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by Luigi Guiso and Giuseppe Parigi (*)

Abstract

Theoretical models of investment under uncertainty predict that the sign and the strength of the investment-uncertainty relationship is in principle ambiguous and can vary greatly across groups of firms depending on the degree of irreversibility of investment and the market power of the firm. This paper investigates the effects of uncertainty on the investment decisions of a sample of Italian manufacturing firms, using information on the subjective probability distribution of future demand for firms' products according to the entrepreneurs. The results support the view that uncertainty slows down capital accumulation. Consistent with the predictions of the theory, there is considerable heterogeneity in the effect of uncertainty on investment: it is stronger for firms that cannot easily reverse investment decisions and for those with substantial market power. We show that the negative effect of uncertainty on investment cannot be due to uncertainty proxying for liquidity constraints. Evidence of a negative effect of past uncertainty on hours currently worked reinforces the conclusion of a negative relationship between uncertainty and investment.

Contents

(*) Banca d'Italia, Servizio Studi.

1. Introduction[1]

Does uncertainty reduce investment? While many would certainly assent to this thesis, their conclusion would not rest on firm theoretical grounds. In principle, the sign of the effect of uncertainty on investment decisions is in fact ambiguous. Depending on assumptions about the production technology, competition in product markets, the shape of adjustment costs and management attitudes toward risk, increases in uncertainty over the demand for the firm's product and over input costs may have opposite effects on investment.

According to one strand in the literature, initiated by Hartman (1972) and followed by Abel (1983, 1985), greater uncertainty will increase the investment of a risk-neutral competitive firm. Given constant returns to scale in production, the marginal value product of capital is a convex function of the uncertain price faced by the firm so that, by Jensen inequality, greater uncertainty raises the marginal valuation of one additional unit of capital thereby increasing investment.[2]

A second line of research emphasizes the role of irreversibility in shaping firms' investment decisions. Building on ideas first put forward by Arrow (1968), such

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1 We are grateful to Giuseppe Bertola and Steve Nickell for numerous comments and discussions. A previous version of this paper was presented at the CEPR European Summer Symposium in Macroeconomics, 28 June-2 July 1995, Perugia and at seminars at University College, London and at the University of Torino. We thank conference and seminar participants for helpful suggestions.

2 One important corollary is that in this setting uncertainty affects investment decisions only through Tobin's marginal q (Abel, 1983; Abel and Eberly, 1994). Caballero and Leahy (1996) show that this conclusion is not robust to the presence of fixed costs of adjustment and departures from perfect competition; in this more general setting Tobin's marginal q fails to be a sufficient statistic for investment.

researchers as Bernanke (1983), McDonald and Siegel (1986), Bertola (1988), Pindyck (1988, 1991) and Dixit and Pindyck (1994) have shown that if risk-neutral monopolistic firms cannot dispose of installed capital, greater uncertainty about future demand reduces current investment. In fact, in an uncertain environment irreversibility increases the value of waiting for at least part of the uncertainty to be resolved and naturally leads to postponing investment. In other words, if investment is irreversible there is an opportunity cost of investing in the current period, since this precludes the option of investing in the future, when more is known. The opportunity cost increases with uncertainty, and this lowers current investment.

While irreversibility is an important ingredient in determining the sign of the investment-uncertainty relationship, other, more subtle assumptions have been shown to play a decisive role. Abel and Eberly (1993, 1994) find that even in the presence of irreversibility, uncertainty has a non-negative effect on investment if the firm operates in competitive markets. Caballero (1991) generalizes this result and shows that assuming constant returns to scale, it is the interplay between the asymmetry in adjustment costs (i.e. the degree of irreversibility) and imperfect competition that shapes the relation: given imperfect competition, the investment-uncertainty relationship is more likely to be negative as the degree of asymmetry in adjustment costs increases, while given symmetric costs of adjustment the nexus between investment and uncertainty progressively weakens and eventually turns negative as the price elasticity of the demand for the firm's product is decreased, i.e. as the firm becomes less and less competitive.[3]

[3] The role of imperfect competition in determining the sign of the effect of uncertainty on the stock of capital was highlighted by Smith (1969) who showed that in a static context without adjustment costs a risk-neutral monopolistic firm lowers its optimal capital

Assumptions about the firm's technology are equally important. Assuming decreasing returns to scale, Hartman (1976) shows that if labor can be flexibly chosen after demand has been observed, greater uncertainty can decrease (increase) investment if the elasticity of substitution between capital and labor is sufficiently high (low). The intuition is that with enough substitutability "increased uncertainty decreases the optimal capital input since little is lost by waiting until the uncertainty is resolved and hiring labor" (p. 678). One consequence is that perceived uncertainty affects the demand for the flexible factor only indirectly, through its effect on installed capital.

In short, even assuming risk neutrality, the sign and intensity of the investment-uncertainty relationship cannot be settled on purely theoretical grounds. It is left as an empirical problem.[4]

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stock in response to an increase in the uncertainty of the demand for its product.

[4] Two additional factors contribute to make the investment-uncertainty relation ambiguous: capital expandability and investment lags. Abel, Dixit, Eberly and Pindyck (1996) show that even when capital is (partially) irreversible uncertainty on future marginal returns to capital has an ambiguous effect on current investment if it is costly to expand the capital stock, in the sense that the future purchasing price of capital might exceed its current value. In these circumstances, increased uncertainty has two opposite effects: it raises the option value of postponing investment due to limited reversibility but increases the option value of anticipating investment due to limited expandability. The net effect is ambiguous and depends on the effect that increased uncertainty has on the relative value of the two options. Bar-Ilan and Strange (1996) concentrate on the second reason. They show that the effect of uncertainty can become ambiguous even in models with irreversible investment if investment lags are present. With uncertain demand, time to build or construction lags push firms to speed up capital accumulation to avoid facing a high demand with a too low stock of capital. Chances of this occurring increase with uncertainty raising the incentive to invest, which counteracts the incentive to postpone investment arising from irreversibility.

In this paper we provide evidence using data on Italian manufacturing firms drawn from the 1993 Survey on Investment in Manufacturing (SIM) conducted annually by the Bank of Italy. Among other things, the survey collects information on the subjective probability distribution of future demand for the firm's product. These data allow us to construct a measure of the uncertainty faced by each individual firm, which can then be related to its investment decision.

One implication of the theory is that the effect of uncertainty on investment may vary depending on firms' technology, the elasticity of the demand for their product and the access to second-hand markets for capital goods. This suggests that the empirical analysis of the investment-uncertainty relationship can be most fruitfully undertaken with microeconomic data, as they potentially allow one to take the heterogeneity of firms into account. Most importantly, firm-level data enable us to design more stringent tests of the theory of investment under uncertainty by comparing, for example, how the investment decisions of firms with different degrees of market power respond to uncertainty.

In Section 2 we briefly summarize the available empirical evidence. Section 3 describes the dataset and the construction of our measure of uncertainty, while Section 4 lays down the empirical specification of the equation. Sections 5 presents some empirical results for the basic specification of the investment equation. The main finding is that, as is implied by models of irreversible investment, uncertainty lowers capital accumulation. In Sections 6 and 7 we show that, consistently with the theory, the negative effect of uncertainty on investment is considerably smaller (in absolute value) for firms that can more easily dispose of installed capital in second-hand markets and for firms with low market power. This conclusion, as argued in Section 8, is robust to the presence of liquidity constraints differentially affecting groups of firms ranked by degree of irreversibility and market power and to the presence of errors in the indicators of capital irreversibility and firms' market power. Furthermore, as is discussed in Section 9, firms with a higher initial uncertainty have lower demand for hours worked once the uncertainty is resolved, as would be the case if uncertainty had a negative effect on the optimal stock of capital. Section 10 concludes.

2. The available evidence

In spite of the long-standing theoretical debate on the effects of uncertainty on investment,[5] so far there have been few empirical studies on this relationship, and the evidence available is far from conclusive. This is not surprising in light of the many difficulties that the study of investment under uncertainty raises.

Models of investment under uncertainty do not in general deliver closed-form solutions, and competing theories cannot be nested; micro-level data with information rich enough to test some of the theoretical predictions are not usually available; the nature of the relationship depends on such factors as the degree of substitutability between factors of production and the extent of returns to scale, which cannot be easily measured; finally, uncertainty is not in general

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5 The debate dates back to the 1960s and early 1970s with a sequence of contributions including Oi (1961), Arrow (1968) and Smith (1969). Sandmo (1971) and Leland (1972) look at the effect of uncertainty on the output choice of a risk-averse firm; Batra and Ullah (1974) extend the analysis to the competitive firm's factor demand, maintaining the assumption of risk aversion. This is relaxed by Hartman (1972) who retains the assumption of perfect competition.

observable, and indirect indicators are often blurred by measurement problems or troubled by issues of identification.

Caballero and Pindyck (1992) and Pindyck and Solimano (1993) use industry-level and cross-country data to test the empirical relevance of models of irreversible investment. If investment is irreversible, firms invest only if the marginal return on capital exceeds a given threshold, which itself rises with uncertainty. These authors find a positive correlation between different measures of the threshold and the variance of the marginal return on capital, which is used as a proxy for uncertainty. However, they observe that this correlation could be due to the way the threshold has been measured rather than to the effect of uncertainty.

Ferderer (1993a) relies on the proportionality between the risk premium and the variance of returns to derive a measure of uncertainty from data on the term structure of interest rates, finding that this measure has a negative effect on producers' durable equipment expenditure. In a related paper (Ferderer, 1993b), he reaches a similar conclusion using data on macroeconomic forecasts made by participants in the monthly survey conducted by Blue Chip Economic Indicators to measure uncertainty with the standard deviation of these point expectations. Ferderer's proposed measures of uncertainty have the advantage of being forward-looking; however, they also run into a number of problems. First, as is pointed out by Leahy and Whited (1996), his proxies for uncertainty are strongly countercyclical and tend to lead the cycle. If current demand reflects expected future demand, it could be that the proxies are capturing expected demand rather than uncertainty; furthermore, a high dispersion of forecasters' expectations in the Blue Chip panel might not signal high uncertainty but instead reflect differences in the information sets of respondents.[6] Second, the use of aggregate data may give rise to problems of simultaneity: if uncertainty affects precautionary saving, aggregate investment will be affected, indirectly.

Alesina and Perotti (1993) analyze a panel of 70 countries over the period 1960-1985 and find a negative correlation between indices of political and social instability, taken as proxies of uncertainty, and investment. While they interpret their results as evidence of a negative effect of uncertainty on capital accumulation, their indicators could signal a reduction in the expected return or in the level of demand, rather than greater uncertainty as such.

