

Investment and Uncertainty in Machinery and Real Estate*

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Contents: 1. Introduction; 2. A Model of Investment in Buildings and Machines; 3. Empirical Assessment; 4. Concluding Remarks; A. Appendix 1.

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O investimento é geralmente tratado como uma variável homogênea na literatura. As grandes diferenças na natureza dos insumos empregados em projetos de investimento levam a idéias interessantes que não são capturadas pela abordagem tradicional. Nesse artigo eu decompou o investimento em máquinas e imóveis e examino o impacto da incerteza econômica sobre cada um desses componentes. Utilizando métodos de estimação com dados em painel para a indústria brasileira, encontramos evidências de que a incerteza reduz ambos os tipos de investimento. Entretanto, o efeito parece ser mais intenso com máquinas, o que poderia ser uma consequência de um custo de reversibilidade mais alto.

Investment is usually treated as an homogeneous variable in the literature. The wide differences in the nature of inputs used in investment projects may lead to interesting insights that are not captured in the conventional approach. In this paper I decompose investment in machinery and industrial real estate and examine the impact of economic uncertainty on each of these components. Using panel data estimation methods for the Brazilian industry, I found that uncertainty exerts a harmful effect on both types of investment. However, the effect is much more intense with machines, which possibly is a consequence of their high reversibility costs.

1. INTRODUCTION

One of the most prominent topics of the modern research in investment theory has been the sensitivity of investment to changes in the level of uncertainty. The early models focus on the fact that

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greater uncertainty increases the marginal profitability of capital and, as a consequence, raises investment (see Abel (1983)). This assertion is based on the convexity of the profit function in prices, which means that the average profit tends to be higher with volatile than with fixed prices.

In the late eighties and nineties economists have recognized the importance of the irreversible nature of investment on the theoretical discussion (see, for example, Pindyck (1988)). In essence, the introduction of asymmetric adjustment cost hypothesis sharply shifts the results, pointing out a negative relationship between investment and uncertainty. The idea is to associate investment opportunities with the rationale of financial options. A firm that decides to carry on an irreversible investment project abdicates the option of waiting for new information and postponing the rise in capacity. The economic value of this option rises in a largely uncertain environment. In this case, the increased fear of being committed to a project that turns out to be unprofitable leads to a delay in the decision in order to keep the investment option alive. By that means, uncertainty can hinder investment. Further contributions to the debate are given by Caballero (1991), who demonstrates that the degree of market competitiveness, besides the asymmetry of capital adjustment costs, greatly influences the sign of the investment-uncertainty relationship.

More recently, there have been some attempts to put the traditional theory and options approach together. Abel et al. (1996) emphasize that, in addition to the reversibility costs, firms also face expandability costs, since the acquisition price of capital may be higher in the future (due to the fact that the expanded capacity may also become profitable to the other competing firms, increasing the demand and the price of capital inputs). If a firm faces large expandability costs, a rise in uncertainty should induce firms to invest. This insight clarifies that, under both q-theory and options pricing approaches, uncertainty has an ambiguous effect on investment. The balance between reversibility and expandability costs determines whether an increase in uncertainty yields a discouragement or an incentive to invest.

The ambiguity of analytical findings stimulated the emergence of an empirical literature mostly directed to the U.K. and U.S. cases.¹ A number of studies deal with aggregate data using time series methods (see Price (1995, 1996)). There has been, however, a growing number of authors who use panel data techniques applied to groups of industrial companies (Henley, 1999), industrial sectors (Campa and Goldberg, 1993) and developing countries (Sérvén, 1998, Pindyck and Solimano, 1993). These works conclude mostly that more uncertainty leads to less investment.

In this paper we consider the heterogeneity of production goods, in the sense that investment may have different properties whether it is in the form of machinery or in the form of real estate. The issue of investment heterogeneity has been tackled before in the literature. A recent example is the work of Cruz and Pommeret (2006), in which embodied technology is introduced in a Pindyck (1988) framework of investment under uncertainty. These authors introduce capital heterogeneity in the sense that every capital has a certain vintage. Capital vintages differ in terms of the amount of energy required for them to operate.

Here we introduce an idea that, to the best of our knowledge, has not yet been addressed in the literature, which is the fact that uncertainty may not affect different types of investment in the same way. For example, investment in industrial real estate is typically much less industry- and firm-specific than investment in machines. While the resale of used machinery may face thin markets with few potential buyers, there are numerous possibilities for the conversion of an industrial building, or even a white-collars office building, into other economic usage. Therefore, one should expect that buildings have smaller reversibility costs than machines. Intuitively, the implication would be that an increased uncertainty worsens investment in machinery much more than investment in buildings. In this paper the validity of this assertion is examined. To do so, I build a model a la Abel et al. (1996), in which reversibility and expandability costs play a key role. However, I split capital stock into buildings and machinery. The idea is to analyze how these two forms of investment react to changes in their resale

¹For a broad discussion of this literature, see Carruth and Henley (1999).

and future purchase prices. The model provides theoretical support for an empirical investigation of the relationships between uncertainty and both types of investment. Along these lines, I use panel data techniques in a sample of twenty-two Brazilian industrial sectors with thirty years of annual data.

The issue of how to measure uncertainty is also discussed in the paper. Most of the empirical studies of uncertainty and investment use sample variability as a proxy for uncertainty. However, this proxy lacks accuracy as long as rational agents may partly predict fluctuations using information contained in their past behavior. Uncertainty should correspond only to the unpredictable changes of the variable. We follow Sérven (1998), adopting an alternative measure of uncertainty, based on the estimation of a generalized conditional heteroskedastic (GARCH) model.

The paper is organized as follows. Section 2 presents the extended version of Abel's model, with investment in Buildings and Machines. Section 3 sets out the empirical approach and presents the main results for the Brazilian economy. Final conclusions are presented in section 4.

2. A MODEL OF INVESTMENT IN BUILDINGS AND MACHINES

2.1. The Problem of the Firm

A firm that decides to hold an investment project typically acquires several types of capital goods. The rise in capacity may involve the construction of a new building, the acquisition of machines, or even the purchase of computers, trucks and other durable goods used in the production process. A given expansion of capital stock can be accomplished through different investment plans. A natural question that comes up from such assertions is to know whether the mechanisms that drive investment decision are the same for the different types of investment. Specifically, do the macroeconomic circumstances that stimulate the purchase of new machines also favor a building-intensive investment project?

A great part of the recent investment literature has combined the uncertainty over future profitability of capital with the fact that investment may be partly or completely irreversible. In this regard, an important result is that the effect of uncertainty on investment depends on its degree of irreversibility. The larger are the discounts involved with capital stock resale, the most attractive is the option of waiting for new information and postponing the investment decision in an uncertain environment. Thereby, when capital cannot be easily reverted, uncertainty tends to hamper investment more intensely.

Interesting insights can be attained through the disaggregation of capital stock into its two main components, namely, machines and buildings. An important stylized fact is that the former is much more firm- and industry-specific than the later. A shoe factory building that shelters the production line may be directed, for example, towards a furniture manufacturing process when the market conditions for shoes change adversely. Yet, the machines used to produce shoes cannot be easily sold due to narrow markets. Certainly there are not many potential buyers for such machines. Besides that, the few possible buyers are subject to the same adverse market conditions that lead to the firm's decision of selling its capital stock. The shoe manufacturer is induced to sell the equipment exactly when no one else is interested in acquiring it.

