a shift in the mix of investment towards working capital and away from fixed assets, the less flexible factor. This drop in fixed asset investment is driven primarily by a reduction in the likelihood of any fixed asset investment. Taken together, the results support a link from inflation uncertainty to real economic activity through a real option model of investment. The results are robust to controlling for inflation levels, exchange rates, and aggregate economic activity as well as instrumenting for the possibly endogenous timing of borrowing decisions

This line of research extends existing work on the relationship between inflation uncertainty and investment in two important directions. First, it utilizes a unique panel of loan-level data to analyze firm behavior in response to inflation. In doing so, it take a step towards understanding the foundations of the negative relationship between inflation uncertainty and investment that is typically observed at the country and industry level. Most importantly, we can observe changes to the composition and timing of investment that are obscured in aggregate data. Second, it extends our understanding of this relationship to less developed countries where prices tends to be more volatile, the mechanisms available to cope with risk limited, and the potential consequences of inflation uncertainty quite large.

Given the magnitude of borrowers' responses to inflation uncertainty, it is tempting to draw welfare conclusions. However any efforts to do so are subject to two important caveats that suggest important avenues for future research. First, the observed changes in investment behavior all appear over the short run. Over the longer term, uncertainty may also dampen downward adjustment of capital stock in response to negative shocks leaving total investment unchanged. While such barriers to adjustment impose a cost on firms, the focus here is on short-run effects. It would be valuable to look at long-run empirical effects of uncertainty on investment behavior. Second, the welfare consequences of investment in small businesses are not well known. Their owners' alternative uses of capital include consumption smoothing and human capital investments, and understanding the relative welfare consequences for different uses of loan proceeds remains an open and important research question. The decision not to invest in fixed assets may also move borrowers across the entry-exit margin. Exploration of the relationship between systemic uncertainty and occupational choice provides another interesting avenue for future research.

References

Abel, Andrew, "Optimal Investment Under Uncertainty," *American Economic Review*, 1983, *73* (1), 228–233.

Abel, Andrew B and Janice C Eberly, "Optimal Investment with Costly Reversibility," *Review of Economic Studies*, 1996, *63* (4), 581–593.

Aghion, Philippe, George-Marios Angeletos, Abhijit Banerjee, and Kalina Manova, "Volatility and Growth: Credit Constraints and the Composition of Investment," *Journal of Monetary Economics*, 2010, *57* (3), 246 – 265.

Ayyagari, Meghana, Thorsten Beck, and Asli Demirgüç-Kunt, "Small and Medium Enterprises Across the Globe: A New Database," 2003. World Bank Policy Research Working Paper 3127.

Barro, Robert J., "Inflation and Growth," *Review-Federal Reserver Bank of St. Louis*, 1996, *78*, 153–169.

Bertola, Giuseppe, "Irreversible Investment," *Research in Economics*, 1998, *52*, 3–37.

Bloom, Nicholas, "The Real Options Effect of Uncertainty on Investment and Labour Demand," Technical Report, Institute for Fiscal Studies, IFS Working Papers 2000.

Bloom, Nick, Steve Bond, and John Van Reenen, "Uncertainty and Investment Dynamics," *Review of Economic Studies*, 2007, *74* (2), 391–415.

Bollerslev, Tim, "Generalized Autoregressive Conditional Heteroskedasticity," *Journal of Econometrics*, 2001, *100* (1), 131–151.

Caballero, Ricardo, "On the Sign of the Investment-Uncertainty Relationship," *American Economic Review*, 1991, *81* (1), 279–288.

Cosimano, Thomas and Dennis Jansen, "Estimates of the Variance of U.S. Inflation Based upon the ARCH Model: A Comment," *Journal of Money, Credit, and Banking*, 1988, *20* (3), 409–421.

Cumby, Robert E. and John Huizinga, "Testing the Autocorrelation Structure of Disturbances in Ordinary Least Squares and Instrumental Variables Regressions," *Econometrica*, 1992, *60* (1), 185–195.

Davidson, Russell and James G. MacKinnon, "Bootstrap Methods in Econometrics," in Kerry Patterson and Terence C. Mills, eds., *Palgrave Handbook of Econometrics: Vol. 1 Econometric Theory*, Palgrave Macmillan, 2006, pp. 812–38.

Dixit, Avinash, "Entry and Exit Decisions under Uncertainty," *Journal of Political Economy*, 1989, *97* (3), 620–638.

_ , "Investment and Employment Dynamics in the Short Run and the Long Run," *Oxford Economic Papers*, 1997, *49* (1), 1–20.

Doms, Mark and Timothy Dunne, "Capital Adjustment Patterns in Manufacturing Plants," *Review of Economic Dynamics*, 1998, *1* (2), 409–429.

Dotsey, Michael and Pierre-Daniel Sarte, "Inflation Uncertainty and Growth in a Cash-in-Advance Economy," *Journal of Monetary Economics*, 2000, *45* (3), 631–655.

Eberly, Janice C and Jan A Van Mieghem, "Multi-factor Dynamic Investment under Uncertainty," *Journal of Economic Theory*, 1997, *75* (2), 345–387.