All the papers cited are based on aggregate data which may be a serious problem for the study of the investment-uncertainty relationship. First, most theories of investment under uncertainty have been developed with reference to the single firm; their aggregate implications have not yet been fully worked out.[7] This is particularly relevant to models of irreversible investment: if different firms are subject to different shocks or have different technologies, then the thresholds that trigger investment will also differ. Second, it is likely that much of the uncertainty springs from shocks specific to the firm, and aggregate indicators of risk are

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6 Investment decisions should be affected by the entrepreneurs' subjective perceptions of future returns from investment; but the participants in the Blue Chip survey are only economists in non financial corporations, financial institutions and professional forecasting firms (see Ferderer, 1993b), whose forecasts might be unrelated to the entrepreneurs expectations.

7 Bertola and Caballero (1994) discuss the aggregate implications of irreversible investment when firms are mainly exposed to idiosyncratic uncertainty. They show that the smoothness of aggregate investment dynamics is consistent with investment decisions at the level of the single unit being triggered by irreversibility constraints and firm-specific shocks.

unlikely to reflect them since idiosyncratic shocks tend to wash out in the aggregation process. Third, the theory of investment under uncertainty carries different implications for different firms classified according to market power, the reversibility of their investment and their technology, and empirical analysis with respect to these features may be undertaken only with micro data, if possible at the firm level. Thus, ignoring firms' heterogeneity and assuming a representative firm to assess the effect of uncertainty using macroeconomic data can result in serious aggregation bias. Finally, as noted, tests based on aggregate data may be undermined by simultaneity problems, whose bias may be significantly reduced in micro-based tests.

We know of only one paper (Leahy and Whited, 1996) in which the investment-uncertainty relationship is investigated on micro data; it uses a panel of 600 US manufacturing firms observed over the period 1981-87. Following Pindyck (1988), Leahy and Whited measure uncertainty as the expected variance of the daily return on the stock market valuation of the firm, on the grounds that greater volatility of demand or factor prices should be reflected in increased volatility of the firm's shares. They find that, so measured, uncertainty has a significant negative effect on firm's investment, as irreversible investment models predict. Splitting the sample on the basis of the relevant industry's labor-capital ratio (used as an indirect measure of the labor share) and its variance (as an indicator of the firm's ability to substitute labor for capital ex-post), they find that uncertainty has a stronger negative impact in the subsample of firms with high substitutability and high labor-capital ratios and argue that this evidence runs contrary to models that predict a positive correlation between investment and uncertainty. Accordingly they interpret their results as consistent with theories of investment that emphasize irreversibility and market power (or decreasing returns).

While the use of firm-level data gives Leahy and Whited a clear advantage with respect to tests based on aggregate data, their results still need some qualification. The use of the variance of stock market returns as a gauge of uncertainty has the advantage that in principle it captures all relevant sources of risk. However, share prices may also respond to extraneous information, reflect irrational behavior and the presence of noise traders, or be dominated by speculative bubbles and subsequent crashes rather than by changes in the firm's fundamentals or in its perceived uncertainty. As Abel and Eberly (1993) show, optimal investment under uncertainty depends only on fundamentals.[8] Consequently, the Leahy-Whited measure of uncertainty is likely to misrepresent entrepreneurs' subjective perceptions of risk and this is what triggers their investment decisions. Moreover, Leahy and Whited fail to explore some of the main empirical predictions of the theory of investment under uncertainty, namely the dependence of the sign and strength of the relationship upon the market power of the firm and the degree of irreversibility of its investment decisions. The present paper overcomes some of these problems. For one thing, our measure of uncertainty, although not immune to criticism,[9] is a direct gauge of the

[8] Leahy and Whited also find that when Tobin's q is added as a regressor, the proxy for uncertainty becomes insignificant. They interpret this as evidence in favour of models of irreversible investment. Their finding is certainly consistent with models of irreversible investment that assume constant returns to scale and perfect competition (Abel and Eberly, 1993 and 1994), i.e. with models where irreversibility plays no active role. However, even Tobin's q is statistically insignificant when added to a regression where the only other explanatory variable is the proxy for uncertainty. Thus, while one cannot reject the assumption that only Tobin's q matters for investment, the null hypothesis that only uncertainty matters probably cannot be rejected either.

[9] One weakness is that it reflects only one source of uncertainty, namely demand shocks. Although this is the source emphasised in the literature, firms also face other risks, such as those arising from

entrepreneur's perceptions of risk conditional on his information. Thus we need make no assumption concerning the information set on which the entrepreneur conditions his expectations, which instead has to be specified (and must contain the same variables across different firms) when the measure of conditional uncertainty is inferred from observed realizations. Since firms are likely to use more information than is usually observed by the econometrician, indirect indicators of uncertainty, such as those constructed in the literature, are likely to be biased upward. Furthermore, the bias need not be constant across firms; rather, it should increase with the gap between the information set on which the entrepreneur conditions his expectations and that used by the econometrician. Secondly, we can take into account the effect of liquidity constraints when assessing the impact of uncertainty on capital accumulation. Controlling for liquidity constraints in tests of the investment-uncertainty relationship is a potentially important problem which has been ignored in the literature: if riskier firms have more limited access to the credit market, then it could be that the uncertainty measures actually proxy for credit constraints rather than identifying changes in the marginal value product of capital. Third, the SIM contains information on firms' access to secondary markets for capital goods, which allows a direct check of the relevance of irreversibility in investment decisions. In the following section we provide a more detailed description of the data and their potential.

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shocks to factor prices. However, if shocks to the demand for the firm's product are uncorrelated with shocks to its factor prices, the estimates of the effect of uncertainty on investment will not be affected by these omitted variables.

3. The data and the measurement of uncertainty

In the empirical analysis we combine information from two main sources: the Survey of Investment in Manufacturing (SIM) of 1993 and the Company Accounts Data Service (CADS) of 1992, which are both described in detail in the Appendix. The investment survey is conducted at the beginning of each year by the Bank of Italy on a representative sample of about 1,000 Italian manufacturing firms stratified according to industry, size and geographical location collecting detailed information on investment and employment decisions in the two years preceding the interview and plans for the next two. Thus, each survey is equivalent to a two-year panel. SIM also reports some characteristics of the firm (year of foundation, branch of industry, ownership structure, geographical location) as well as a limited number of economic variables, including the volume of sales, the number of man-hours worked (in 1994), planned price increases, access to the credit market and to the secondary market for installed capital (in 1995). It neglects some important features of firms' activity, not looking for data on capital stock, income, purchases of raw materials, cash flow or financial assets and liabilities. However, this information can be obtained from the CADS sample, which collects balance-sheet and profit-and-loss data on a non-random sample of more than 30,000 Italian non-financial firms.

The final database for our analysis thus represents the merge of SIM and the CADS datasets; since not all the SIM firms (991 in the 1993 survey) are also present in the CADS sample, 204 observations are lost. After deleting 108 missing observations on the stock of capital and 130 on our measure of uncertainty, we obtain a final reference sample of 549 firms,[10] but the main features of the total SIM sample are preserved with only minor differences (see Table A1 in the Appendix), which suggests that the merge should not affect the results of our analysis. In Section 6 we also draw on the 1995 SIM to construct an indicator of investment irreversibility while in Section 8 we rely on the 1994 SIM and merge its data on hours worked, hourly wages and sales with the 1993 responses on expected demand and perceived uncertainty to extend the analysis to the effect of uncertainty on the demand for labour hours, the flexible factor.

3.1 *Measuring uncertainty*

A distinctive feature of the 1993 SIM is that each firm in the sample was asked to report its subjective probability distribution (SPD) of the evolution of the future demand for its product. From this one can compute not only the level of expected demand but also a measure of conditional uncertainty, that can be correlated with investment plans. Specifically, each firm was asked to assign weights (summing to 100) to a set of intervals for the rate of growth in demand one and three years ahead, on the assumption that the price of its product was kept constant.[11] The respondent is either the owner of the firm or a member of its top management, except in very large firms. This ensures that the subjective probability distribution reflects the perceptions of a person with direct responsibility for firm's decisions. Hence, given the

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10 The reference sample makes use of the three-year ahead expectations to measure uncertainty. If expectations one year ahead are instead used the final sample contains 606 observations due to a lower number of missing values for the one year responses (see Section 3.1)

11 The exact wording of the question along with the intervals are reported in the appendix.

distribution we can derive central tendency indices and a measure of subjective uncertainty concerning demand.[12]

Let $\tilde{d}_i$ denote the random variable "growth rate of the demand for the firm's product in the *i* years following 1993" with i=1,3 and F_0 the volume of firm's sales in 1993 (year 0). The future level of demand for the firm's product (holding its relative price constant) is then given by:

$$\tilde{F}_i = (1+\tilde{d}_i)F_0 \qquad i = 1,3 .$$

The conditional mean and variance of future demand as perceived in 1993 will be our measures of the firm's assessment of the level of demand and of perceived uncertainty. They are given respectively by:

$$_0y_i = (1+{}_0d_i^e)F_0$$
$$_0\sigma_i^2 = {}_0\sigma_{di}^2 F_0^2$$

where $_0d_i^e$ and $_0\sigma_{di}^2$ are the conditional mean and variance of the growth rate of demand *i* years ahead, which can be readily calculated from the subjective probability distributions.[13]

The top panel of Table 1 shows the frequency distribution of the coefficient of variation of expected demand, given by $_0\sigma_i / {}_0y_i$, for the whole SIM sample. Not all

12 Guiso, Jappelli and Terlizzese (1992) use similar information on households' subjective expectations of future earnings to test for precautionary savings.

13 Note that what one would really like to know is the conditional variance of the shock to the demand, not the conditional variance of the demand itself, which is what we use as a measure of uncertainty. Obviously, given that firms' forecast assume that the price is kept unchanged, the two variances coincide if the shock to demand is additive, while the variance of the shock is proportional to the variance of demand if the shock is multiplicative.