In this section we present a two-period model of a representative firm that must decide how much to invest in period one, subject to uncertain returns in period two. The firm's return is deterministic in period one, but it is stochastic in period two. Investment can be held in two forms: buildings and machinery. The idea is to extend the analysis of Abel et al. (1996) by separating capital input in its two main components. We assume that capital stock installed in period one is not completely irreversible. It can be sold in period two, but the resale price should be lower than its current price. That is, firms face costly reversibility. In a similar way, capital stock can also be increased in period two, but its future purchasing price should be higher than its current price. The reason is that when a firm perceives the raise in capital stock as a profitable alternative, the other competing firms are probably having the same sight. This behavior generates a demand pressure that leads to a higher price of capital goods in period two. Thus, firms also face costly expandability.



We consider a representative firm that chooses, in period one, the amount of capital stock to be used in the manufacturing process, being aware that this choice cannot be easily modified in period two. The innovation is to split capital stock into buildings, B , and machines, M . First-period choices are given by B_1 and M_1 . With such levels of inputs the firm obtains a first-period return of $r(B_1, M_1)$, where $r_B > 0$, $r_M > 0$, $r_{BB} < 0$, $r_{MM} < 0$ and $r_{MB} > 0$. Therefore, the return function is strictly increasing and strictly concave in both arguments. The latest inequality implies that machines and buildings are complements in the sense of having a small elasticity of substitution, which seems to be a sensible assumption. First-period prices of buildings and machines are given by β and μ , respectively.

In the second period the firm earns a return of $R(B, M, e)$, where e is a stochastic shock with c.d.f. given by $F(e)$. The return function has the same properties in both periods. The only difference is that in the second period the return becomes stochastic. We assume that $R_e > 0$, $R_{Be} > 0$ and $R_{Me} > 0$, which means that a positive shock increases not only the level of returns, but also the marginal return of both inputs.

The next step is to define three critical values for the shock term e : a small positive shock e_H , a small negative shock e_L , and a large negative shock e_{ML} . The value e_H is such that $R_B(B_1, M_1, e_H) = \beta_H$ and $R_M(B_1, M_1, e_H) = \mu_H$, where β_H and μ_H are the second-period purchasing prices of capital in the form of buildings and machinery, respectively. We assume that the second-period purchasing prices of both types of capital are higher than their respective first-period current prices, that is, $\beta_H > \beta$ and $\mu_H > \mu$. If capital stock is not altered, e_H is the precise value of the shock that equates the second-period marginal return of capital to its second-period purchasing price. For the sake of simplification, we assume that this value is the same for the two types of capital.

If the shock is positive but smaller than e_H , marginal returns will be lower than purchase prices and the firm will not change its first-period capital stock. The expansion of capital stock will be profitable only when the stochastic shock is at least as large as e_H . The value e_L is assumed to be the level of shock that equates second period marginal return of building units with their resale price. It is defined by $R_B(B_1, M_1, e_L) = \beta_L$, where $\beta_L < \beta$ is the resale price of a building unit. The hypothesis of a small reversibility cost of buildings implies that the resale price, β_L is slightly lower than the first-period purchasing price, β . By that means, the equality among marginal return and resale price of buildings is achieved with a relatively mild negative shock in the second period.

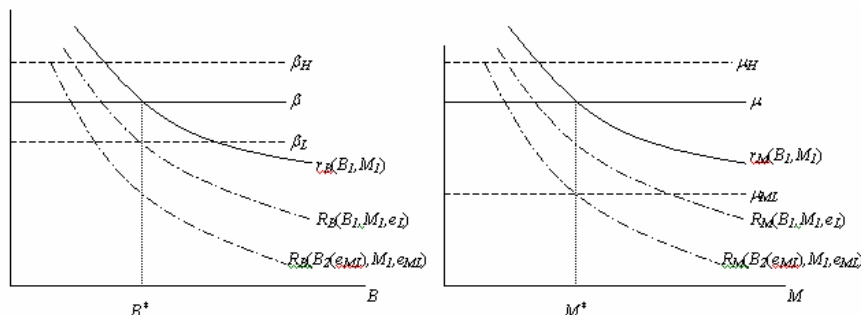
Investment in machinery, on the other hand, is assumed to be highly irreversible. This irreversibility can be defined as a large difference between first-period acquisition and second-period resale prices. Therefore, the value of the negative shock that equates marginal return with resale price of machines, e_{ML} , is by assumption very low. More precisely, e_{ML} is the size of e that sets $R_M(B_2(e_{ML}), M_1, e_{ML}) = \mu_{ML}$, where $\mu_{ML} < \mu$ is the resale price of machinery. If the shock is negative but smaller in absolute terms than e_{ML} , then the former stock of machines will be kept up in the second period. With a negative shock higher in absolute terms than e_{ML} the firm will adjust its stock of machines. At the level e_{ML} the firm will also adjust its stock of buildings, generating a positive impact on marginal return of machines. This impact accounts for the replacement of B_1 by $B_2(e_{ML})$ in the marginal return function.

The building-machinery framework is illustrated in 1. First-period prices are given by the solid horizontal lines β and μ . The solid curves R_B and R_M describe the first-period marginal return functions of buildings and machines, respectively. The equilibrium capital stock in the first period does not necessarily correspond to the intersection of marginal return and price curves (positions B^* and M^* in the graph).² Optimal first-period levels are affected by the balance between expandability and reversibility costs, as well as by the shape of the c.d.f. $F(e)$. The intuition is straightforward. An easily expandable but nearly irreversible project will probably hold a lower level of capital compared to an

²Indeed, this intersection will be the first-period equilibrium only in a particular situation in which opposite forces that affect second-period expected profitability exactly offset each other. Another possibility is the trivial case of a zero discount factor, occurring when the future is discounted at an infinitely large tax.

easily reversible but nearly non-expandable one.³ In addition, if a bad shock is much more likely than a good shock (if the c.d.f. begins with a sharp increase), first-period capital stock tends to be low.

Figure 1 – Investment Prices and Marginal Revenues



The shock is represented by a shift in the marginal revenue function. A good (bad) shock implies that the marginal revenue curve shifts upward (downward). Figure 1 depicts two bad shocks. The small bad shock e_L is represented by a short downward shift of the marginal revenue curves (the upper dashed curves). If, for convenience, we assume that $B_1 = B^*$ and $M_1 = M^*$, then e_L would not be large enough to induce the firm to disinvest. Marginal returns would still remain at least as large as resale prices. The firm would choose to sell buildings if the shock is larger than e_L . From e_L to e_{ML} there is some disinvestment in buildings but not in machinery. The great bad shock e_{ML} is the edge of inaction related to the stock of machines. It is represented by a large downward shift of marginal revenue curves. When the shock is worse than e_{ML} , the second-period marginal return of machines at the level $M_1 = M^*$ is lower than its resale price. In this case, the market conditions become so adverse that it is desirable to sell machines, in spite of their high reversibility costs.