Engle, Robert F., "Autoregressive Conditional Heteroscedasticity with Estimates of the Variance of United Kingdom Inflation," *Econometrica*, 1982, *50* (4), 987–1007.

_ , "Estimates of the Variance of U.S. Inflation Based upon the ARCH Model," *Journal of Money, Credit, and Banking*, 1983, *15* (3), 286–301.

Fischer, Stanley, "The Role of Macroeconomic Factors in Growth," *Journal of Monetary Economics*, 1993, *32* (3), 485–512.

_ **and Franco Modigliani**, "Towards an Understanding of the Real Effects and Costs of Inflation," *Review of World Economics*, 1978, *114* (4), 810–833.

Friedman, Milton, "Nobel Lecture: Inflation and Unemployment," *Journal of Political Economy*, 1977, *85* (3), 451–472.

Hartman, Richard, "The Effects of Price and Cost Uncertainty on Investment," *Journal of Economic Theory*, 1972, *5* (2), 258–266.

Holland, A. Steven, "Inflation Regimes and the Sources of Inflation Uncertainty: Comment," *Journal of Money, Credit, and Banking*, 1993, *25* (3), 514–520.

Huizinga, John, "Inflation Uncertainty, Relative Price Uncertainty, and Investment in U.S. Manufacturing," *Journal of Money, Credit, and Banking*, 1993, *25* (3), 521–549.

Jansen, Dennis, "Does Inflation Uncertainty Affect Output Growth? Further Evidence," *Federal Reserve Bank of St. Louis Review*, 1989, *71* (4), 43–54.

Judson, Ruth and Athanasios Orphanides, "Inflation, Volatility and Growth," *International Finance*, 1999, *2* (1), 117–138.

Lee, Jaewoo and Kwanho Shin, "The Role of a Variable Input in the Relationship between Investment and Uncertainty," *American Economic Review*, 2000, *90* (3), 667–680.

Lucas, Robert, "Some International Evidence on Output-Inflation Tradeoffs," *American Economic Review*, 1973, *63* (3), 326–334.

Nilsen, Oivind Anti and Fabio Schiantarelli, "Zeros and Lumps in Investment: Empirical Evidence on Irreversibilities and Nonconvexities," *Review of Economics and Statistics*, 2003, *85* (4), 1021–1037.

Pindyck, Robert S., "Irreversible Investment, Capacity Choice, and the Value of the Firm," *American Economic Review*, 1988, *78* (5), 969–985.

_ , "Irreversibility, Uncertainty, and Investment," *Journal of Economic Literature*, 1991, *29* (3), 1110–1148.

_ , "A Note on Competitive Investment under Uncertainty," *American Economic Review*, 1993, *83* (1), 273–277.

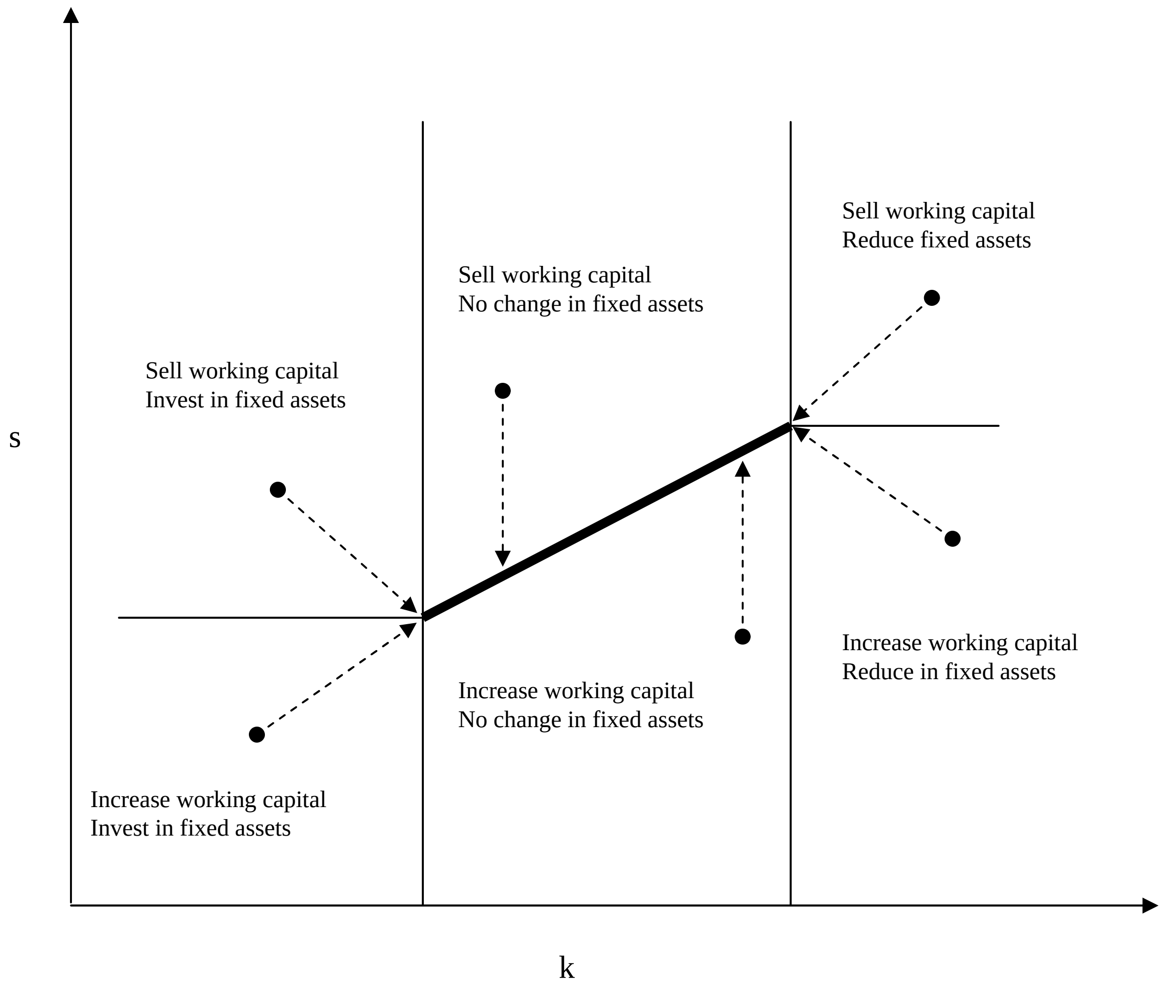
_ **and Andres Solimano**, "Economic Instability and Aggregate Investment," Working Paper 4380, National Bureau of Economic Research 1993.