Table 1

FREQUENCY DISTRIBUTION OF THE COEFFICIENT OF VARIATION OF FUTURE DEMAND AND EXPECTED DEMAND GROWTH
(coefficient of variation)

Interval (a)	1 year ahead		3 years ahead	
	Number of firms	Frequency (a)	Number of firms	Frequency (a)
0 - 1	205	23.4	-	-
1 - 3	473	53.9	198	24.7
3 - 5	126	14.4	224	28.0
5 - 8	43	4.9	137	17.1
8 - 10	18	2.1	49	6.1
10 - 13	9	1.0	66	8.2
13 - 15	1	0.1	29	3.6
15 - 20	1	0.1	44	5.5
20 - 25	1	0.1	14	1.8
Above 25	-	-	40	5.0
Mean	2.3		7.7	
Median	1.6		4.9	
Total	877	100	801	100

EXPECTED DEMAND GROWTH

	Number of firms	Frequency (a)	Number of firms	Frequency (a)
Negative (a)				
More than 15	7	1.9	35	4.4
15 - 10	27	3.1	7	0.9
10 - 4	60	6.8	11	1.4
4 - 0	92	10.5	40	5.0
Positive (a)				
0 - 4	282	32.2	85	10.6
4 - 10	220	25.1	119	14.9
10 - 15	80	9.1	69	8.6
15 - 25	72	8.2	131	16.4
More than 25	27	3.1	304	37.8
Mean	5.1		26.2	
Median	3.2		15.8	
Total	877	100	801	100

(a) Percent.

firms reported the subjective probability distribution of demand growth, and of those that did, not all reported it for both time horizons: of 991 firms, 877 gave the distribution one year ahead but only 801 also reported it three years ahead.[14]

Not surprisingly, the level of uncertainty is much higher when expectations refer to the more distant future: the mean value of the coefficient of variation of expected demand three years ahead is 7.7 percent compared with 2.3 percent for the one-year expectations. Overall, uncertainty appears somewhat small by this gauge, perhaps because firms can exploit private information to forecast demand.

Although the distribution of the coefficient of variation is highly skewed to the right, there is enough variability across firms to estimate the relationship between perceived uncertainty and investment. The coefficient of variation of the one-year expectations does not exceed 1 percent for 23.4 percent of the firms, and the 1-3 percent range embraces the majority of the sample; 14.4 percent of the firms have a coefficient in the interval 3-5 percent, and for 8.3 percent of the sample it is greater than 5 percent. The heterogeneity in perceived uncertainty three years ahead is greater: for 12.3 percent of the firms the coefficient of variation is more than twice the mean (8.3 percent for the

[14] A probit regression for the probability of firms' reporting the subjective probability distribution against a set of observable characteristics, such as industry, location, type of ownership and size, found no systematic effects; the only exception is the dummy for publicly owned firms, which are less likely to report both the one-year and three-year expectations. This may well be due to the fact that the publicly owned firms in the sample are large (2,186 employees on average) compared to private firms (687 employees) so that the respondents to the survey questions are not close enough to the top management to be able to report the probability distribution of the future demand for the firm's product.

one-year expectations) and for 25 percent of the sample it exceeds 10 percent.[15]

In principle, the uncertainty that is relevant to current investment decisions is the uncertainty perceived over the entire planning horizon. To come as close as possible to this requirement, in our estimation we rely primarily on the variance of expected demand three years ahead. This is likely to be a reasonably good proxy of uncertainty for two reasons: first, if the discount rate (interest rate plus depreciation rate) is sufficiently high, then longer-term uncertainty is likely to have little impact on current investment decisions; and second, if demand is generated by a constant-variance random process, long-term uncertainty can be expressed as a function of the variance of the one-period innovations in demand. However, we also report estimates using the one-year measure; to facilitate coefficient comparisons we will calculate the three-year variance with reference to the average annual growth rate of demand. As we will see, results are invariant with respect to the choice of the proxy for uncertainty.

The bottom panel of Table 1 shows the frequency distribution of the expected growth rate of demand one and three years ahead. The one-year average for the whole sample

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15 A least squares of the coefficient of variation of expectations one and three years ahead against a set of (nearly) time-invariant firm characteristics, such as location, industry, type of ownership, size and organization, can explain about 20 percent of the sample variability. With the exception of the "production of autos, tracks and buses", which appears to be more uncertain than average, demand uncertainty has no clear sectoral pattern. Proprietorship firms, firms in the South and small firms exhibit significantly higher uncertainty, while large firms are less uncertain about future demand. Finally the type of ownership (state or private owned) has no significant effect on demand uncertainty. Interestingly, while size, location and type of organization help in predicting firms' uncertainty, none of the listed characteristics has explanatory power in a regression of the firm's expected growth rate of demand one or three years ahead.

is 5.1 percent, but over the longer horizon expected growth is more than five times that figure.[16] For most firms, one-year expected growth falls in the interval 0-4 percent, while over 10 percent anticipate exceptional growth (above 15 percent), but 22 percent expect demand to fall. Over the medium term expectations are more optimistic: only 11.7 percent expect a decline which is consistent with a larger share of firms anticipating the end of the 1990-1993 recession over the longer run.[17]

Table 2 shows the sample means of several variables for the final sample used in the estimation and for the sub-samples of firms with low and high uncertainty; firms are assigned to the high or low uncertainty group depending on whether the three-year coefficient of variation is above or below the sample mean. Low-uncertainty firms are more likely to be located in the North, to be publicly owned and to have a higher cash-flow (in proportion to capital stock). They also report lower planned investment as a share of the capital stock (5.9 percent as against 6.1 percent), suggesting a

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16 The median expected growth rate is 3.2 percent for the one-year expectations and 15.8 percent for the three-year horizon. Interestingly, uncertainty is greater among the more pessimistic firms, especially over the longer horizon. Using the three-year expectations, the coefficient of variation among the firms that expect an increase in demand is 7.49 percent compared to 9.58 percent among the firms that expect a decline. The corresponding figures for the one-year expectations are 2.24 and 2.36.

17 In Italy, 1993 was a year of deep recession, with industrial production falling by 2.4 percent; 1994, to which the SIM expectations are referred, was a year of fast recovery, and industrial production increased by 5.2 percent. Due to the combination of a sharp devaluation (which greatly benefited export-oriented firms) and a tight fiscal policy (which heavily affected firms with a domestic market), the recession and the subsequent recovery were unevenly distributed. This is consistent with a substantial share of firms expecting a drop in the demand for their product in 1994 as shown in Table 1. Furthermore, it is likely that the speed of the recovery was at least partly unanticipated: merging the 1993 and 1994 surveys and comparing the actual with the one-year expected growth in demand, 51.6 percent of the firms underestimated growth while only 34.9 overstated it; the remaining 13.5 percent were on target.

Table 2

FIRMS WITH LOW AND HIGH UNCERTAINTY: SAMPLE MEANS OF SELECTED VARIABLES (*)

Variable	Low uncertainty	High uncertainty	Total selected sample
Planned investment/Stock of capital	0.0592	0.0610	0.0599
Expected level of demand/ Stock of capital	2.1102	2.3094	2.1809
Cash flow/Stock of capital	0.0711	0.0283	0.0559
Coeff. of variation of expected demand growth (a)	0.0114	0.0452	0.0234
Employees < = 100 (0,1)	0.2034	0.2154	0.2076
Employees > 100 (0,1)	0.7966	0.7846	0.7923
Geographic location			
North (0,1)	0.7458	0.7077	0.7322
South (0,1)	0.0734	0.0769	0.0747
Publicly owned firms (0,1)	0.0424	0.0205	0.0346
Private firms (0,1)	0.8362	0.8410	0.8379
Access to the second-hand market for capital (0,1)	0.5141	0.5846	0.5392
Capital/Labour ratio (b)	220.5424	228.6128	223.4089
Credit-rationed firms (0,1)	0.1205	0.0860	0.1081
Number of firms	354	195	549

(*) The threshold to split the sample is the mean of the subjective coefficient of variation of the three-year expected demand, computed using the subjective probability distribution of the annual average growth rate of demand. The (0,1) notation indicates that the variable is a dummy which is equal to 1 if the firm has the specified characteristic.

(a) Using the SPD of three-year ahead annual average growth rate of demand.
(b) Millions of 1993 lire.

positive correlation between uncertainty and investment. However, the two groups differ in several important ways that are likely to affect investment plans either directly or indirectly. For example, low-uncertainty firms are less likely to have access to second-hand markets for capital goods (as indicated by the share of firms that purchased or sold investment goods second-hand in 1993) which could make them more cautious in their investment plans; they are also more likely to be credit-rationed (as gauged by the share of firms that applied for credit but were turned down; see the variables definitions in the Appendix) which might constrain investment; furthermore, the low-uncertainty group also has lower expected demand which could well explain its lower investment plans. Thus, properly testing different theoretical predictions on the investment-uncertainty relation requires that all these factors be controlled for. To this we now turn.

4. The empirical model

The main problem in assessing the effects of uncertainty on investment is that models of investment under uncertainty deliver closed-form solutions to the optimization problem of the firm only under highly restrictive assumptions on the degree of competition in the product market, on technology and on the form of adjustment costs. In particular, there is no-closed form solution to the general model of investment under uncertainty with asymmetric adjustment costs and no restrictions on returns to scale in production or on the price elasticity of the demand faced by the firm.

Abel and Eberly (1993, 1994) do obtain a closed-form solution to the investment problem with irreversibility and convex adjustment costs, but only for the perfectly competitive firm with constant returns to scale. The solution, however, cannot be generalized to firms with market power or producing with decreasing returns to scale. A closed-form solution for irreversible investment can be obtained for the monopolistic firm with decreasing returns to scale, but only under restrictive assumptions on the shape of the adjustment cost function (Caballero, 1991). Thus, in general, one cannot nest the two competing models of investment under uncertainty (i.e. the Hartman-Abel model and the Arrow-Bertola-Pindyck theory of irreversible investment) into a structural parametric model.

The specification for the empirical analysis may be seen as a Kind of very simple flexible accelerator model augmented with uncertainty. In other terms, we adopt a reduced-form specification for the rate of investment which is assumed to depend on past realized investment, expected demand and its uncertainty. More specifically, we use the following specification:

$$\frac{{}_0I_1^p}{K_0} = \alpha_0 + \alpha_1\left(\frac{I_0}{K_{-1}}\right) + \alpha_2 \frac{{}_0y_i}{K_{-1}} + \alpha_3 \frac{{}_0\sigma_i^2}{K_{-1}} + \alpha_4 Z_i + \varepsilon_1$$

where ${}_0I_1^p$ represents the investment planned by the firm at the end of 1993 (year 0) for 1994 (year 1) at 1993 prices; I_0, the volume of investment made in year 0; K_j, the stock of capital at the end of year *j*, where $j = (0,-1)$; ${}_0y_i$, the level of demand expected at the end of year 0 for year *i*, when the subjective probability distribution of demand growth *i* = (1, 3) years ahead is used to calculate expectations; ${}_0\sigma_i^2$, our measure of the firm's uncertainty on future demand as perceived at the end of 1993 for year *i*; Z_i, a vector of additional controls (scaled by the stock of capital); and ε_1, a stochastic error term. Clearly, irreversible investment models predict $\alpha_3 < 0$, while the Hartman-Abel theory implies $\alpha_3 > 0$.