Summing up, there is a range of inaction for the adjustment of both types of capital in the second period. Nevertheless, the hypothesis of near irreversibility of machines assigns a larger range of inaction to their second-period adjustment. Thus, the firm must choose one among four different regimes in period two: disinvestment in machines and buildings, disinvestment only in buildings, inactivity or investment in machines and buildings. If the amount of buildings and machines held by the firm in period one is B_1 and M_1 respectively, the expected present value of the flow of returns is given by

$$\begin{aligned}
 V(B_1, M_1) = & r(B_1, M_1) + \\
 & \gamma \int_{-\infty}^{e_{ML}} \{R(B_2(e), M_2(e), e) + \beta_L[B_1 - B_2(e)] + \mu_{ML}[M_1 - M_2(e)]\} dF(e) + \\
 & \gamma \int_{e_{ML}}^{e_L} \{R(B_2(e), M_1, e) + \beta_L[B_1 - B_2(e)]\} dF(e) + \gamma \int_{e_L}^{e_H} R(B_1, M_1, e) dF(e) + \\
 & \gamma \int_{e_H}^{\infty} \{R(B_2(e), M_2(e), e) - \beta_H[B_2(e) - B_1] - \mu_H[M_2(e) - M_1]\} dF(e) \quad (1)
 \end{aligned}$$

³This is certainly the case if the equality between first-period prices and marginal returns occurs with the same level of capital in both projects.



where $0 < \gamma < 1$ is the discount factor. Equation 1 states that the value of the firm, V , corresponds to the sum of expected returns obtained in both periods. The first term in the right-hand side of (1) is the first-period return. The second, third, fourth and fifth terms in the right-hand side of the equation represent the expected value of second-period returns, discounted by the factor γ . This return can be accomplished through each of the four regimes. If e is lower than e_{ML} , the discounted average return is given by the second term. The firm wishes to reduce the stock of buildings from B_1 to $B_2(e)$ and the stock of machines from M_1 to $M_2(e)$. The shortening in the second-period return is more than compensated by the resources from selling buildings, $\beta_L[B_1 - B_2(e)]$, and machines, $\mu_L[M_1 - M_2(e)]$. If e lies between e_{ML} and e_L , then the firm sells buildings but keeps its first-period stock of machines. In this case, the average second-period cash flow is represented by the third term on the right-hand side of (1). The fourth term gives the discounted average return with complete inaction. When the shock ranges from e_L to e_H the impact on returns is not large enough to compensate the reversibility/expandability costs. The firm buys machines and buildings if $e > e_H$. A higher return, given by $R(B_2(e), M_2(e), e)$, is obtained at the expenses of the purchase of new buildings, $\beta_H[B_2(e) - B_1]$, and new machines, $\mu_H[M_2(e) - M_1]$.

The representative firm is assumed to maximize the present value of its two-period profits. For that reason, the first-period stock of buildings and machines must be chosen according to the optimization problem given by

$$\text{Max}_{B_1, M_1} V(B_1, M_1) - \beta B_1 - \mu M_1 \quad (2)$$

This maximization yields the two following first-order conditions

$$r_B(B_1, M_1) + \gamma \beta_L F(e_L) + \gamma \int_{e_L}^{e_H} R_B(B_1, M_1, e) dF(e) + \gamma \beta_H [1 - F(e_H)] = \beta \quad (3)$$

$$r_M(B_1, M_1) + \gamma \mu_{ML} F(e_{ML}) + \gamma \int_{e_{ML}}^{e_L} R_M(B_2(e), M_1, e) dF(e) + \gamma \int_{e_L}^{e_H} R_M(B_1, M_1, e) dF(e) + \gamma \mu_H [1 - F(e_H)] = \mu \quad (4)$$

These two expressions state that the marginal value of each type of capital in period one should be equal to its respective first-period price. This marginal value is the sum of first-period and expected second-period marginal returns. As we emphasized before, optimal levels of B_1 and M_1 depend, among other things, on the shape of the c.d.f.. If the probabilities are strongly concentrated in low levels of e , then $F(e_L)$ and $F(e_{ML})$ are relatively high and $[1 - F(e_H)]$ is relatively low. As long as $\beta_H > \beta_L$ and $\mu_H > \mu_{ML}$, the equilibrium asserted by equations 3 and 4 hints that the firm chooses low levels of B_1 and M_1 . Furthermore, it seems intuitive that a high probability of a bad shock in period two induces the firm to hold a small capital stock in period one. If, otherwise, the probabilities are scarce in low levels of e and concentrated above e_H , then $F(e_L)$ and $F(e_{ML})$ are relatively low and $[1 - F(e_H)]$ is relatively high. A large probability of a good shock in period two implies that the firm expects a high second-period marginal return of capital (since it is assumed that R_{Me} and R_{Be} are positive). Provided that firms face costly expandability, a natural consequence is the undertaking of a large stock of machines and buildings in period one.

2.2. Changing Reversibility and Expandability Costs

An interesting exercise is to examine the effect of variations in reversibility and expandability costs on the first-period stock of buildings and machines. To do so, we have to use comparative static multipliers. Differentiating expressions (3) and (4) with respect to first-period building and machinery stocks and second-period purchase and resale prices, we obtain

$$r_{BB}dB_1 + r_{BM}dM_1 + \gamma F(e_L)d\beta_L + \gamma\Gamma_1dB_1 + \gamma\Gamma_3dM_1 + \gamma[1 - F(e_H)]d\beta_H = 0 \quad (5)$$

$$r_{MM}dM_1 + r_{MB}dB_1 + \gamma F(e_{ML})d\mu_{ML} + \gamma\Gamma_4dM_1 + \gamma\Gamma_2dM_1 + \gamma\Gamma_3dB_1 + \gamma[1 - F(e_H)]d\mu_H = 0 \quad (6)$$

where the Γ 's are:

$$\begin{aligned} \Gamma_1 &= \int_{e_L}^{e_H} R_{BB}(B_1, M_1, e)dF(e) < 0 \\ \Gamma_2 &= \int_{e_L}^{e_H} R_{MM}(B_1, M_1, e)dF(e) < 0 \\ \Gamma_3 &= \int_{e_L}^{e_H} R_{BM}(B_1, M_1, e)dF(e) = \int_{e_L}^{e_H} R_{MB}(B_1, M_1, e)dF(e) > 0 \\ \Gamma_4 &= \int_{e_{ML}}^{e_H} R_{MM}(B_2(e), M_1, e)dF(e) < 0 \end{aligned}$$

Putting expressions (5) and (6) in a matrix form, we have

$$\begin{aligned} &\begin{bmatrix} r_{BB} + \gamma\Gamma_1 & r_{BM} + \gamma\Gamma_3 \\ r_{MB} + \gamma\Gamma_3 & r_{MM} + \gamma(\Gamma_4 + \Gamma_2) \end{bmatrix} \cdot \begin{bmatrix} dB_1 \\ dM_1 \end{bmatrix} = \\ &= \begin{bmatrix} -\gamma F(e_L) & -\gamma[1 - F(e_H)] & 0 & 0 \\ 0 & 0 & -\gamma F(e_{ML}) & -\gamma[1 - F(e_H)] \end{bmatrix} \cdot \begin{bmatrix} d\beta_L \\ d\beta_H \\ d\mu_{ML} \\ d\mu_H \end{bmatrix} \quad (7) \end{aligned}$$

As long as we are investigating the behavior of a maximizing firm, second-order conditions for a strict maximum in (2) assure that the Hessian matrix in the left-hand side of (7) is negative definite, which implies that its determinant is necessarily positive. This restriction is used to define the sign of comparative static multipliers. It can be verified by Cramer's Rule that all of these multipliers are positive. First-period stocks of buildings and machines are positively related to their respective resale prices in period two. The more reversible is investment, the lesser is the fear of being caught in the future with a large and unprofitable capital stock. Hence, a higher degree of reversibility induces the firm to hold a higher capital stock and, as a consequence, to increase investment. Cross effects are also positive, which is a result of the complementarity hypothesis stated previously. The representative firm wants to use more machines when they become more reversible. Provided that a higher stock of machines rises marginal productivity of buildings, an increase in the machine resale price likewise has a positive impact on the stock of buildings.