Ramey, Garey and Valerie A. Ramey, "Cross-Country Evidence on the Link between Volatility and Growth.," *American Economic Review*, 1995, *85* (5), 1138 – 1151.

Sakellaris, Plutarchos, "A Note on Competitive Investment under Uncertainty: Comment," *American Economic Review*, 1994, *84* (4), 1107–1112.

Zeira, Joseph, "Cost Uncertainty and the Rate of Investment," *Journal of Economic Dynamics and Control*, 1990, *14* (1), 53–63.

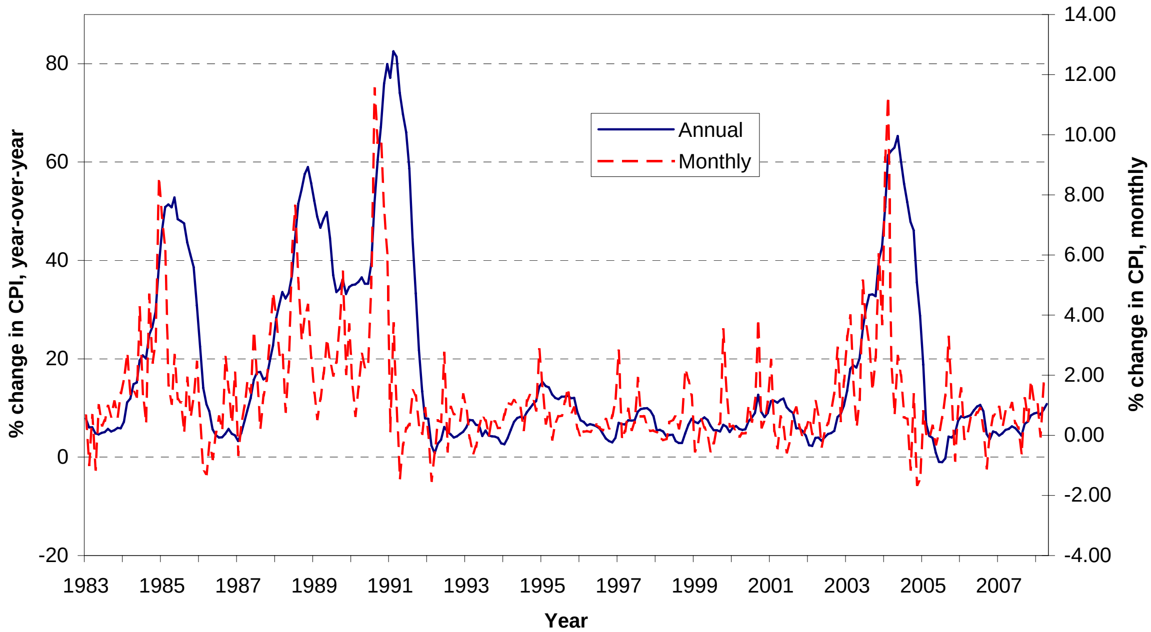
Figure 1: Optimal Investment Policy



Notes: *s*=log(*S/X*) and *k*=log(*K/X*) where *S* represents short-term assets (working capital), *K* represents long-term assets, and X represents the index of demand and productivity conditions. Dashed arrows indicate optimal policy responses.