It is worth emphasizing that the dependent variable is the investment planned at the end of 1993 for 1994, not actual investment in 1994. The former, we believe, is the proper variable to correlate with our measure of perceived uncertainty; in this way we match investment decisions with the information available to the firm at the time the plans are made and uncertainty is perceived. In Section 5 we also discuss results obtained when actual investment is used as the dependent variable.

5. Results

Table 3 gives the parameter estimates of two variants of the above investment equation using the three-year (first two columns) and the one year (last two columns) subjective probability distribution of demand growth to measure uncertainty and expected demand. Estimates are made for the entire sample of firms present in both the 1993 SIM and the 1992 CADS. To account for extreme observations and departures of the residuals from normality we have estimated the parameters using Li (1985) robust estimator. Having cross-sectional data, we cannot eliminate fixed unobservable characteristics of the firm that could affect the investment-uncertainty relationship, such as the entrepreneur's risk aversion, by first differencing the variables. Insofar as perceived uncertainty is correlated with these attributes, omitting them biases the results. We try to compensate at least partially in three ways. First, we include a set of dummy variables (not reported in the tables) for industrial

Table 3

INVESTMENT AND UNCERTAINTY
DEPENDENT VARIABLE: RATIO OF INVESTMENT PLANNED ONE YEAR AHEAD TO THE STOCK OF CAPITAL (*)

Variable	Expectations three years ahead		Expectations one year ahead	
	(1)	(2)	(3)	(4)
I / K	0.4192 (0.037)	0.3960 (0.0188)	0.4648 (0.0173)	0.4531 (0.0174)
${}_0y_i / K$	0.0063 (0.0006)	0.0057 (0.008)	0.0071 (0.0006)	0.0063 (0.0008)
$\left({}_0\sigma_i / K\right)^2$	-0.0879 (0.0288)	-0.0750 (0.0290)	-0.0718 (0.0202)	-0.0650 (0.0201)
CF / K	-	0.0103 (0.0044)	-	0.0118 (0.0043)
RAT	-	-0.003 (0.004)	-	-0.0021 (0.0040)
Constant	0.0105 (0.0117)	0.0128 (0.0118)	0.0061 (0.0109)	0.0071 (0.0109)
Number of observations (a)	549	518	606	572
F-test for all coefficients = 0	34.28 (29, 519)	30.40 (31, 486)	41.80 (29, 576)	39.15 (31, 540)

Standard errors in parentheses; number of degrees of freedom for the F-test.

(*) The estimates have been conducted using a robust technique to account for heteroschedasticity and outliers (see Li, 1985). To control for unobservable factors arising from differences in entrepreneurs' preferences or firms' technology and for cyclical differences across firms, regressions include a set of dummy variables: 16 dummies for the industry; 2 for the geographical location (North or South); 3 for the size of the firm according to its number of employees (< 100; 100-200; > 500); 2 for the type of ownership (public, private) and 3 for merger, acquisition and divestiture operations. The uncertainty measure is the subjective variance of future demand computed using the SPD of the three-year annual average growth rate of demand.

(a) The number of observations in the regressions reported in column 2 (respectively 4) differs from that in column 1 (respectively 3) due to some missing observations in the *RAT* indicator.

sector, location, type of ownership and size, which can capture some of the firms' unobservable heterogeneity in technology, market structure and management tastes. Second, we account for differences in entrepreneurs' absolute risk aversion by assuming that they will be reflected in the sensitivity of investment to uncertainty, i.e. in the size of α_3; assuming that absolute risk aversion is decreasing in wealth, we account for this dependence by letting $\alpha_3(K_{-1}) = \frac{\alpha_3}{K_{-1}}$ and rescale the uncertainty term in the investment equation by the (end-of-period) stock of capital as a proxy of the entrepreneur's wealth. Third we will report results for subgroups of firms that theory predicts will react differently to uncertainty: while the omission of unobservable variables potentially biases the estimates of α_3, we hope that the extent of the bias will be the same across groups.

The first column of Table 3 presents the parameter estimates of the basic investment equation. The sign of the coefficient of past investment is consistent with results in the literature of estimates of dynamic investment equations showing that changes in investment determinants, such as sales or cash-flows, affect capital accumulation only gradually (Fazzari, Hubbard and Petersen, 1988). The level of expected demand has a positive and highly significant effect on investment plans: this is consistent with firms facing an inelastic demand curve and thus, indirectly, with models that give rise to a concave marginal value product of capital. Our proxy for uncertainty has a negative effect on investment plans and its coefficient is significantly different from zero (t-value = -3.05). This result is in accordance with irreversible investment models and contradicts theories that predict a positive relationship between investment and uncertainty. Other things being equal, an increase in the variance of expected demand (scaled by the capital stock) from its sample mean to the 95th percentile reduces investment by 3.1 percent. Evaluated at the sample mean, the elimination of uncertainty would increase investment by a similar amount: this represents a sizable if not exactly overwhelming effect.

It might be objected that the negative effect of uncertainty on investment arises because uncertainty is actually proxying for credit constraints. If, as is argued by Stiglitz and Weiss (1981), credit rationing is related to the firm's inherent riskiness, then riskier firms are more likely to be credit-constrained and thus to invest less.[18] To assess the validity of this interpretation, in column 2 we have added a measure of the firm's cash flow (*CF*)[19] that is often employed as a proxy for liquidity constraints in investment equations; since cash flow can reflect differences across firms in future profitability rather than liquidity constraints (Bond and Meghir, 1994), we have also inserted a direct indicator of access to credit (*RAT*) that is equal to 1 if at the end of 1993 the firm was rationed in the credit market, constructed using information from SIM on the result of credit applications.[20] The estimates show that firms with less abundant internal funds or with limited access to credit markets invest less. However, they also suggest that

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18 Table 2 shows that low-uncertainty firms are more likely to be credit-rationed than firms in the high uncertainty group. On the face of it this is prima facie counterintuitive, since models of rationing based on adverse selection or moral hazard predict that riskier firms are more likely to be denied credit. Note, however, that low-uncertainty firms are also more likely to have irreversible investment, and irreversible capital is likely to have little value when pledged as collateral. We will discuss this point further in Section 6.

19 The cash-flow of the firm refers to 1992. Since cash-flow is endogenous, using its lagged value helps reducing simultaneity bias.

20 Each firm in the SIM sample is asked to report whether it has applied for credit and has been turned down by a financial intermediary; this information allows us to define an indicator of the firm's access to the credit market. For details on the way the *RAT* dummy has been constructed, see the Appendix and Angelini and Guiso (1995).

uncertainty affects investment independently of credit rationing: the presence of the cash-flow variable and the dummy for credit rationing do reduce the coefficient of the proxy for uncertainty (from 0.088 to 0.075 in absolute value), but it nevertheless remains significant.

The estimates discussed so far make use of the three-year subjective probability distribution to compute expected demand and uncertainty. In column 3 and 4 of Table 3 we check the robustness of our results with respect to the length of the time horizon, using the one-year distribution to compute the mean and variance of future demand. As can be seen, the coefficient of the uncertainty variable is slightly smaller when one-year expectations are used, but it is estimated with even greater precision. Overall, the main findings are unchanged.[21] Essentially, this is because the firms that are more uncertain over the short term are also more uncertain over the longer term: the correlation coefficient between the two measures of uncertainty is equal to 0.97.

Our left-hand-side variable in the regressions shown in Table 3 is the investment planned by the firm at the end of 1993 for the following year. As mentioned in Section 4, the reason for preferring planned to actual investment is that the former is based on the same information available to the firm when reporting its subjective probability distribution of future demand. Obviously, it would be indifferent to use actual investment as the dependent variable if all plans were fully carried out. However, planned and actual investment differ, often by a substantial margin, as firms respond to the accrual of new information. Matching plans and realizations

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[21] The sample is larger than in the first two columns of Table 3 because, as noted in Section 3, there are fewer missing observations to the one year expectations. Estimating the equation with one year expectations on the same sample as in columns 1 and 3 does not change the results.

using the 1993 and 1994 SIM, only for 49 percent of the firms present in both surveys (835 out of 991 firms in the 1993 survey and 985 in the 1994 survey) was actual investment within 5 percent (above or below) the plan. Nevertheless, one expects that firms with higher perceived uncertainty at the end of 1993 - and thus with lower investment plans - ended up with lower actual investment in 1994. And this is indeed the case. Merging the 1993 and 1994 samples and using actual investment as the dependent variable in our basic specification, we still find that uncertainty has a negative effect on investment, though the coefficient is halved and is less precisely estimated (-0.042 with a standard error equal to 0.0356).[22]

As a further check of the robustness of our results, we have estimated the investment equation excluding large firms. The reason for this is that, as mentioned in Section 3.1, in the case of large firms the actual respondent may not be the owner of the firm or a member of its top management, with the consequence that the reported subjective probability distribution may not accurately reflect the expectations of those who make the investment decisions. However, excluding firms employing more than 1,000 workers leaves the results unchanged: the coefficient of expected demand in the basic specification (i.e. that in column 1 of Table 3) is 0.0062 (standard error 0.0006) and that of the conditional variance is -0.0828 (standard error 0.0287), only slightly less than that estimated using the full sample.[23]

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22 Due to attrition, the number of observations in the merged sample reduces to 479; but the result does not depend on the reduced size of the sample. Using investment plans as the explanatory variable in this smaller sample, the coefficient and significance of the proxy for uncertainty are essentially the same as in Table 3.

23 Results are basically the same if only firms with more than 5,000 or more than 2,500 employees are excluded. Excluding firms with more than 1,000 employees reduces the sample size to 479 firms; the

Our conclusion is that the negative effect of uncertainty is consistent with the irreversibility of the investment decisions of firms facing inelastic demand.