First-period stocks of buildings and machines are also positively related to their respective purchase prices in period two. It means that when expandability is undermined (when the costs of expanding capital stock in the future increases), then firms will hold a higher stock of capital in the present. By doing this, they partly get rid of incurring large costs to adjust their capital stock in the future to a favorable market change. Once more, cross effects are positive. If there is an increase in the second-period purchasing price of buildings, then firms will raise their first-period stock of buildings. Since machines and buildings are complements, the optimal level of the former will also rise.

2.3. The Effect of Uncertainty with Total Irreversibility and Non-expandability

Here we consider a mean-preserving spread, the famous Rothschild and Stiglitz (1970, 1971) characterization of an increase in the uncertainty of a distribution. In our setup, we consider a spread in the distribution function of the random shock, $f(e)$, in which the tails become thicker, but the mean is preserved. Hence, the probability of either a very bad or a very good shock increases, but the expected value of the shock remains the same.

We consider the case where the firm has to commit in the second period with the levels of capital acquired in the first period. So investment is completely irreversible and non-expandable. In this case, the value of the firm is given by

$$V(B_1, M_1) = r(B_1, M_1) + \gamma \int_{-\infty}^{\infty} R(B_1, M_1, e) dF(e) \quad (8)$$

And the first-order conditions for the profit maximization become

$$r_B(B_1, M_1) + \gamma \int_{-\infty}^{\infty} R_B(B_1, M_1, e) dF(e) = \beta \quad (9)$$

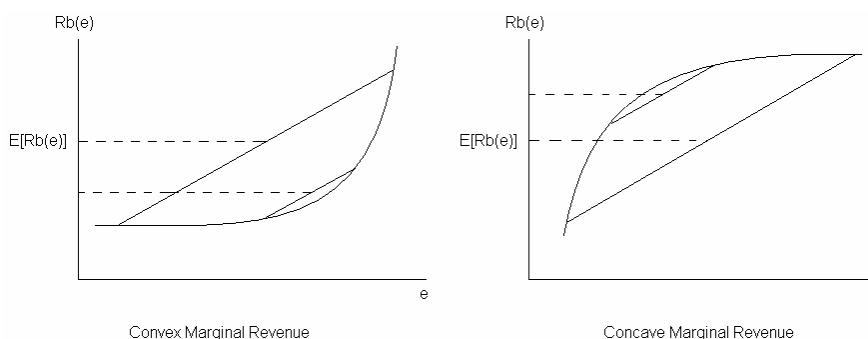
$$r_M(B_1, M_1) + \gamma \int_{-\infty}^{\infty} R_M(B_1, M_1, e) dF(e) = \mu \quad (10)$$

Essentially, what we have here is that the first-period marginal revenue of each input plus the discounted expected value of the second-period marginal revenue has to be made equal to its price. The integrals on the left-hand sides of (9) and (10) are the expected values of second-period marginal revenues. Our interest is on how these expected values will change with a mean-preserving spread in $f(e)$. The effect of uncertainty in the first-period investment will depend on the shapes of functions R_B and R_M . So far, we imposed the restriction that the shock affects positively marginal revenues (R_{Be} and R_{Me} are both positive). But the effect of uncertainty will depend on the signal of the second derivatives of R_B and R_M with respect to the shock e (see Figure 2).

If marginal revenues are convex on e , then more uncertainty raises the expected second-period marginal revenue, and as a consequence induces a higher investment in period one. If, on the other hand, marginal revenues are concave on e , then uncertainty hampers investment in period one. By the same token, if R_B and R_M are linear on e , then uncertainty does not affect investment.

3. EMPIRICAL ASSESSMENT

In this section we analyze the effect of uncertainty on different types of investment, from an empirical standpoint. Specifically, we intend to investigate whether the less irreversible nature of the investment in buildings, compared to machinery, makes it more sensitive to changes in uncertainty. To

Figure 2 – A Mean-Preserving Spread

do so, we use a panel of the Brazilian industry spanning the years 1966 to 1995 and comprising 22 industrial sectors (see Appendix 1). The data are mainly drawn from industrial surveys produced by IBGE, which is the Brazilian government institute for statistics.

Our first task is to construct a proxy for uncertainty. A number of empirical studies about the investment-uncertainty relationship adopt sample variability as the indicator of uncertainty. For time-series analysis the typical procedure is to use first differences of aggregate series like inflation, real exchange rate or interest rate. Another possibility is to proxy uncertainty by calculating deviations of the time mean for each of these series.

It is worth noting that the empirical literature quite often relies on panel data techniques to study the effects of uncertainty on investment (see, for example, Sérven (1998), Aizenman and Marion (1996), Pindyck and Solimano (1993), among others). When the cross-section dimension is taken into account, uncertainty is usually measured by second moments for each point in time. Volatility indicators may be the standard deviations of aggregate series in the case of cross-country studies, or of company-level variables in the case of individual firms. The intuition behind the use of sample variation as a proxy of uncertainty may be considered incomplete. The idea is that when a variable becomes more volatile, it would be more difficult to make accurate predictions about its future values. Therefore, uncertainty would increase. However, sample variation comprises predictable as well as unpredictable movements of the variable. It is straightforward that uncertainty must match only the unpredictable component of a variable's path (since something that is deterministically predicted cannot be uncertain).

A number of studies have adopted more refined measures of uncertainty (see Sérven (1998), Price (1995, 1996) and Pereira (2001)). It is argued that good proxies for uncertainty should be based on the volatility of the variable's innovations, not on its full volatility. If the variable can be described by a stochastic process, then the usual hypothesis of a constant variance for the error term should be ruled out. This approach leads to the generalized conditional heteroskedastic (GARCH) model, first developed by Bollerslev (1986). In GARCH specifications the conditional variance of the residual is assumed to follow an ARMA process. The use of maximum likelihood techniques allows a simultaneous estimation of an AR process for the variable and an ARMA process for the conditional variance of the error term. Uncertainty is given by the fitted values of this conditional variance. We follow this GARCH-based approach, selecting two variables to be examined: the aggregated industrial value and the average earnings (which we just call wages). Thus, two uncertainty series are obtained for each of the twenty-two industrial sectors, generating two uncertainty panels. The following univariate GARCH is estimated sector by sector separately

$$y_{i,t} = a_0 + a_1 t + b y_{i,t-1} + \mu_{i,t} \quad (11)$$



$$h_{i,t} = c_i + d_i \mu_{i,t-1}^2 + e_i h_{i,t-1} \quad (12)$$

where: $i = 1, 2, \dots, 22$ and $t = 1, 2, \dots, 30$; y is the selected variable (wages or aggregated value by industry); and $h_{i,t}$ is the variance of $\mu_{i,t}$ conditional on information available in period t . We also estimate two more uncertainty panels based on the same $GARCH(1, 1)$ model, but excluding the constant and/or the trend in the AR equation whenever they are not significant at the 5% level.