Figure 2: Dominican Republic Consumer Price Inflation

January 1983 to April 2008

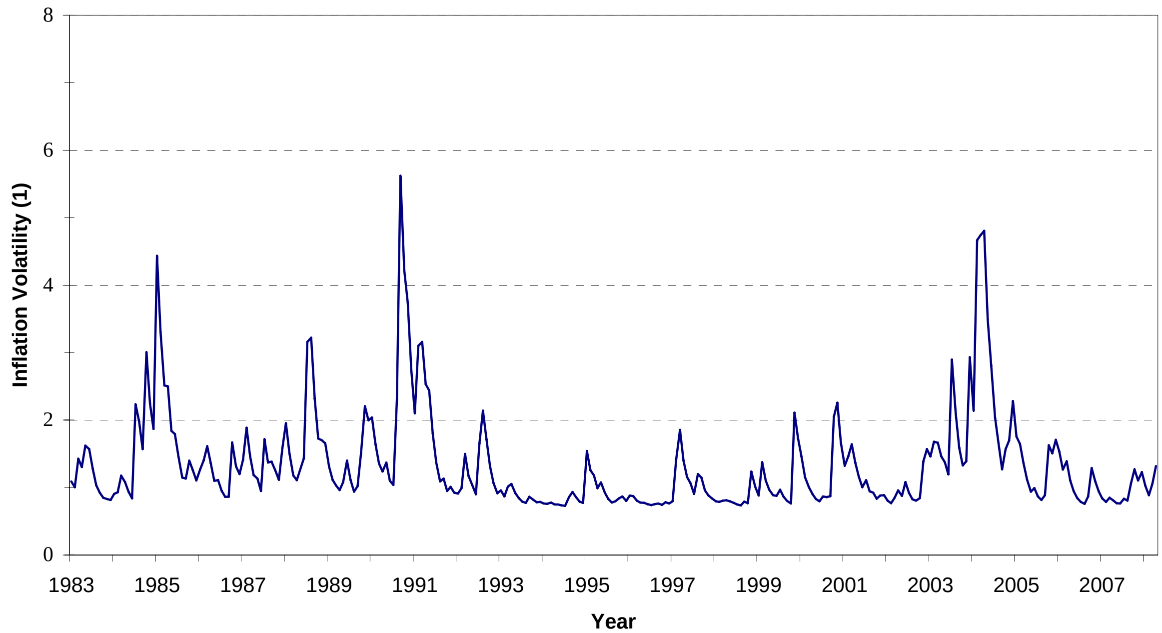


Notes:

(1) Percent change in seasonally adjusted consumer price index *indice de precios al consumidor* .

Figure 3: Dominican Republic Monthly Consumer Price Inflation Volatility

January 1983 to April 2008



Notes:

(1) Conditional standard deviation of seasonally adjusted consumer price index indice de precios al consumidor, calculated based on GARCH(1,1) model.

Table 1: Example of effect of uncertainty on investment decision

Initial capital expenditures	8,000		
Monthly discount rate	2%		
	Certain Profit Stream	Uncertain Profit Stream	
		Profit stream ±50% resolved in one month	
Invest today	Certain	High	Low
Probability	- -	0.50	0.50
Monthly expected profits	200	300	100
Discounted value of profits	10,000	15,000	5,000
Expected NPV	2,000	2,000	
Wait for one month and decide			
Monthly expected profits	200	300	100
Discounted value of profits	10,000	15,000	5,000
NPV		7,000	(3,000)
Expected NPV	2,000	3,500	(1,500)
Make investment	*yes*	*yes*	*no*
Expected NPV		3500	0
Expected NPV	2000	3500	
Discounted NPV	1,961	3,431	
Optimal strategy	***Invest today***	***Wait***	

Notes: Corresponds to the investment choice and uncertainty example discussed in section 2, which follows closely work by Huizinga (1993) and Pindyck (1991).

Table 2: Inflation uncertainty estimates & model diagnostics

	ARCH Model 1 (1)	ARCH Model 2 (2)	ARCH Model 3 (3)	GARCH Model 1 (4)	GARCH Model 2 (5)
Model parameters					
AR (p)	1	1	3	1	1
ARCH (q)	1	3	3	1	3
GARCH (r)	- -	- -	- -	1	1
Parameter estimates					
ρ_0 $(x10^3)$	9.607	8.261	8.208	8.178	8.145
	(1.994)	(2.171)	(2.223)	(2.113)	(2.095)
ρ_1	0.675	0.637	0.673	0.637	0.640
	(0.015)	(0.038)	(0.073)	(0.054)	(0.058)
ρ_2			-0.112		
			(0.075)		
ρ_3			0.077		
			(0.056)		
η_0 $(x10^3)$	0.086	0.061	0.063	0.026	0.025
	(0.009)	(0.007)	(0.007)	(0.006)	(0.010)
η_1	0.895	0.536	0.527	0.446	0.510
	(0.146)	(0.096)	(0.107)	(0.080)	(0.098)
η_2		0.145	0.161		-0.117
		(0.035)	(0.044)		(0.101)
η_3		0.154	0.121		0.069
		(0.046)	(0.052)		(0.061)
ξ_1				0.494	0.493
				(0.066)	(0.169)
Model diagnostics					
Unconditional variance	2.64	2.29	2.24	2.29	2.32
log likelihood	927.6	945.7	947.0	946.5	947.4
AIC	-1847.1	-1879.5	-1878.0	-1882.9	-1880.8
BIC	-1832.1	-1856.9	-1848.0	-1864.2	-1854.6

Notes: These are estimation results for equations (2) through (5) with lag lengths as indicated. AIC is the Akaike Information Criterion and BIC is the Bayesian Information Criterion. Inflation series data based on monthly consumer price index (*Indice de precios al consumidor*) as reported by the Central Bank of the Dominican Republic for the from January 1982 to February 2008.