6. Irreversibility

If the foregoing conclusion is correct, the firms that can more easily sell off installed capital when demand proves to be lower than anticipated should be less responsive to uncertainty. To test this hypothesis, we have constructed two different indicators of irreversibility of installed capital. The first is based on information collected in the 1995 SIM on firms' access to secondary markets for their capital equipment; the second is based on "cyclicity", the degree of the cyclical volatility of the firm's industry on the grounds that, as we shall explain shortly, the more cyclical the industry is the more illiquid the firm's capital is likely to be. As far as the first indicator is concerned, in the 1995 SIM each firm has been asked whether, based on the characteristics of the capital in use, it would be hard to sell its machinery second-hand (see the Appendix for the exact wording). Four options were given, reflecting increasing order of difficulty: a) it can be resold relatively easily without incurring significant losses with respect to its value in use; b) it can be resold, but it requires some time to find a buyer and losses are incurred; c) it takes a long time to find a buyer and one can only be found if the selling price drops considerably below value in use; d) there is essentially no second-hand market at all. The first case corresponds to easily reversible investment, while the last implies complete irreversibility of capital in place, possibly cases where

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coefficients of the other variables are essentially unchanged with respect to the full sample estimates.

machines are designed to be used only in a specific firm and accordingly cannot be converted to alternative uses even within the firm's industry. The other two instances reflect cases in which firm's capital can, to a greater or lesser extent, be redeployed; a buyer can thus be found but second-hand markets are illiquid and investment is consequently at least partially irreversible. The first possibility was chosen by slightly under 20 percent of the respondents, implying that about 80 percent of the firms judge their capital to be partly or totally irreversible.[24]

If the firms interviewed in 1995 were all present in the 1993 SIM, then one could use this information to split the 1993 sample into two groups, those with less and those with more irreversible capital, and test whether the negative effect of uncertainty on investment is actually greater among firms in the second group. However, due to attrition, this procedure would cause a loss of over a third of the observations. In order to avoid so significant a reduction in the size of the sample we proceeded as follows: we first estimated a probit model of the probability that a firm's investment is at least partly irreversible (i.e. it answers (b), (c) or (d)) on the 1995 sample using 16 sector dummies, 4 location dummies and 3 size dummies as explanatory variables. We then used the estimated coefficients to assign to each firm in the 1993 sample a probability that its investment is irreversible. Finally we split the sample classifying as high or low irreversibility, firms whose predicted probability was above or respectively below the sample mean.

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[24] Out of 999 firms in the 1995 SIM, 845 answered this question and 154 skipped it. 144 reported that they have little difficulty in reselling capital in place, i.e. they chose answer (a); 224 chose answer (b) and 232 answer (c), while 245 reported that there is no second-hand market for their capital, i.e. chose answer (d).

The second indicator of capital irreversibility is based on industry cyclicity and relies on the idea put forward by Shleifer and Vishny (1992) that an asset liquidity - defined as the difference between its selling price and its value in best use - depends on the cash availability of firms in the same industry as the firm that wants to liquidate excess capital. If other firms in the industry, which are likely to be the next-best users of the assets on sale, are also experiencing problems, then the firm will have a hard time finding a buyer at a price close to the value in best use and will likely have to resort to outsiders. The latter, in turn, since will incur reconversion costs and, as outsiders know less than insiders about the quality of the assets and may need to hire an expert to run the equipment, thus facing agency problems, can only buy at a considerably lower price than an industry insider would be willing to pay if only he were not liquidity constrained.

This reasoning suggests that asset illiquidity - i.e. capital irreversibility - is likely to plague industries that are hit mainly by common shocks more severely than industries where idiosyncratic shocks are more important. Thus, one way to measure the capital irreversibility of a firm is to look at the cyclicity of its industry. Industries where firm-specific shocks are relatively important will be characterized by smaller fluctuations in output; industries where aggregate disturbances are dominant will experience large swings. The capital of firms in the former industries should have a low degree of irreversibility, that of firms in the latter group should be relatively high. To construct such an indicator, we used seasonally adjusted quarterly data on industrial production over the period 1953-1995 using a three-digit industry classification. For each of the 44 industries we computed the variance of the cyclical component of the log of industrial production.[25] We then assigned the variance so computed to each of the 1993 SIM firms on the basis of their industry code. A firm thus classifies as high or low capital irreversibility if the variance of its industry is above or below the median.[26]

Table 4 shows the results of the estimates. The first two columns report coefficient estimates when the sample is split according to the indicator based on the 1995 SIM question on access to the second-hand market. Even for firms with a low degree of investment irreversibility the effect of uncertainty is negative and significant at the confidence level of 5.3 percent. However, in the subsample of firms with a high degree of investment irreversibility the coefficient of the variance of expected demand is more than twice as large in absolute value (0.154 compared to 0.065) and is estimated with greater precision (t-value = 2.76). The assumption that the coefficient of the variance of demand is the same in the two groups is strongly rejected (t-value = 22.74), lending support to the idea that uncertainty is especially relevant whenever it is costly to dispose of excess capital. This conclusion is broadly confirmed if industry cyclicity is used to split the sample. In the subsample of firms in low-cyclicity industries, i.e. with relatively liquid assets and thus low irreversibility, the point estimate of the coefficient of demand uncertainty is -0.0315 (third column), but the assumption that it is equal to zero cannot be rejected (t-value = -0.504); among the firms in highly cyclical

25 The cyclical component was computed by taking a three-term moving average of deviations from trend of the log of industrial production; the trend was computed using the Hodrick-Prescott methodology.

26 Among the highly cyclical industries are shipbuilding, railroad equipment, precision tools and surgical equipment and the production of investment goods. Industries with low cyclicity are the tobacco industry, salt mining, pharmaceuticals and virtually all food industries.

Table 4

IRREVERSIBILITY, UNCERTAINTY AND INVESTMENT
DEPENDENT VARIABLE: RATIO OF INVESTMENT PLANNED ONE-YEAR AHEAD TO THE STOCK OF CAPITAL (*)
(expectations three years ahead)

	Degree of irreversibility (based on 1995 SIM)		Degree of irreversibility (based on industry ciclicity)	
Variable	Low	High	Low	High
I / K	0.4940 (0.0292)	0.4087 (0.0254)	0.3129 (0.0278)	0.5436 (0.0243)
${}_0y_3 / K$	0.0014 (0.0007)	0.0111 (0.0013)	0.0071 (0.0010)	0.0034 (0.0009)
$({}_0\sigma_3 / K)^2$	-0.0653 (0.0336)	-0.1542 (0.0559)	-0.0315 (0.0625)	-0.0572 (0.0297)
Constant	0.0242 (0.0170)	0.0095 (0.0998)	0.0227 (0.0112)	0.0112 (0.0120)
Number of observations	261	288	276	273
F-test for all coefficients = 0	24.41 (15, 245)	32.72 (15, 272)	26.63 (14, 261)	50.50 (15, 257)
t-test for equality of the effect of uncertainty	22.26 (547)		6.14 (547)	

Standard errors in parentheses; number of degrees of freedom for the F-test a the *t*-test.

(*) The estimates have been conducted using a robust technique to account for heteroschedasticity and outliers (see Li, 1985). To control for unobservable factors arising from differences in entrepreneurs' preferences or firms' technology, regressions include a set of dummy variables: 2 for the geographical location (North or South); 3 for the size of the firm according to its number of employees (< 100; 100-200; > 500); 2 for the type of ownership (public, private) and 3 for merger, acquisition and divestiture operations. The uncertainty measure is the subjective variance of future demand computed using the SPD of the three-year annual average growth rate of demand.

industries, i.e. is with a high degree of irreversibility, uncertainty has a stronger negative effect (-0.0572) and is statistically significant at the 5.5 percent confidence level. Furthermore, the assumption that the uncertainty coefficient is the same in the two groups is easily rejected (*t*-value = 6.12).

As a further check of our result we have re-estimated the basic investment equation using a third criteria to split the sample on the basis of SIM information on transactions in the secondary market for capital goods and on leasing investment. More precisely, the irreversibility indicator is constructed setting it equal to 1 whenever in 1993 the firm sold or bought investment goods in the second-hand market or leased them, and 0 otherwise. Leased investment is considered as reversible because normally, as part of the leasing contract, the client acquires the option to return the good. As a consequence, leasing companies only finance the purchase of goods that enjoy large second-hand markets (such as cars or easily reconvertible machinery). Williamson (1988) identifies the possibility of leasing given assets with the feature that the underlying assets are fully redeployable. While this is only a rough indicator, as it could reflect differences across firms in their position over the cycle, it is likely to capture the essence of the reversibility of investment decisions, namely the possibility of freely disposing of capital. Using this indicator to split the sample confirms the results of Table 4: uncertainty lowers investment in both groups, but among firms with more irreversible investment the effect is considerably larger (-0.533 compared to -0.082 if three-year expectations are used and -0.313 against -0.070 using one-year expectations). Overall, these results suggest that the irreversibility of investment decisions is an important factor in determining the effect of uncertainty on capital accumulation.

7. Competition

The availability of firm-level data makes it is possible to test a further implication of the theory of investment under uncertainty: that for given technology and asymmetry of the adjustment cost function, the effect of uncertainty should depend on the degree of competition in the market for the firm's product. The greater the monopoly power of the firm, the more likely that an increase in uncertainty will reduce investment.

To test this hypothesis, we split the sample on the basis of the firm's market power. This is negatively correlated with the price elasticity of the demand for the firm's product, which, however, is not observable. In splitting the sample we follow Domowitz, Hubbard and Petersen (1986) and compute the firm's profit margin on unit price as (value added - labour costs)/(total income + change in stocks); for a price-setting firm with constant returns to scale, the lower the elasticity of demand the higher the margin.[27] We then classify firms as having more or less monopoly power depending on whether their profit margin is above or below either the mean or the median value for the firm's industry: in this way we hope to account for possible cyclical effects on the measurement of the margin arising from cyclical differences across industries.

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27 Although since Lerner (1934) classical work the price-cost margin has been widely used as an index of monopoly power, it is not immune to criticism. For a discussion of the use of profit margins to measure firm's market power see Martin (1984).

The parameter estimates of the basic investment equation for the two subsamples are presented in Table 5. The first two columns report results when the sample is split according to the mean value of the margin; the last two take the median as benchmark. The main findings do not depend on the choice of the threshold used to split the sample. Expected demand always has a positive effect on investment but, in accordance with theoretical predictions, the coefficient is larger in the higher margin subsample. This is consistent with imperfect competition and indirectly supports our measure of firms' market power. The estimated coefficient for uncertainty is negative in all specifications but is considerably smaller in absolute value for firms with low market power (point estimates range from -0.0666 (t-value = -2.00) in column 1 to -0.0686 (t-value = -1.94) in column 3); in the subsample of firms with a high degree of market power, it is almost three times as large and highly significant (-0.170 and -0.168 with t values equal to 3.71 and 3.81 respectively). Taken together, the results discussed in this and the previous sections support models that explicitly allow for some degree of irreversibility, possibly varying across firms, and for imperfect competition.