In addition to the two uncertainty panels, we estimate for the inflation and the interest rate the same univariate $GARCH(1, 1)$ given by (11) and (12). That gives us two additional uncertainty series. However, unlike wages and production, these are not sector specific. They vary over time, but not across sectors. We obtain a single time series for inflation uncertainty and a single time series for interest rate uncertainty. In a panel data context, these work as time dummies, capturing the effect of a particular year over all the twenty two sectors.

As long as the time dimension spans only 30 years of annual data, we do not have many degrees of freedom in the estimation of the GARCH. For example, in the full setup with constant and trend given by equations 11 and 12, we would be left with only 24 degrees of freedom. Hence, we did not pursue more complex auto-regressive specifications, in which the lack of degrees of freedom would become a serious issue. We just used the parsimonious $GARCH(1, 1)$. Since the original work of Bollerslev (1986), a number variations of the GARCH model have been developed. There are nowadays in the literature at least twelve variants of the GARCH model. Some of them imply the lost of degrees of freedom, some of them do not. To name a few, the EGARCH (exponential general autoregressive conditional heteroskedastic) model has the conditional variance expressed in logs. The QGARCH (quadratic GARCH) adds to the conditional variance equation 12 in the case of our $GARCH(1, 1)$ non-quadratic lags of the error μ , allowing one to capture eventual asymmetries between positive and negative shocks. The GARCH-M (GARCH-in-mean) adds a conditional variance term in the mean equation. In spite of this variety, the bulk of the literature on economic uncertainty has still been using the simple $GARCH(1, 1)$ structure to model economic uncertainty (see, for example, Conin and Kennedy (2007), and Atta-Mensah (2004)).

Before analyzing the investment-uncertainty relationship for the Brazilian industry it is worth looking at some descriptive statistics of our investment panel. Table 1 presents this basic information separately for the investment in buildings and in machinery. The mean, median and standard deviation are calculated for the full sample, for the sector averages (between groups), and for the deviations of respective group means (within groups). This latest option puts away the variation related to sector particularities (since sector means are supposedly different for different sectors), allowing the analysis of the time-series dimension. Table 1 reveals at least three important aspects. First, medians are always smaller than means, which implies that frequency distributions are positively skewed in both time-series and cross-section dimensions. Accordingly, distributions have lower frequencies in their upper tails, suggesting that large levels of investment are concentrated in some few years and sectors. The second point is that variation is higher over time than across sectors in both types of investment. This result reinforces the stylized fact of the non-smoothness of investment over time in disaggregated series.⁴ The kinky path is a consequence of the irreversible nature of investment, which produces a range of inaction and a profitability threshold. Investment projects are performed only when the expected future profitability exceeds this threshold. A third feature is the fact that investment in machinery is much more volatile than investment in buildings, in a proportion of nearly two to one.

We have seen in the model that, in the case of a bad shock, capital in the form of buildings would be firstly sold due to a lower reversibility cost. The question is, shouldn't we expect a higher volatility of investment in industrial real estate, rather than in machinery? These aspects might not be contra-

⁴This is specially valid for disaggregated investment. It is quite obvious that periods of positive investment are imperfectly synchronized across sectors, generating a smoother dynamics for the aggregated investment. Bertola and Caballero (1994) show the interactions between firm-level irreversibility, idiosyncratic uncertainty and the smoothness of aggregated investment.

Table 1 – Descriptive Statistics of Investment in Brazil

	In thousands of Reais of 1995					
	Buildings			Machinery		
	full	between groups ^a	within groups ^b	full	between groups ^a	within groups ^b
Mean	203	203	0	494	494	0
Median	76	116	-18	240	305	-33
Standard Deviation	446	249	373	885	500	738
Number of Observ.	660	30	660	660	30	660

^a Sector averages.

^b Deviations from sector averages.

ditory if we think that machines depreciate faster than real estate. Hence the cycle of reinvestment should take place more often for machines than for buildings.

To investigate how private investment in machinery and in real estate are affected by uncertainty, we use a conventional empirical equation that relates investment to uncertainty measures and to a set of variables typically used to describe investment. Besides the GARCH-based uncertainty proxies, we use three other variables in the empirical specification: aggregated industrial value, interest rates and inflation. The first one should capture the effects of economic activity on the investing decision.⁵ Investment tends to be higher in periods of high production and high capacity utilization.

While aggregate industrial value is obtained from a pooled sample, interest rates and inflation are macroeconomic variables that vary over time, but not across sectors. When their values are replicated to each sector they actually work as time dummies. Interest rates are the standard measure of the user cost of capital. The larger is the opportunity cost of investing, proxied by the interest rate, the less attractive is investment. The data for interest rates in Brazil are usually available in high frequency series (like daily or weekly rates). This kind of information has the inconvenience of covering small time spans. To put this problem aside, we use the return of CDB bonds (certificado de depósitos bancários). Prior to 1970, however, these data are not available. The missing values are then fulfilled with the return offered by a federal public bond named ORTN (obrigações reajustáveis do tesouro nacional).

The data for inflation is based on the IGP-DI (índice geral de preços – disponibilidade interna), a widely used price index in Brazil. Inflation is employed essentially as a control variable that corrects an undesirable feature of PIA data set (see Appendix 1). It is also important to account for the dynamics of investment. Current changes in the capital stock likely depend on past changes. Some kind of inertia may be present, especially with annual data. Therefore, we also included lagged investment among the regressors. The equation to be estimated is given by:

$$I_{i,t} = \theta I_{i,t-1} + f_i + \beta_1 U_{i,t}^1 + \beta_2 U_{i,t}^2 + \beta_3 y_{i,t} + \beta_4 r_t + \beta_5 \pi_t + \beta_6 U_t^\pi + \beta_7 U_t^r + \epsilon_{i,t} \quad (13)$$

where: I is investment in machines or in buildings; U^1 is the uncertainty proxy based on the value aggregated by industry; U^2 is the uncertainty proxy based on wages; y is the aggregated industrial value; r is the interest rate; π is inflation U^π is the uncertainty proxy based on inflation; U^r is the uncertainty proxy based on interest rates; and ϵ is the random disturbance. The f_i term is a sector specific constant in the case of fixed effects approach, or a sector specific disturbance in a random effects estimation.

The problems of random effects techniques have been increasingly recognized in the literature. The main drawback is the likely correlation of individual effects with the observed exogenous variables.

⁵The use of production variables in investment equations usually brings about problems of endogeneity. If strong exogeneity of dependent variables is not assured, they may be correlated with residuals. In this case, consistent estimates can be obtained throughout instrumental variables procedures.