Table 3: Summary statistics for borrower data

A. Loan Characteristics	Mean (1)	Median (2)	Standard Deviation (3)
Actual loan size, real	21,031	15,443	18,016
Monthly sales, real	36,571	29,000	27,435
Annual interest rate (%)	53.7	60.0	9.7
Default rate (%)	1.4	0.0	11.7
Days late payment during loan	15.5	0.0	47.9
Fixed assets, business, real	39,280	13,150	74,238
Share of requested amount intended for working capital	96.6	100.0	18.0

B. Business Types	n	%
Clothing store	9,408	19.8%
Convenience store or grocery	13,879	29.3%
Restaurant	4,511	9.5%
Personal care	8,293	17.5%
Other	11,352	23.9%
Total	47,443	

Notes: Real amounts in Dominican pesos indexed based on Dominican consumer price index, January 2006.

Table 4: Investment and asset allocation

	(1)	(2)	(3)	(4)	(5)
A. Business investment (real)					
Inflation uncertainty, month of borrowing	-2,493.3***	-357.9	-576.5*	-2,034.7**	-320.7
	(644.2)	(388.0)	(328.4)	(871.6)	(678.2)
Inflation level, month of borrowing	-68.8	-49.5	-415.3***	-465.0***	-1,072.1***
	(74.4)	(55.1)	(48.7)	(116.0)	(134.7)
Inflation level, year-over-year		-214.1***	-215.9***		-489.9***
		(25.3)	(22.4)		(121.1)
GNP growth, year-over-year		-206.5**	62.9		-59.2
		(84.2)	(74.8)		(178.1)
Exchange rate, month of borrowing		116.7***	528.0***		1,102.5***
		(39.9)	(33.9)		(200.1)
B. Fixed asset investment (real)					
Inflation uncertainty, month of borrowing	-362.6***	-194.8**	-204.9**	-273.7**	-181.0
	(86.5)	(83.9)	(82.8)	(113.7)	(168.3)
Inflation level, month of borrowing	-44.8***	-90.7***	-107.1***	-46.6*	-148.5***
	(11.0)	(13.8)	(14.1)	(24.0)	(39.3)
Inflation level, year-over-year		-57.7***	-58.7***		-68.4***
		(6.7)	(6.7)		(16.3)
GNP growth, year-over-year		12.8	21.5		4.5
		(21.7)	(21.8)		(48.9)
Exchange rate, month of borrowing		150.3***	169.1***		187.4***
		(10.9)	(12.6)		(27.3)
C. Share of loan intended for working capital (%)					
Inflation uncertainty, month of borrowing	1.25***	0.74***	0.73***	0.78***	0.80***
	(0.26)	(0.25)	(0.25)	(0.22)	(0.30)
Inflation level, month of borrowing	0.18***	0.29***	0.29***	0.10**	0.30***
	(0.03)	(0.03)	(0.03)	(0.05)	(0.07)
Inflation level, year-over-year		0.17***	0.17***		0.13***
		(0.01)	(0.01)		(0.02)
GNP growth, year-over-year		-0.19***	-0.18***		-0.12*
		(0.04)	(0.04)		(0.07)
Exchange rate, month of borrowing		-0.49***	-0.49***		-0.43***
		(0.02)	(0.02)		(0.04)
Controls					
Sales (quintic polynomial)	-	-	x	x	x
New or repeat borrower	-	-	x	-	-
Business type	-	-	x	-	-
Individual Fixed Effects	-	-	-	x	x
N	47,443	47,443	47,443	31,076	31,076

Notes: Dependent variable listed in panel heading; regressors below. Table reports coefficient estimates with bootstrapped standard errors, calculated as described in Appendix A, in parentheses. *** Significant at 1%; ** significant at 5%; * significant at 10%. Loan size is quintic polynomial of total real loan amount, business type includes indicators for clothing stores, food stores, restaurants, beauty & fashion and other. Fixed effects regressions include only those borrowers reporting multiple loans. All amounts in real Dominican pesos indexed based on Dominican consumer price index, January 2006.