8. Robustness of results and extensions

The estimates reported in Table 4 can be criticized on the ground that both indicators of irreversibility can lead to misclassification of firms between the two groups. For instance, if the first indicator is used, it may be that firms affected by adverse shocks at the time of the interview are less optimistic than those hit by positive shocks about the possibility of finding a buyer for their equipment, and thus tend to overstate capital irreversibility. Alternatively one could argue that due to phrasing problems, the question on access to the second-hand market for capital can be misunderstood. On the other hand, sectoral cyclicity is also likely to be an imperfect indicator of firms' capital irreversibility, since the two-digit classification may combine firms in high- and low-cyclicity industries. A similar argument can be made for the mark-up indicator used to split the sample in Table 5. As is shown by Lee and Porter (1984), if regime classification is based on an imperfect indicator, least squares estimates of the parameters will in general be inconsistent, and the bias will be proportional to the extent of the misclassification. However, they also show that if the true parameter differs across regimes and, say, is smaller in regime 1 and larger in regime 2, than estimates will be biased upwards in regime 1 and downwards in the other. Consequently the difference in the estimated parameter will be biased towards zero.[28] Thus, if the true effect of uncertainty is more strongly negative among firms with irreversible capital (high market power), our estimate of the effect of uncertainty on investment among those firms is, if anything, an

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[28] More precisely, Lee and Porter show that the estimated parameter ($\hat{\alpha}_3^1$), say the effect of uncertainty in sample 1 (firms with irreversible investment), will be a weighted average of the true parameter (α_3^1) in sample 1 and the true parameter (α_3^2) in sample 2 (firms with reversible investment); the weights are the conditional probabilities of correctly assigning a firm to sample 1, π, and the probability of assigning it to sample 1 when in fact should be assigned to sample 2, $1-\pi$, given that the noise indicator assigns the firm to sample 1. That is $\hat{\alpha}_3^1 = \pi\alpha_3^1 + (1-\pi)\alpha_3^2$. Similarly, the estimated effect of uncertainty in the second sample will be $\hat{\alpha}_3^2 = p\alpha_3^2 + (1-p)\alpha_3^1$, where p is the probability of correctly assigning a firm to sample 2 conditional on the indicator saying that it should be so classified. It then follows that if the true parameters do not differ across regimes the estimates are consistent; if they do differ and uncertainty has a stronger negative impact among firms with irreversible investment ($\alpha_3^1 < \alpha_3^2$) the estimate $\hat{\alpha}_3^1$ will be biased upwards and $\hat{\alpha}_3^2$ downwards. The difference $\hat{\alpha}_3^1 - \hat{\alpha}_3^2$ will consequently be biased towards zero.

Table 5

MARKET POWER, INVESTMENT AND UNCERTAINTY
DEPENDENT VARIABLE: RATIO OF INVESTMENT PLANNED THREE YEARS AHEAD TO THE STOCK CAPITAL (*)
(expectations three years ahead)

Variable	Degree of market power (splitting criterion: mean)		Degree of market power (splitting criterion: median)	
	Low	High	Low	High
I / K	0.4370 (0.0299)	0.4677 (0.0245)	0.4722 (0.0227)	0.4064 (0.0305)
${}_0y_3 / K$	0.0045 (0.0011)	0.0106 (0.0008)	0.0048 (0.0012)	0.0106 (0.0008)
$({}_0\sigma_3 / K)^2$	-0.0666 (0.0333)	-0.1698 (0.0458)	-0.0686 (0.0353)	-0.1683 (0.0442)
Constant	0.0101 (0.0130)	0.0034 (0.0183)	0.0070 (0.0138)	0.0005 (0.0177)
Number of observations	224	325	262	287
F-test for all coefficients = 0	13.53 (24, 199)	60.88 (24, 300)	24.31 (24, 237)	53.65 (24, 262)
t-test for equality of the effect of uncertainty	28.86 (547)		28.93 (547)	

Standard errors in parentheses; number of degrees of freedom for the F-test and the t-test.

(*) The estimates have been conducted using a robust technique to account for heteroschedasticity and outliers (see Li, 1985). To control for unobservable factors arising from differences in entrepreneurs' preferences or firms' technology, regressions include a set of dummy variables: 16 dummies for the industry; 2 for the geographical location (North or South); 3 for the size of the firm according to its number of employees (< 100; 100-200; > 500); 2 for the type of ownership (public, private) and 3 for merger, acquisition and divestiture operations. The uncertainty measure is the subjective variance of future demand computed using the SPD of the three-year annual average growth rate of demand.

understatement of the true negative effect, while that among firms with less irreversible capital (low market power) overstates the negative effect.

When splitting the sample between firms with a low and a high degree of investment irreversibility, the estimates reported in Table 4 take the degree of competition as given. Those reported in Table 5, when splitting the sample among firms with low and high market power, take as given the degree of irreversibility. If, as is argued by Caballero (1991), high market power and high investment irreversibility both tend to amplify the negative effect of uncertainty on investment, then grouping firms with low market power and irreversibility, on the one hand, and high market power and irreversibility on the other, one should find a stronger negative effect in the latter group than in any of the other estimates that consider the high market power or the high irreversibility group in isolation; and conversely. And this indeed proves to be the case. The first two columns of Table 6 report estimates of the basic investment equation for the two extreme groups characterized by low market power (using the mean as a benchmark) and irreversibility (using the indicator based on the 1995 SIM information) and high market power and irreversibility, respectively. In the first group the estimated coefficient equals -0.0401 and does not differ significantly from zero (*t*-value = -0.998): this is smaller (in absolute terms) than the estimates reported in the first column of Table 4 (-0.0653, *t*-value = -1.94) and the first column of Table 5 (-0.0666, *t*-value = -2.00). In the second group the estimated coefficient of uncertainty is -0.2610 (*t*-value = -4.14) and shows a significantly stronger effect on investment than that estimated in the second column of Table 4

Table 6

LIQUIDITY CONSTRAINTS, MARKET POWER, IRREVERSIBILITY AND INVESTMENT DEPENDENT VARIABLE: RATIO OF INVESTMENT PLANNEDTHREE YEARS AHEAD TO THE STOCK CAPITAL (*)
(expectations three years ahead)

	Degree of irreversibility and market power		Degree of irreversibility (based on 1995 SIM)		Degree of market power (splitting criterion: mean)	
Variable	Both low	Both high	Low	High	Low	High
I / K	0.5539 (0.0827)	0.4755 (0.0393)	0.5030 (0.0281)	0.4074 (0.0263)	0.4296 (0.0297)	0.4885 (0.0249)
${}_0y_3 / K$	0.0032 (0.0014)	0.0171 (0.001)	0.0036 (0.0009)	0.0079 (0.0014)	0.0044 (0.0011)	0.0054 (0.0012)
$({}_0\sigma_3 / K)^2$	-0.0401 (0.998)	-0.2610 (0.0631)	-0.0899 (0.0329)	-0.1160 (0.0569)	-0.0538 (0.0332)	-0.1098 (0.0464)
CF / K	-	-	-0.0179 (0.0063)	0.0144 (0.0065)	0.0065 (0.0050)	-0.0283 (0.0089)
RAT	-	-	-0.0048 (0.0036)	-0.0033 (0.0018)	-0.0021 (0.0016)	-0.0135 (0.0064)
Constant	0.0157 (0.0189)	0.0048 (0.0166)	0.0178 (0.0164)	0.0123 (0.0105)	0.0081 (0.0126)	0.0208 (0.0187)
Number of observations	108	172	249	269	213	305
F-test for all coefficients = 0	5.64 (15, 92)	50.32 (14, 157)	26.09 (16, 232)	23.77 (17, 251)	12.52 (26, 186)	41.90 (26, 278)
t-test for equality of the effect of uncertainty	35.78 (278)		6.31 (516)		15.13 (516)	

Standard errors in parentheses; number of degrees of freedom for the F-test and the t-test.

(*) The estimates have been conducted using a robust technique to account for heteroschedasticity and outliers (see Li, 1985). To control for unobservable factors arising from differences in entrepreneurs' preferences or firms' technology, regressions include a set of dummy variables: 16 dummies for the industry; 2 for the geographical location (North or South); 3 for the size of the firm according to its number of employees (< 100; 100-200; > 500); 2 for the type of ownership (public, private) and 3 for merger, acquisition and divestiture operations. The uncertainty measure is the subjective variance of future demand computed using the SPD of the three-year annual average growth rate of demand.

or in the second column of Table 5 (-0.1542 and -0.1698 respectively).[29]

The estimates shown in Table 4 refer to the basic specification of the investment equation. It might be objected that what is driving the result is not the interaction between uncertainty and irreversibility but rather the fact that, as argued by Williamson (1988) in a partial equilibrium context and by Shleifer and Vishny (1992) in a general equilibrium framework, firms with highly illiquid capital have lower debt capacity, since their assets are less valuable as collateral. Thus, it may be that the stronger negative effect of uncertainty among firms classified as "irreversible" reflects lower investment due to credit constraints. A similar argument can be made for the estimates reported in Table 5: if firms with a low degree of market power are more dependent on external finance than firms that, thanks to market power, can generate internal funds, then the negative effect of uncertainty might reflect liquidity constraints. To assess the validity of this explanation in Table 6 (columns 3 to 6) we add to the basic specification the proxies for liquidity constraints discussed in Section 4 (i.e. the firm's cash flow and the indicator of credit rationing). Interestingly, among the firms with a low degree of irreversibility or low market power the coefficient of uncertainty becomes less negative than in Table 4 and Table 5. However, uncertainty still has a

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29 Among the firms excluded, i.e. those with a high irreversibility and low market power or the reverse (269 observations) the estimated coefficient of uncertainty is equal to -0.0646 (t-value = -1.78) and is, as expected, lower than that in the group of firms with both low irreversibility and market power but greater than that estimated for the sample of firms with high irreversibility and market power. For comparison with the estimates shown in Tables 4 and 5 in the specification reported in the first two columns of Table 6 we do not include controls for liquidity constraints. Adding the cash-flow variable and the credit rationing indicator leaves the results unchanged: in the first regime the estimated coefficient of uncertainty is -0.0107 (t-value = -0.26) and in the second regime, -0.270 (t-value = -4.02).

stronger negative effect among firms with a high degree of irreversibility or high market power. In both cases the assumption that the effect of uncertainty is the same in the two samples is easily rejected (*t*-value = 6.31 when the sample is split by degree of reversibility; *t*-value = 15.13 when it is split by market power). Furthermore, investment is more responsive to cash-flow among firms with highly irreversible capital and low market power. Thus, while firms with a higher degree of irreversibility are likely to have a lower debt capacity and their investment consequently to be more dependent on internal funds, the differences in the effect of uncertainty between the two groups cannot be explained by differential access to the credit market. The same holds when the comparison concerns firms with respectively low and high market power.