For example, an industrial sector that faces highly unionized workers should have high wage-related uncertainty levels. If the degree of unionization is considered as an individual effect, and if this effect is treated as a random error, then the consistency hypothesis are clearly violated in the regression model. An alternative is to estimate (13) by the fixed effects method. However, since the work of Nickell (1981), it has been largely pointed out that the fixed effects model estimated by OLS contains serious problems of bias when lags of the dependent variable are included in the regressors. The use of instrumental variable procedures is the standard way to tackle these problems as well as problems of endogeneity of the production variable y (see footnote 5). However, instead of performing fixed effects estimation, we take first differences of (13) in order to remove individual effects:⁶

$$\Delta I_{i,t} = \theta \Delta I_{i,t-1} + \beta_1 \Delta U_{i,t}^1 + \beta_2 \Delta U_{i,t}^2 + \beta_3 \Delta y_{i,t} + \beta_4 \Delta r_t + \beta_5 \Delta \pi_t + \beta_6 \Delta U_t^\pi + \beta_7 \Delta U_t^r + u_{i,t} \quad (14)$$

where: $u_{i,t} = \epsilon_{i,t} - \epsilon_{i,t-1}$. Instrumental variables are required to put aside problems of endogeneity of regressors and of correlation between the lagged difference of the dependent variable and the residuals $u_{i,t}$.⁷ Second- and higher-order lags of the endogenous variable can be used as instruments (see Arellano and Bond (1991)). The use of these instruments is based on the fact that $E[\Delta I_{i,t-2} \Delta I_{i,t-1}] \neq 0$ and $E[\Delta I_{i,t-2} u_{i,t}] = 0$. Yet, this latest equality requires serially uncorrelated residuals.⁸

Before the empirical implementation of (14), an important aspect of the data should be regarded. Instead of total sector investment, we take the average investment of one firm in that sector (see again Appendix 1). The choice of a variable sample in the data assembling methodology prevents the use of total values and leads to grouped data methods. Specifically, repeated cross-sections can be used as a pseudo-panel model that looks like a standard model of panel data (see, for example, Deaton (1985), and Menezes-Filho et al. (2000)).

The results of the instrumental variables estimation of (14) are presented in Table 2. The first part of the table reports the estimates of investment in machines, while the second part refers to investment in buildings.⁹ The lags from two to twelve of the dependent variable are used as instruments.

The first column of Table 2 shows that investment is always negatively related to its previous value. However, statistical significance at the conventional levels is obtained only for buildings. Intuitively, if a firm acquired a new building last year, there is probably no need for purchasing new buildings this year. The coefficients of the interest rate have the expected negative sign for most of the regressions of machines and buildings as well. A high interest rate tends to depress both types of investment, since it is closely related to the opportunity cost of capital. These estimates, however, are not highly significant. The 10% level of significance is reached only in few regressions.

Each regression in Table 2 is performed with a different set of regressors. The same regression is run with the investment in machines and in buildings. So we can compare the results of each regression in the upper part of the table with the corresponding regression in the lower part of the table. The role of inflation is to control for one imperfection of the database. We have seen that our data set tends to underreport real investment in periods of high increases in price levels. Therefore, the estimated coefficients of inflation in Table 2 have the expected sign. It should be noted, however, that investment and

⁶More detail of this approach can be found in Sérven (1998) or in Arellano and Bond (1991).

⁷In this respect, it can be seen that $E[\Delta I_{i,t-1} u_{i,t}] = E[(I_{i,t-1} - I_{i,t-2})(\epsilon_{i,t} - \epsilon_{i,t-1})] = E(I_{i,t-1} \epsilon_{i,t-1}) = E(\epsilon_{i,t-1}^2) \neq 0$. Thus, the use of OLS in (11) does not yield unbiased and consistent estimates of parameters.

⁸For instance, if $\epsilon_{i,t}$ follows an AR(1) process like $\epsilon_{i,t} = \rho \epsilon_{i,t-1} + \psi_{i,t}$, then: $E[\Delta I_{i,t-2} u_{i,t}] = -\rho E[I_{i,t-2} \epsilon_{i,t-2}] \neq 0$. In this case, the second-order lag of the endogenous variable would not be a valid instrument.

⁹Besides our two key uncertainty measures U^1 and U^2 , we also tried proxies constructed with the same GARCH(1,1) model, however taking out the constant and the trend in the AR equation whenever they do not have significance at the 5% level. The results are very similar to the ones presented in Tables 2 and 3, being available upon request.

inflation are negatively related not only because an inflationary environment harms capital profitability, but also because the methodology of gathering data yields underreported values when inflation is high. The levels of significance for the inflation ($\Delta\pi$) coefficient vary through the regressions. They are significant at the 10% level on half of the regressions reported in Table 2. The value aggregated by industry is negatively related with investment in machines, contrarily to theoretical predictions, and positively related with investment in buildings. Yet, they tend to be non-significant at the conventional levels.

The most interesting aspect of Table 2 is the uncertainty coefficients estimates. The second column of the table (ΔU^1) suggests that uncertainty related to production does not exert a significant influence on both categories of investment. Nevertheless, uncertainty related to wages has large and, in many cases, highly significant coefficients, as can be seen in the third column of the table (ΔU^2). The results provide empirical support to the main assertion of the model presented in section 2, namely the idea that uncertainty has a larger impact on investment in machinery compared to investment in real estate, because of the less reversible nature of the former. It should be noted that coefficients for wage-related uncertainty are always higher, in absolute values, when investment in machinery is the dependent variable. The estimates of β_2 are from 2.1 to 9.3 times larger in the upper portion than in the down portion of the table. This empirical finding suggests that uncertainty affects investment in machinery more intensely than investment in buildings.

Table 2 – Pooled Instrumental Variables Estimation of the Investment Equation

Dependent variable	Lagged dep. variable	ΔU^1	ΔU^2	ΔU^r	ΔU^π	ΔU^r	ΔU^π	ΔU^y
Inv. in machines	-0.080 (0.250)	1.920 (1.362)	-462.81* (267.43)	-1.652.96 (9294.91)			-0.137 (0.469)	
	-0.022 (0.284)	2.133 (1.477)	-589.67* (326.28)			-56.563 (37.296)	-0.602 (0.551)	
	-0.0001 (0.230)	1.734 (1.611)	-615.44* (326.43)	-2268.9 (8787.2)	0.115 (0.413)	-36.107 (30.166)		
	-0.152 (0.253)	1.680 (1.787)		12473.4 (11690.3)	0.670* (0.417)	-83.027* (46.529)	-1.515** (0.712)	-0.060 (0.299)
	-0.090 (0.184)		-507.396** (224.298)		0.337 (0.271)	-36.878*1 (22.104)		
	-0.025 (0.224)		-322.36 (267.71)	5517.61 (9224.23)	0.645* (0.366)	-69.768* (37.499)	-1.004* (0.603)	-0.073 (0.214)
	-0.118 (0.189)		-586.91*** (222.49)			-34.382 (22.784)		
	-0.128 (0.209)		-515.05** (237.23)			-55.987* (32.241)	-0.578 (0.420)	-0.029 (0.199)
Inv. in buildings	-0.059 (0.214)	-0.830 (0.852)	-62.294 (113.974)	-3873.1 (5447.8)			-0.828** (0.350)	
	-0.103 (0.291)	-1.196 (0.783)	-63.398 (139.78)			-3.565 (22.030)	-0.694** (0.343)	
	-0.267* (0.164)	-0.393 (0.656)	-226.08** (89.20)	-594.09 (3364.9)	-0.441*** (0.133)	10.958 (13.659)		
	-0.096 (0.245)	-0.298 (0.981)		7568.1 (6864.1)	-0.177 (0.289)	0.722 (24.104)	-0.851 (0.542)	0.253 (0.151)
	-0.291* (0.160)		-234.259*** (85.206)		-0.457*** (0.131)	8.491 (13.555)		
	-0.204 (0.259)		-129.101 (162.737)	6427.5 (6195.4)	-0.366 (0.350)	4.310 (24.141)	-0.501 (0.692)	0.246* (0.142)
	-0.421*** (0.109)		-156.69*** (57.89)			-2.958 (9.256)		
	-0.266* (0.141)		-67.683 (75.011)			-9.510 (11.196)	-0.464*** (0.158)	0.099 (0.076)

Notes: The symbols ***, ** and * are used to indicate significance at 1%, 5% and 10%, respectively. Standard errors are in brackets.