Table 5: Any fixed asset investment

	(1)	(2)	(3)	(4)
A. Any fixed asset investment, Probit Marginal Effect at means (%)				
Inflation uncertainty, month of borrowing	-1.66***	-0.98***	-0.95***	
	(0.32)	(0.22)	(0.21)	
Inflation level, month of borrowing	-0.25***	-0.32***	-0.32***	
	(0.05)	(0.05)	(0.05)	
Inflation level, year-over-year		-0.12***	-0.12***	
		(0.01)	(0.01)	
GNP growth, year-over-year		0.04***	0.04***	
		(0.01)	(0.01)	
Exchange rate, month of borrowing		0.40***	0.39***	
		(0.02)	(0.02)	
B. Any fixed asset investment, Linear Probability Model (%)				
Inflation volatility, month of borrowing	-1.22***	-0.78***	-0.77***	-0.79**
	(0.25)	(0.26)	(0.26)	(0.31)
Inflation level, month of borrowing	-0.17***	-0.29***	-0.30***	-0.30***
	(0.03)	(0.04)	(0.04)	(0.07)
Inflation level, year-over-year		-0.17***	-0.17***	-0.13***
		(0.02)	(0.02)	(0.02)
GNP Growth, year-over-year		0.16***	0.16***	0.11
		(0.05)	(0.05)	(0.07)
Exchange rate, month of borrowing		0.49***	0.50***	0.43***
		(0.02)	(0.02)	(0.04)
Controls				
New or repeat borrower	-	-	x	-
Business type	-	-	x	-
Individual Fixed Effects	-	-	-	x

Notes: Dependent variable listed in italicized panel heading; regressors below. Table reports coefficient estimates with bootstrapped standard errors, calculated as described in Appendix A, in parentheses. *** Significant at 1%; ** significant at 5%; * significant at 10%. Loan size is quintic polynomial of total real loan amount, business type includes indicators for clothing stores, food stores, restaurants, beauty & fashion and other. Fixed effects regressions include only those borrowers reporting multiple loans. All amounts in real Dominican pesos indexed based on Dominican consumer price index, January 2006.

Table 6: Investment and asset allocation, instrumental variables estimation

Instrumenting based on due date of previous loan

	(1)	(2)	(3)	(4)	(5)
A. Business investment (real)					
Inflation uncertainty, month of borrowing	-3,893.2***	-565.3	-213.3	-4,201.1***	-1,380.2
	(1216.7)	(2065.4)	(1632.0)	(592.5)	(1774.2)
Inflation level, month of borrowing	-34.0	-385.7	-219.1	0.6	-1,553.0***
	(182.9)	(284.0)	(247.5)	(165.3)	(460.2)
Inflation level, year-over-year		-328.5***	-183.7**		-668.6***
		(102.2)	(88.2)		(100.3)
GNP growth, year-over-year		-477.2	-115.0		-776.7**
		(455.5)	(424.3)		(334.5)
Exchange rate, month of borrowing		296.6***	532.9***		1,486.4***
		(98.4)	(90.9)		(79.1)
B. Fixed asset investment (real)					
Inflation uncertainty, month of borrowing	-472.4***	-182.7	-167.0	-285.8**	-589.5
	(146.9)	(289.8)	(302.9)	(133.1)	(439.3)
Inflation level, month of borrowing	-125.3***	-256.1***	-239.7***	-67.6	-220.4**
	(29.9)	(50.2)	(49.7)	(44.9)	(103.3)
Inflation level, year-over-year		-109.0***	-99.4***		-75.2***
		(20.6)	(21.6)		(28.5)
GNP growth, year-over-year		-107.9*	-91.4		-6.5
		(60.3)	(61.2)		(76.3)
Exchange rate, month of borrowing		256.0***	256.5***		280.4***
		(28.9)	(30.3)		(38.8)
C. Share of loan intended for working capital (%)					
Inflation uncertainty, month of borrowing	1.47***	0.62	0.64	0.71***	1.58*
	(0.36)	(0.73)	(0.76)	(0.27)	(0.89)
Inflation level, month of borrowing	0.46***	0.72***	0.70***	0.26***	0.34*
	(0.08)	(0.11)	(0.11)	(0.09)	(0.19)
Inflation level, year-over-year		0.31***	0.30***		0.11**
		(0.04)	(0.05)		(0.05)
GNP growth, year-over-year		0.20	0.19		-0.23*
		(0.13)	(0.14)		(0.13)
Exchange rate, month of borrowing		-0.74***	-0.72***		-0.52***
		(0.05)	(0.05)		(0.06)
D. Any fixed asset investment (%)					
Inflation uncertainty, month of borrowing	-1.41***	-0.57	-0.57	-0.72***	-1.53*
	(0.37)	(0.78)	(0.80)	(0.27)	(0.90)
Inflation level, month of borrowing	-0.45***	-0.75***	-0.73***	-0.25***	-0.36*
	(0.08)	(0.12)	(0.12)	(0.10)	(0.19)
Inflation level, year-over-year		-0.31***	-0.30***		-0.12**
		(0.04)	(0.05)		(0.05)
GNP growth, year-over-year		-0.23*	-0.22		0.19
		(0.14)	(0.14)		(0.13)
Exchange rate, month of borrowing		0.74***	0.72***		0.53***
		(0.05)	(0.05)		(0.06)
Controls					
Sales (quintic polynomial)	-	-	x	x	x
Loan size (quintic polynomial)	-	-	x	-	-
New or repeat borrower	-	-	x	-	-
Business type	-	-	x	-	-
Individual Fixed Effects	-	-	-	x	x
N	30,395	30,395	30,395	23,922	23,922