9. Factor flexibility and uncertainty

In this section we further explore the investment-uncertainty relationship, looking at it from a different perspective. As Hartman (1976) has shown, if some factors can be chosen flexibly once uncertainty has been resolved, the firm can partially adjust if the investment choice proves *ex-post* to have been a poor decision. In turn, it is this possibility (along with decreasing returns or imperfect competition) that can lead the firm to decrease investment when faced with uncertainty: if demand turns out to be different than expected it can profitably be satisfied by changing the flexible factor. Since the choice of the flexible factor is made after the shock has been observed, whereas investment decisions are made prior to the realization of demand, it is clear that increased uncertainty will affect this choice only through its effect on the stock of capital.

One way to test for the effect of uncertainty on investment is to look at the effect that uncertainty has *ex-post* - i.e. in the period after the expectations of future demand were formed - on the demand for the flexible factor.

Assuming that hours of work can be flexibly modified - for instance resorting to overtime - and that capital and labour are complementary factors in production, if uncertainty has a negative effect on the stock of capital, then, conditional on a given realization of demand, it should also reduce hours of work. We test this implication of the theory of investment under uncertainty by combining data on hours worked, sales and hourly wages from the 1994 SIM survey with our measure of conditional uncertainty and expected demand from the 1993 survey. Let

$$H_{jt} = h(F_{jt},\ W_{jt},\ K_{jt}({}_{t-1}y_{jt},\ {}_{t-1}\sigma^2_{jt}))$$

be the demand for labour hours by firm *j* in year *t* (1994 in our case) conditional on the realized value of demand at time *t*, F_{jt}; the hourly wage, W_{jt}; and the (as of time *t* fixed) stock of capital, K_{jt}, available at *t* but chosen at *t*-1 (i.e. at the end of 1993), on the basis of demand expected at *t*-1 for *t*, ${}_{t-1}y_{jt}$, and the uncertainty perceived at time *t*-1, ${}_{t-1}\sigma^2_{jt}$. If investment and uncertainty are negatively correlated, then, other things being equal, a higher value of the variance of demand expected at the end of year *t*-1 should lower the number of hours worked in year *t* if $\partial H / \partial K > 0$. Furthermore, once proper account has been taken of the stock of capital at *t*, perceived uncertainty and expected demand should have no effect on hours demanded.

Figure 1 lends support to this conjecture; it shows that there is a negative correlation between the number of hours worked in 1994 and the level of demand uncertainty perceived in the previous year. A more formal test is conducted in the estimates reported in Table 7, which control explicitly for the hourly wage rate and the realization of demand. We report results for expectations both one year and three years ahead. In the one-year expectations, if the stock of capital is not included among the regressors (column 1), past expectations of demand have a positive and significant effect on currently worked hours, while past perceived demand uncertainty affects current hours negatively, even after controlling for the realization of demand and the hourly wage rate. The hypothesis that the two coefficients are jointly equal to zero is rejected by an F test at the 5 percent confidence level ($F(2, 496)=4.28$, p-value = 0.0144). As is shown in column 2, if the stock of capital is added as an explanatory variable, the coefficients of past expected demand and (to a lesser extent) perceived uncertainty are reduced in value, and lose statistical significance: in this case the hypothesis that they are jointly equal to zero cannot be rejected at the confidence level of 5 percent ($F(2, 495) = 3.12$, p-value = 0.0449).[30] When three-year expectations are used, results are less clear-cut; the effect of past expected demand on currently worked hours is positive and that of uncertainty is negative, but the hypothesis that their coefficients are jointly equal to zero cannot be rejected, even if the stock of capital is not included ($F(2, 446) = 2.39$, p-value = 0.093). Compared to the estimates based on one-year expectations this loss of precision comes essentially

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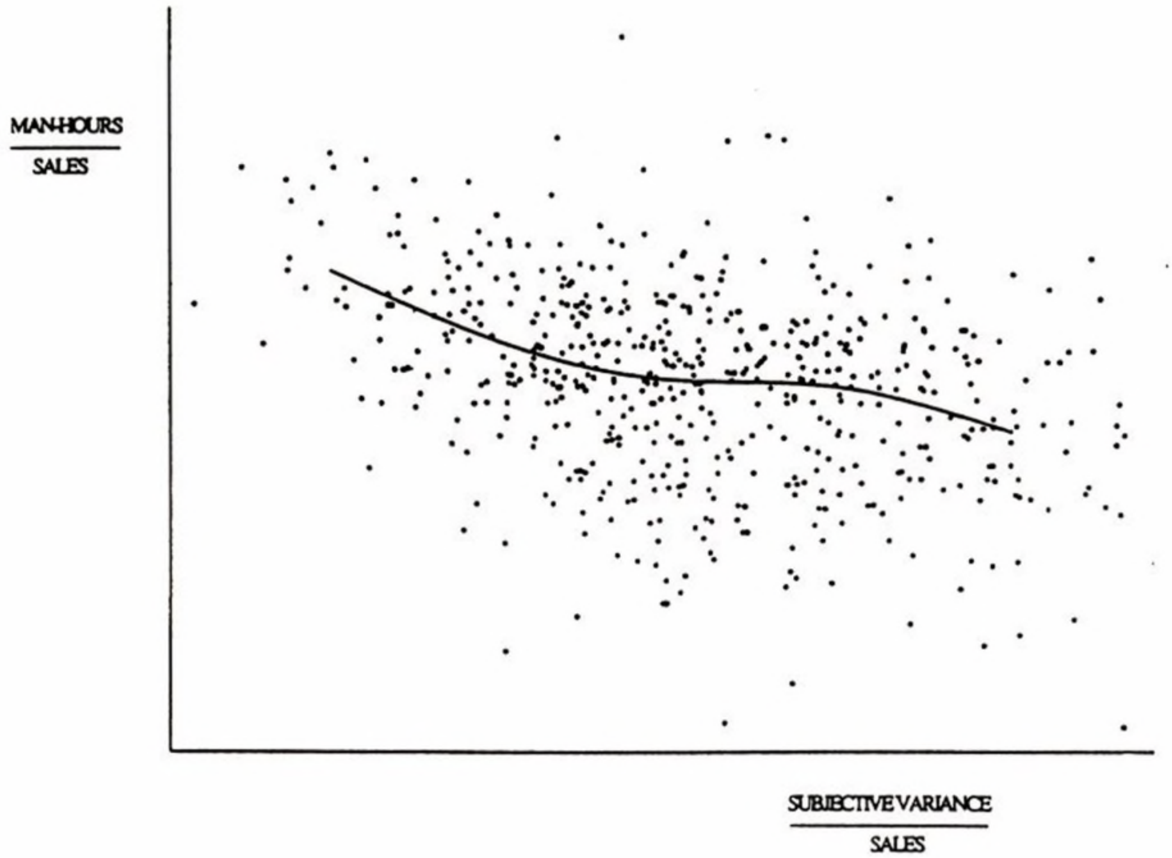
30 Notice that even after controlling for the stock of capital, (past) expected demand and uncertainty seem to retain some effect on current hours. One plausible explanation is that this reflects the fact that hours are unlikely to be fully flexible because overtime is subject to limits and workers to firing costs that induce some irreversibility.

Figure 1

MAN-HOURS AND UNCERTAINTY



because the latter estimates are based on a larger sample.[31] When the investment equation with one-year expectations is estimated over the same sample as with three-year expectations, results are in fact close to those reported in colums 3 and 4 of Table 7.[32]

These findings provide additional independent evidence of a negative effect of uncertainty on investment; furthermore, they support Hartman (1976) explanation of the negative correlation between investment and uncertainty as arising from the *ex-post* substitutability between the quasi-fixed factor (capital) and the flexible factor (labour).

10. Concluding remarks

At least since Keynes, uncertainty about future demand or factor costs has been regarded as a crucial determinant of investment decisions. The presumption, among commentators, is that uncertainty can severely slow capital accumulation: accordingly, it is often cited as an important factor when explaining specific episodes of investment contraction. While many would certainly assent to this thesis, their conclusion does not rest on firm theoretical grounds. In principle, the effect of uncertainty on investment decisions is actually ambiguous. Depending on ones' assumptions concerning the production technology, the structure of product markets, the

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31 Sample attrition reduces the number of observations to 477 if expectations three years ahead are used and to 527 with one-year expectations.

32 In the specification without the stock of capital the coefficient of expected demand is 0.9648 and that of unceratinty -0.328; their significance is reduced (*t*-values 1.710 and 1.864 respectively) and the *p*-value for the hypothesis that the two coefficients are jointly equal to zero rises to 0.0423, from 0.0144 when the full sample is used.

Table 7

TOTAL MAN-HOURS AND UNCERTAINTY DEPENDENT VARIABLE: TOTAL MAN-HOURS SCALED BY TOTAL SALES (*)

Variable	Expectations three years ahead		Expectations one year ahead	
	(1)	(2)	(3)	(4)
F_1	3.7520 (1.1229)	4.2700 (1.0642)	3.4737 (1.0395)	4.0935 (0.9967)
$(W / P)_1$	-1.1719 (0.5437)	-1.2933 (0.5193)	-1.4945 (0.4861)	-1.5600 (0.4692)
${}_0y_i$	0.8633 (0.5251)	0.7359 (0.5016)	1.1927 (0.5218)	0.8988 (0.5046)
${}_0\sigma_i^2$ (a)	-0.2854 (0.1897)	-0.2672 (0.1790)	-0.3241 (0.1650)	-0.2929 (0.1578)
K_1	-	1.2463 (0.0938)	-	1.2111 (0.0915)
Constant	81,651.3 (15,770.4)	56,428.0 (15,435.3)	83,958.7 (14,483.3)	63,914.6 (14,308.1)
Number of observations	477	477	527	527
F(2, *n-k*)	2.39 (2, 446)	2.11 (2, 445)	4.28 (2, 496)	3.12 (2, 495)

Standard errors in parentheses; number of degrees of freedom for the F-test.