The set of instruments is compounded of the lags from 2 to 12 of the dependent variable taken in first differences. Here r is the interest rate p is the inflation rate, y is the value aggregated by the industry, and U^1 , U^2 , U^r and U^π are, respectively, production, wages, interest rate and inflation-related uncertainty proxies.

To evaluate the robustness of these findings we perform the same estimates of Table 2 with a different set of instruments. Instead of the lags from two to twelve of the dependent variable, we use the



lags from one to six of the independent variables used in each estimation (not including the lags of the lagged dependent variable). The results are presented in Table 3. Unlike Table 2, each regression in Table 3 has a different set of instruments. The results are not much different from those of Table 2. Once more, investment is negatively related to its lagged values. Yet, statistical significance is considerably higher for buildings. The estimates for the interest rate coefficients are not significant at the conventional levels, but they reinforce the expected negative relationship among investment and the user cost of capital. Table 3 also reports negative coefficients for inflation, which is in line with our previous findings, and positive and in some cases highly significant coefficients for the value aggregated by industry. Hence, investment tends to happen in sectors and years where production is large. Most importantly, uncertainty coefficients are again much higher for machines than for buildings. However, differently from the results in Table 2, investment in machines is significantly affected by both production- and wage-related uncertainty. Investment in buildings, on the other hand, have much smaller and generally non-significant uncertainty coefficients. The effect of inflation uncertainty is slightly more intense on investment in buildings than on machinery. We did not find statistical significance for the interest rate uncertainty coefficient in any of the regressions performed in Table 3. In a broad sense, it can be said that Table 3 replicates the main results of Table 2.

Table 3 – Pooled Instrumental Variables Estimation of the Investment Equation with a Different Set of Instruments

Dependent variable	Lagged dep. variable	ΔU^1	ΔU^2	ΔU^r	ΔU^π	ΔU^w	ΔU^p	ΔU^y
Inv. in machines	-0.231 (0.251)	-0.196** (0.097)	-43.493 (38.557)			-2.126 (2.782)		
	-0.171 (0.166)	-0.185** (0.089)	-74.784** (35.026)			-3.218 (2.734)	-0.063 (0.052)	0.062* (0.034)
	-0.004 (0.269)	-0.205** (0.092)			-0.033 0.041	-1.457 (2.743)		
	-0.059 (0.184)	-0.234** (0.091)		-690.76 (479.35)	-0.057 0.040	1.348 (2.622)	-0.031 (0.020)	0.020 (0.029)
	-0.343* (0.198)		-79.612** (36.305)			-3.999 (2.642)	-0.085* (0.048)	0.083** (0.035)
	-0.205 (0.181)		-55.781* (33.306)	-241.215 (425.491)	-0.027 (0.036)	-1.449 (2.280)	-0.054 (0.053)	0.061** (0.029)
	-0.168 (0.162)	-0.225*** (0.079)	-74.546** (33.999)	-418.008 (364.266)	-0.062* (0.037)			0.053 (0.033)
	-0.086 (0.156)	-0.225*** (0.087)	-63.755* (33.488)	-649.333 (458.821)	-0.061 (0.038)	-1.153 (2.509)	-0.017 (0.061)	0.046 (0.029)
Inv. in buildings	-0.433*** (0.152)	-0.070 (0.055)	9.176 (21.291)			-2.330 (1.650)		
	-0.675*** (0.120)	-0.076 (0.050)	-17.035 (19.859)			-2.526 (1.565)	-0.003 (0.032)	0.065*** (0.019)
	-0.581*** (0.222)	-0.060 (0.051)			-0.051** (0.026)	-1.312 (1.839)		
	-0.388*** (0.145)	-0.085* (0.049)		-73.824 (257.175)	-0.061*** (0.021)	0.438 (1.414)	-0.002 (0.037)	0.025* (0.015)
	-0.648*** (0.131)		-17.859 (20.099)			-2.585* (1.526)	-0.012 (0.029)	0.060*** (0.019)
	-0.458*** (0.130)		-21.502 (18.949)	58.106 (238.39)	-0.050** (0.020)	-0.617 (1.310)	-0.029 (0.032)	0.034** (0.016)
	-0.515*** (0.101)	-0.072* (0.044)	-29.055 (18.752)	66.258 (202.504)	-0.066*** (0.020)			0.051*** (0.017)
	-0.477*** (0.115)	-0.072 (0.047)	-20.653 (18.717)	-58.765 (251.523)	-0.058** (0.021)	0.078 (1.384)	-0.004 (0.036)	0.035*** (0.015)

Notes: The symbols ***, ** and * are used to indicate significance at 1%, 5% and 10%, respectively. Standard errors are in brackets.

The set of instruments is compounded of the lags from 1 to 6 of the independent variable taken in first differences (not including the lags of the lagged dependent variable). Here r is the interest rate p is the inflation rate, y is the value aggregated by the industry, and U^1 , U^2 , U^r and U^π are, respectively, production, wages, interest rate and inflation-related uncertainty proxies.

One of the key issues in working with instrumental variables is the quality of the instruments. More specifically, they have to be relevant (i.e., correlated with the potential endogenous variables in question), and exogenous (i.e., they should not be correlated with the residuals). The lack of exogene-

ity of the instruments seems to be a particularly common problem in regressions with instrumental variables. Even though we are using lagged values as instruments, in the tradition of dynamic panel estimation, we have to ascertain that they are indeed exogenous. Hence we perform a test for overidentifying restrictions. We use here a J-test. Basically, we estimate the equation 14 using instrumental variables. Then we regress the computed residuals on the instruments. We compute the F-statistic of the latter regression from testing that all the coefficients are jointly zero. We hence compute the overidentifying restriction test statistic, which is given by $J = mF$, where m is the number of instruments. The test statistic is distributed as Qui-square with $m - r$ degrees of freedom, where r is the number of endogenous variables.

The results of the test for overidentifying restrictions are reported on Table 4. The lags 2 to 12 of the dependent variable seem to be good instruments for most of the regressions of Table 2. The only exceptions are the last 2 ones with investment in buildings as the dependent variable. In the majority of cases, the J test generates statistics that are non-significant at the conventional levels, indicating that the instruments are indeed exogenous, solving the problem of endogenous regressors. Hence the key result of Table 2 is valid, and for 14 out 16 regressions performed we can conclude that our instrumental variables estimators are consistent. The results are not that straightforward in Table 3. When we use the lags 1 to 6 of the regressors as instruments, they do not solve the endogeneity problem in the bottom half of the table (when investment in buildings is the endogenous variable). Hence the instrumental variables estimators might not be consistent due to the potential endogeneity of some regressors. In this case, our comparison of uncertainty effects might be compromised. In spite of that, our results provide good evidence that the investment in the form of machines tends to suffer more from economic uncertainty (especially wage-related uncertainty) than the investment in the form of buildings and real estate in general.