Notes: Dependent variable listed in italicized panel heading; regressors below. Table reports coefficient estimates with bootstrapped standard errors, calculated as described in Appendix A, in parentheses. *** Significant at 1%; ** significant at 5%; * significant at 10%. Loan size is quintic polynomial of total real loan amount, business type includes indicators for clothing stores, food stores, restaurants, beauty & fashion and other. Fixed effects regressions include only those borrowers reporting multiple loans. Inflation uncertainty and all other macro economic variables at time of loan instrumented for with corresponding variables at time prior loan came due. All amounts in real Dominican pesos indexed based on Dominican consumer price index, January 2006.

Table 7: Investment deferral from past loan cycles

	(1)	(2)	(3)	(4)	(5)	(6)
A. Fixed asset investment (real)						
Inflation uncertainty, month of borrowing	-370.2***	-172.4	-341.4	-411.6***	-154.6	-343.8
	(122.6)	(107.3)	(258.1)	(103.4)	(106.8)	(246.4)
Inflation level, month of borrowing	-77.0***	-117.6***	-70.2	-84.8***	-145.2***	-100.9*
	(19.6)	(23.7)	(52.0)	(19.7)	(23.8)	(52.1)
Inflation uncertainty, last loan period	-227.9*	-155.4	-130.1	-288.4**	-239.0	-156.1
	(121.7)	(147.5)	(176.3)	(123.1)	(146.9)	(184.4)
Inflation uncertainty, two loans prior				196.6	-103.4	226.9
				(177.9)	(143.7)	(286.3)
B. Share of loan intended for working capital (%)						
Inflation uncertainty, month of borrowing	1.23***	0.73***	0.90**	1.31***	0.77***	1.03***
	(0.31)	(0.25)	(0.42)	(0.25)	(0.25)	(0.40)
Inflation level, month of borrowing	0.24***	0.32***	0.16*	0.22***	0.37***	0.19**
	(0.04)	(0.05)	(0.09)	(0.04)	(0.05)	(0.09)
Inflation uncertainty, last loan period	0.61***	0.54**	0.07	0.66***	0.61**	0.13
	(0.20)	(0.27)	(0.33)	(0.20)	(0.27)	(0.36)
Inflation uncertainty, two loans prior				-0.51	0.50	-0.60
				(0.42)	(0.32)	(0.53)
C. Any fixed asset investment, Linear Probability Model (%)						
Inflation uncertainty, month of borrowing	-1.20***	-0.78***	-0.90**	-1.30***	-0.82***	-1.03**
	(0.31)	(0.27)	(0.43)	(0.26)	(0.27)	(0.41)
Inflation level, month of borrowing	-0.23***	-0.33***	-0.15*	-0.21***	-0.37***	-0.17*
	(0.04)	(0.05)	(0.09)	(0.04)	(0.05)	(0.09)
Inflation level, year-over-year		-0.16***			-0.17***	
		(0.02)			(0.02)	
GNP growth, year-over-year		0.19**			0.19**	
		(0.07)			(0.07)	
Exchange rate, month of borrowing		0.50***			0.51***	
		(0.04)			(0.04)	
Inflation uncertainty, last loan period	-0.63***	-0.56**	-0.07	-0.68***	-0.62**	-0.12
	(0.21)	(0.27)	(0.33)	(0.21)	(0.27)	(0.36)
Inflation uncertainty, two loans prior				0.43	-0.54*	0.56
				(0.41)	(0.32)	(0.53)
Controls						
Other macro environment†	-	x	-	-	x	-
Business characteristics	-	x	-	-	x	-
Individual fixed effects	-	-	x	-	-	x
N	30,528	30,528	24,041	19,584	19,584	15,401

Notes: Dependent variable listed in panel heading; regressors below. Table reports coefficient estimates with bootstrapped standard errors, calculated as described in Appendix A, in parentheses. *** Significant at 1%; ** significant at 5%; * significant at 10%. Other macro environment variables comprise current inflation levels, current GNP growth, and exchange rates. Business characteristics include quintic polynomial of sales, business type and borrowing status (new or repeat borrower). Fixed effects regressions include only those borrowers reporting multiple loans. All regressions include only those observations for which sufficient prior loan period data is available.All amounts in real Dominican pesos indexed based on Dominican consumer price index, January 2006.