(a) The coefficient is multiplied by 1,000.

(*) All variables are scaled by total sales. F_1 represents total sales in 1994 at 1993 prices: the deflator is constructed using the growth rate of sales prices in 1994 with respect to 1993 directly reported by the firms in the SIM; ${}_0y_i$ is the level of demand at constant prices $i = (1,3)$ years ahead, with expectations formed at the end of 1993; $(W / P)_1$ is the hourly wage deflated by sales prices; ${}_0\sigma_i^2$ is the variance of the level of demand computed using the SPD of the $i = (1,3)$ years ahead growth rate of demand; K_1 is the stock of capital in 1994 at 1993 prices. $F(2, n-k)$ is the value of the F statistic for the null hypothesis that the coefficients of expected demand and the conditional variance are jointly equal to zero. The estimates have been conducted using a robust technique to account for heteroschedasticity and outliers (see Li, 1985). The regressions include a set of dummy variables (not reported in the table) to account for differences in behaviour arising from heterogeneity in entrepreneurs' tastes or firms' technology; these include the industry (16 dummies), its geographical location (North and South), the type of ownership (public or private) and merger, acquisition and divestiture operations. The number of observations differs from that in the sample used in the estimations reported in Tables 3 and 4 because observations were lost when merging the 1993 and 1994 samples. However, there is no significant change in the characteristics of the two samples.

shape of adjustment costs and management attitudes toward risk, the effect on investment of an increase in uncertainty over the demand for the firm's product and over input costs can be either positive or negative.

This paper uses data on Italian manufacturing firms in 1993 drawn from the Survey on Investment in Manufacturing (SIM) conducted annually by the Bank of Italy. Among other things, the survey reports the subjective probability distribution of future demand for the firm's product, allowing us to construct a measure of the uncertainty faced by each individual firm, which can be related to its investment decision.

The main findings are consistent with theories that predict a negative relation between investment and uncertainty. Other things being equal, we find that firms with higher perceived uncertainty invest less. Increasing the variance of expected demand from its sample mean to the 95th percentile lowers investment by 3.1 percent, while the elimination of uncertainty would increase investment by a comparable amount. We also show that the negative effect of uncertainty on investment cannot be explained by uncertainty proxying for credit constraints, credit rationing naturally being more likely among riskier firms. When a direct measure of credit rationing is used to control for access to credit, the effect of uncertainty on investment is slightly reduced but the main results are unchanged.

Our estimates show, however, that there is considerable heterogeneity in the effect of uncertainty across groups of firms that differ in the degree of reversibility of investment decisions or in market power. Uncertainty has a substantially stronger negative influence on the investment choices of firms that cannot easily dispose of excess installed capital equipment in second-hand markets; the effect is still negative but considerably smaller in the subsample of firms that (according to an indicator of transactions in the secondary market) can more easily resell their machinery. Furthermore, consistently with simulation results in the theoretical literature, the investment-uncertainty relationship is more markedly negative for firms that are likely to face an inelastic demand for their product. Overall, the results confirm the predictions of models of investment under uncertainty that rely on irreversibility and market power as important descriptive elements of the firm environment. At the same time they suggest that for firms facing a demand with high price elasticity and those whose capital goods are relatively easy to resell if necessary, uncertainty is unlikely to be particularly important.

APPENDIX

Data sources and variables' definitions

1. Data sources

Two main sources have been used in the empirical analysis: The Bank of Italy Survey of Investment in Manufacturing (SIM) and the database of the Company Accounts Data Service (CADS).

SIM

Since 1984 the Bank of Italy has run a yearly survey on a sample of manufacturing firms, collecting information on investment effected and investment and employment plans. It also reports a set of characteristics of the firms (location, ownership structure, industrial sector, year of foundation), qualitative information on production capacity and capacity utilization, the reasons for any revisions of investment plans, total sales, export sales and expected variations in costs. The number of firms in each cross-section is around 1,000. The survey also functions as panel; due to attrition, the number of firms in the panel is less than 500. Interviews are conducted at the beginning of each year by well trained officials of the Bank of Italy.

In order to ensure representativeness, the sample is stratified by sector of activity, firm size and region. Since 1987 the stratification has referred to the joint frequency distribution of the population of firms in September 1987 according to the criteria cited provided by the National Statistical Institute (Istat). Prior to 1987 the unit surveyed was the plant; since 1987 it has been the firm. Small firms (under 50 employees) are excluded in order to keep sample size under control. In case of mergers, acquisitions and break-ups, information is collected to take them into account.

Data are subject to detailed controls for correctness and consistency; any time doubts arise on a specific variable, the firm is contacted again and the data adjusted. Together with the relatively small size of the sample, and the professional qualifications of the interviewers, who have established long-term relations with the firms' managers, this guarantees high data quality.

Since 1988 the survey has included a questionnaire on access to credit. In 1992 a monographic section was added, to collect detailed information on selected topics of particular interest. In 1992, for instance, the focus was on the structure of the firm's ownership and control; in 1993, on product demand expectations and uncertainty; in 1994, on commercial debt and plant-level wage bargaining.

The Company Accounts Data Service (CADS)

The CADS dataset is the principal source of information on the balance sheets and income statements of firms. These data have been collected since 1982 by a consortium of banks interested in pooling information on their clients. The whole sample includes some 30,000 Italian non-financial firms; the sample, however, is not randomly drawn, since a firm enters only by borrowing from one of the banks in the consortium. Balance sheets are reclassified in order to reduce the dependence of the data on the accounting conventions used by each firm to record income figures and asset values.

2. Variables

Cash-flow. Cash-flow at current prices in 1992. Source: CADS.

Capital stock. Beginning-of-period stock of capital in equipment and non-residential buildings at 1993 prices. It is computed by CADS with a procedure based on the perpetual inventory method, using as benchmark the capital stock in 1984, valued at replacement cost, collected by a special survey conducted by Mediocredito Centrale on a subsample of 6,000 firms in the CADS database. These values have been updated to 1992 with the investment figures from the CADS database using depreciation rates computed by Barca and Magnani (1989) and Istat. The stock for 1993 has been extrapolated with the data on investment contained in SIM.

Credit rationing indicator. Dummy variable equal to 1 if the firm is credit-constrained. It is constructed using the answers provided by the firms in the SIM sample to three questions on access to credit. Specifically, firms are asked: i) whether at the current market interest rate they wish a larger amount of credit; ii) whether they would be willing to accept a small increase in the interest rate charged in order to obtain more credit; iii) whether they have applied for credit but have been turned down. A firm is classified as credit-constrained if, given a positive answer to either the first *or* the second question, it also answers "yes" to the third. Source: SIM.

Degree of capacity utilisation. Degree of capacity utilisation for year *t* as reported by the firm. Source: SIM.

Effective investment. Total fixed investment in equipment and non-residential buildings at current prices undertaken by the firm in the year. Source: SIM.

Planned investment. Total fixed investment in equipment and non-residential structures at 1993 prices planned by the firm at the end of 1993 for 1994. Source: SIM.

Real hourly wage rate. Wage bill in 1994 divided by total hours worked, deflated by the sales price deflator. Source: SIM.

Reversibility indicator. We use three indicators of reversibility: the first is based on a direct question on the possibility of selling installed capital second-hand; the second, on industry cyclicity; and the third, on transactions in the secondary market and leased investment. The construction of the cyclicity indicator is described in the text. The first indicator is derived following the procedure of Section 6 and is based on the following question in the 1995 SIM:

> "Bearing in mind the type of machinery used in making your main product, we would like to know whether a second-hand market exists where in case of need it could be sold. Please choose one of the following alternatives:
> a) Yes, and it is relatively easy to find a buyer in a short time willing to pay a reasonable price.
> b) Yes, but it takes time to find a buyer and selling prices are not very rewarding.
> c) Yes, but it is very difficult to find a buyer and selling prices can become very low.
> d) No, there is no such market."

The third indicator is a dummy variable equal to 1 for firms with more easily reversible investment and is constructed using the answers to specific SIM questions on purchases and sales of capital goods in second-hand markets and on leasing investment. The indicator is 1 if in 1993 the firm purchased or sold investment goods second-hand or leased them.

Sales. Total sales in the year at current prices. Source: SIM.

Sales price. Percentage rate of change of the sales price from year t-1 to year t , as reported directly by the firm. Source: SIM.

Total man-hours worked. Total man-hours effectively worked in 1994. Source: SIM.

ncertainty and expected demand. The SIM question on xpectations of future demand aims at eliciting the ntrepreneur's subjective probability distribution of future demand for the firm's product. Specifically, each firm was asked the following:

> "We would like to know your forecast of the future path of the demand for your products, both in the short and the medium term. Report your forecast about the growth rate of the demand for your product (with respect to the level in 1993), keeping prices constant. Suppose you have 100 points; assign these points to the following intervals, so that they reflect the probability of the events listed (0 means that the event is impossible, 100 that it occurs for sure; a value *x* between 0 and 100 means that the probability of that event occurring is *x*)."

The two horizons were 1994 and 1994-96, in both cases relative to 1993. The intervals were:

Positive:	more than 50 percent
	25 to 50 percent
	15 to 25 percent
	10 to 15 percent
	6 to 10 percent
	4 to 6 percent
	2 to 4 percent
	0 to 2 percent
Negative:	0 to 2 percent
	2 to 4 percent
	4 to 6 percent
	6 to 10 percent
	10 to 15 percent
	more than 15 percent

The expected value and the variance of the distribution have been computed using the method described in Section 3; we have assumed that the central values of the open intervals "more than 50 percent" and "more than 15 percent" are, respectively, 75 and 25 percent. To compute the variance of the growth rate of future demand we have assumed that the distribution is uniform within the intervals.

Table A1

COMPARISON OF THE INVIND AND THE INTEGRATED SIM-CADS SAMPLES: MEANS OF SELECTED VARIABLES

	SIM-CADS sample	SIM sample
Sector (0,1)		
Public	0.033	0.060
Private	0.838	0.801
Location (0,1)		
North	0.732	0.713
Centre	0.193	0.199
South	0.075	0.088
Investment/sales	0.049	0.047
Share of sales exported	0.314	0.306
Share of credit-rationed firms	0.108	0.128
Firm size (number of employees)	546	719
Number of firms in the sample (a)	549	991

(a) Merging the SIM and the CADS samples leads to a loss of 204 observations; 238 additional observations are lost because of missing values of the capital stock (108 observations) and of the proxy for uncertainty (130 observations).

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