Table 4 – J-test for Overidentifying Restrictions

	Instruments used in Table 2			Instruments used in Table 3		
	J statistic	Degrees of freedom	Significance level	J statistic	Degrees of freedom	Significance level
Dep. variable: investment in machines	7.501	6	0.277	18.994	14	0.165
	2.764	6	0.838	26.481	24	0.329
	4.730	5	0.450	9.202	14	0.818
	4.502	4	0.342	17.537	29	0.953
	10.399	7	0.167	21.570	19	0.306
	2.895	4	0.576	26.265	29	0.611
	10.351	8	0.241	23.197	24	0.508
	6.403	6	0.380	27.184	34	0.790
Dep. variable: investment in buildings	4.579	6	0.599	51.735***	14	0.000003
	2.967	6	0.813	82.192***	24	0.0000003
	9.214	5	0.101	23.446*	14	0.053
	2.402	4	0.662	55.006***	29	0.0025
	9.903	7	0.194	72.034***	19	0.0000004
	1.973	4	0.741	74.554***	29	0.000007
	51.086***	8	0.0000003	70.942***	24	0.0000016
	24.626***	6	0.0004	90.063***	34	0.0000006

Notes: The symbols ***, ** and * are used to indicate significance at 1%, 5% and 10%, respectively. For Table 2, the set of instruments is compounded of the lags from 2 to 12 of the dependent variable taken in first differences. For Table 3, the set of instruments is compounded of the lags from 1 to 6 of the independent variables taken in first differences (not including the lags of the lagged dependent variable).

4. CONCLUDING REMARKS

Investment is largely treated in the literature as an homogeneous variable. This usual approach rules out interesting insights related to differences in the nature of the inputs used in a project. As a general rule, investment projects involve the purchase of several types of capital goods. The market for each of these goods may have so many idiosyncrasies that the willingness to purchase them may not



react to conventional variables in the same way. Specifically, if the expansion in capacity is concentrated in an easily expandable but nearly irreversible good, uncertainty reduces the incentive to invest. If, otherwise, the project is based on a non-expandable but easily reversible input, uncertainty tends to accelerate investment.

This paper decomposes investment in industrial real estate and machinery. The main concern is to analyze how each of these components is affected by uncertainty. The existing theoretical analysis suggests, in large part, the presence of opposing effects, which means that the sign of the investment-uncertainty relation can be assessed only empirically. In this regard, the paper performs an empirical investigation using Brazilian industry data. Instead of calculating naive measures of uncertainty, we construct more refined proxies based on the volatility of the innovations to two key variables: aggregated industrial value and average wages. We also construct proxies based on inflation and interest rates. But since these vary through time but not across sectors, they work as time dummies. We then focus our attention on the uncertainty panels associated with production and wages.

The estimation procedures rely on panel data methods. I use the first differences approach to remove fixed effects and also the instrumental variables method to tackle problems of inconsistency. As expected, the pooled estimates reveal mostly negative relations between interest rates and investment, and mostly positive relations between the value aggregated by industry and investment. When significant at the conventional levels, the uncertainty related to production has a negative impact on investment. But the significance of these estimates vary with the set of instruments used. Most importantly, wage-related uncertainty has a large (negative) and significant effect on both types of investment. Wage uncertainty harms investment in machinery and in buildings, but the effect on the former is considerably higher.

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A. APPENDIX 1

This appendix presents some features and definitions of the data used in the econometric section of the paper. The investigation is based on a panel of Brazilian industries with yearly observations and a set of twenty-two industrial sectors (one mining and twenty-one manufacturing sectors). We use the following arrangement: mineral extraction; nonmetallic minerals; metallurgy; mechanics; electric and communications equipment; transportation equipment; wood; furniture; paper and cardboard; rubber; leather and hides; chemicals; pharmaceuticals; perfumes, soaps and candles; plastics; textiles; clothing, footwear and clothing goods; food products; beverages; tobacco; printing; and miscellaneous.

The raw data is essentially extracted from PIA (Pesquisa Industrial Anual), which is a yearly industrial survey produced by IBGE (Instituto Brasileiro de Geografia e Estatística), the Brazilian government institute for statistics. We also use IBGE's Industrial Census, that takes the place of PIA in 1975, 1980 and 1985.

The main variable in the analysis is investment. PIA has information about the acquisition as well as the sale of production goods for each of the twenty-two industry classes. These goods are split into two main groups. The first one embraces machines, equipment, appliances, vehicles and furniture. The second group refers to real estate, specifically, buildings, land and other landed properties. In order to obtain the average purchase and average sale in each sector, total purchases and sales are divided by the number of informant firms (otherwise, the values would be sensitive to the number of firms in the sample, which varies across the years and sectors). We define investment (or net investment) as the average purchase minus the average sale.

Three more variables are used in order to construct two proxies for uncertainty. The first proxy is based on the aggregated industrial value. Once more, we obtain the average aggregated industrial value through the ratio of the raw information and the number of informant firms. The second proxy is based on the average earnings of occupied people (comprising all kinds of wages and earnings as well as social charges), which is obtained as follows

$$AEOP_{j,t} = \frac{OEWE_{j,t}/NIF'_{j,t}}{OP_{j,t}/NIF''_{j,t}}$$

where $OEWE_{j,t}$ is the overall expenses on wages and other earnings of sector j at the time t , with the respective number of informant firms given by $NIF'_{j,t}$, and $OP_{j,t}$ is the occupied people of sector j at the time t , with the respective number of informant firms given by

$$NIF''_{j,t}$$

The value in the numerator is the average labor expenses and the value in the denominator is the average occupied people.

Our time span goes from 1966 to 1995. The sample, however, is not complete. In 1971 and 1991 PIA was not performed. Moreover, the sale of production goods and the aggregated industrial value were not reported, respectively, by the 1970's industrial census and by the 1986/87's PIA. Since some of the econometric procedures used require continuous samples, we choose an arbitrary method to fulfill the missing values. We estimate an ARMA process with the unavailable data being fulfilled by interpolation (average between the previous and the subsequent value). Fitted values are then used to complete the missing periods.

Monetary values are deflated by IPA-DI (índice de preços por atacado – disponibilidade interna), which is the main wholesale price index in country-regioncountry-regionBrazil. A better strategy would be to use more specific price indexes, for instance, in the case of wages. Nevertheless, none of these indexes are available for the entire time span used in the analysis.

We should emphasize that we are subject to a typical caveat in dealing with Brazilian annual data. PIA's methodology does not involve deflation across the year. Information is gathered on an accounting



basis (which implies that nominal values in the beginning and in the end of the year are summed and then reported to IBGE). With low levels of inflation this effect can be ignored, but in a highly inflationary environment, the quality of the data might be an issue.

Our database has yet another unfavorable feature. From 1966 to 1973 the information about the sale of production goods is not fully disaggregated. Therefore, we use the category named “others” that denotes not only the disinvestment in real estate, but also the sale of vehicles and furniture. It can be argued, however, that this is not a major caveat since sales tend to be much smaller than acquisitions. In 1973, for example, average overall acquisitions (that is, the ratio between overall purchases and overall informants) were more than 4.6 times larger than average overall sales.