Table 8: Loan volumes and the demand channel

	Total monthly loan volume (RD$000)		Mean loan amount requested†		Mean loan disbursed†	
	(1)	(2)	(3)	(4)	(5)	(6)
Inflation uncertainty, month of borrowing	5,388***	-774	-2,554***	-340	-2,035***	-218
	(2028)	(1665)	(663)	(394)	(516)	(215)
Inflation level, month of borrowing	451	3	-47	-2	61	204***
	(592)	(467)	(75)	(56)	(47)	(38)
Inflation level, year-over-year		371***		-203***		-83***
		(91)		(25)		(14)
GNP growth, year-over-year		-3		-208**		-188***
		(370)		(85)		(42)
Exchange rate, month of borrowing		52		63		-222***
		(131)		(40)		(24)
N	82	82	46,815	46,815	46,815	46,815

Notes: Dependent variable listed in panel heading; regressors below. Table reports coefficient estimates with bootstrapped standard errors, calculated as described in Appendix A, in parentheses. *** Significant at 1%; ** significant at 5%; * significant at 10%. Other macro environment variables comprise current inflation levels, current GNP growth, and exchange rates. Business characteristics include quintic polynomial of sales, business type and borrowing status (new or repeat borrower). Fixed effects regressions include only those borrowers reporting multiple loans. All regressions include only those observations for which sufficient prior loan period data is available. All amounts in real Dominican pesos indexed based on Dominican consumer price index, January 2006.

A Inference

The following appendix describes the empirical strategy to account for the presence of generated regressors and conduct valid inference when estimating the effect of inflation uncertainty on investment choice. The measure of inflation uncertainty included in equations (6) through (10) of Section 5 is calculated from monthly Dominican CPI data using an autoregressive process of the form

$$\pi_t = \rho_0 + \rho_1 \pi_{t-1} + u_t, \tag{10}$$

where π_t is reported CPI inflation in month t and u_t is the conditionally-heteroskedastic, stochastic disturbance term distributed $u_t|\Psi_{t-1} \sim N(0, h_t^2)$. For clarity, we can rewrite $u_t = v_t h_t$ where $v_t \overset{iid}{\sim} N(0,1)$. Based on various information criteria discussed in Section 3, the preferred model is GARCH(1,1), such that

$$h_t^2 = \eta_0 + \eta_1 u_{t-1}^2 + \xi_1 h_{t-1}^2. \tag{11}$$

This model yields estimates of $\hat{\theta} \equiv \{\hat{\rho}_0, \hat{\rho}_1, \hat{\eta}_0, \hat{\eta}_1, \hat{\xi}_1\}$ as well as predicted values of $\widehat{h_t}$.

I use the predicted standard deviation of inflation, $\widehat{h_t}$, as an explanatory variable in regressions predicting investment behavior of small enterprises. Those regressions take the form

$$y_{it} = \alpha + \beta X_{it} + \gamma_1 \widehat{h_t} + \gamma_2 \widehat{h_t} X_{it} + \delta M_t + \varepsilon_{it}, \tag{12}$$

where X_{it} is a vector of characteristics for firm i at time t and M_t is a vector of other macro economic variables (e.g., exchange rate, GDP growth, etc.) at time t.

Calculation of standard errors in estimates of (12) need to be adjusted to reflect the fact that the measure of inflation uncertainty, $\widehat{h_t}$, is a generated regressor. To do so, I execute the following bootstrap algorithm. First, I generate a bootstrap draw for the entire history of the inflation series. Following Davidson and MacKinnon (2006), I bootstrap the DGP based on the estimates $\hat{\eta}_0$, $\hat{\eta}_1$, and $\hat{\xi}_1$ from (11). I then generate draws of $v^{*(b)}$ drawing each $v_t^{*(b)}$ from an independent standard normal distribution. Because the GARCH model is recursive, I initialize the process setting $h_1^{2*(b)} = \hat{\eta}_0/(1-\hat{\eta}_1-\hat{\xi}_1)$, the stationary variance of the error process. I then generate $u_1^{*(b)} = v_1^{*(b)} h_1^{*(b)}$ and the remainder of the series recursively: $h_i^{*(b)} = \hat{\eta}_0 + \hat{\eta}_1 \left(u_{i-1}^{*(b)} \right)^2 + \xi_1 h_{i-1}^{*(b)}$ and $u_i^{*(b)} = v_i^{*(b)} h_i^{*(b)}$ for $i = 2, ...T$. The full inflation series is constructed mechanically from (10) using the estimated values of $\hat{\rho}_0$ and $\hat{\rho}_1$. I then calculate the GARCH parameters, $\hat{\theta}^{(b)}$, from this bootstrap sample. Using these estimated parameters and the observed inflation series, I calculate a bootstrap sample disturbance and variance series by substituting into equations (10) and (11). Second, I merge the bootstrapped inflation series into the loan-level panel data and draw a bootstrap sample with replacement from the panel, with blocks at the individual firm level. Using this sample, I generate a bootstrap estimate for each parameter in (12), e.g., $\hat{\gamma}_1^{*(b)}$. I repeat these steps $B = 500$ times, obtaining B bootstrap replications of the parameters of interest and calculate the bootstrap estimate of variance in the usual way. For example, the bootstrap estimate of variance for $\hat{\gamma}_1$ is $s_{\hat{\gamma}}^2 = (B-1)^{-1} \sum_{b=1}^{B} (\hat{\gamma}^{*(b)} - \hat{\gamma}^*)$, where $\hat{\gamma}^* = B^{-1} \sum_{b=1}^{B} \hat{\gamma}^{*(b)}$. The square root of $s_{\hat{\gamma}}^2$ yields the bootstrap standard error.