Entrepreneurial Risk, Investment and Innovation*
(Preliminary version. Comments welcome)

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Abstract

A number of studies show that entrepreneurial households face a large amount of unvidersifiable risk. This paper studies the effects of this risk on the relationship between uncertainty, innovation and investment dynamics. In the first part of the paper we develop a simple model of a risk averse entrepreneurial household that can invest in a risky technology or in a risk free asset. The idiosyncratic risk of the technology is not insurable. We calibrate the model so that a simulated industry of entrepreneurial households matches the cross sectional volatility of profits and the distribution of the concentration of wealth (the percentage of net worth that each entrepreneurial household invests in their own business) across US entrepreneurial households. We show that, due to the lack of diversification, a small increase in uncertainty has a large negative effect on the investment decisions of entrepreneurial firms. Given that entrepreneurial firms are on average much smaller than publicly owned firms, this result provides a plausible explanation of the findings of Ghosal and Loungani (2000), who show that the negative impact of uncertainty on investment is much greater in US industries dominated by small firms than in those dominated by large firms. In the second part of the paper we study a unique dataset of italian manufacturing firms with both information about the property structure and about the type of investment performed by the firms. We show that an increase in uncertainty negatively affects the investment in innovation of entrepreneurial firms, while it does not affect the investment in innovation of non entrepreneurial firms.

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1 Introduction

This paper studies the effect of undiversifiable entrepreneurial risk on the relationship between uncertainty and aggregate investment. Entrepreneurial households, defined as the households whose primary source of income comes from a private business they own and manage, account for a consistent share of total output and employment in the US. Moreover many of these households, even the more wealthy ones, are undiversified. Moskowitz and Vissing-Jørgensen (2002) document that 48% of all private equity is owned by households for whom it constitutes at least 75% of their total net worth. Heaton and Lucas (2000) study the implications of entrepreneurial undiversifiable risk for portfolio choices and asset prices. Meh and Quadrini (2004) and Angeletos (2003) show, in a general equilibrium framework with incomplete markets, that when the entrepreneurial households are not able to diversify the idiosyncratic risk of their business they underinvest in their risky technology. This implies a lower aggregate capital in equilibrium with respect to a complete markets economy.

This paper analyses to what extent entrepreneurial risk is important in explaining the relationship between uncertainty and investment dynamics. From a theoretical point of view the effect of uncertainty on investment is ambiguous. If the marginal revenue product of capital is a strictly convex function of the price of output, then increased uncertainty about the future price of output tends to increase investment (Abel, 1983). Irreversibility and risk aversion instead generally imply that uncertainty has a negative effect on investment (Caballero, 1991; Pindyck, 1993; Abel et al, 1996; Nakamura, 1999). Most of the empirical literature finds that uncertainty reduces investment[1], and usually argues that fixed capital irreversibility is the likely explanation.

The contribution of this paper is to show that entrepreneurial risk is an important factor in understanding the relationship between uncertainty, investment and innovation. The intuition is that investment becomes very sensitive to uncertainty when risk aversion is combined with an high concentration of risk, like in the case of entrepreneurial house-

[1] See Carruth, Dickerson and Henley (2000) for a review of this literature.

holds. We illustrate this effect by considering a model of an entrepreneurial household that can invest in a risky technology and in a risk free asset. The idiosyncratic risk of the technology is not insurable. The household is born with an initial endowment of wealth, and every period decides how much to consume, to invest in the risky technology and to lend or borrow at the market risk free interest rate r. We solve the model and use it to simulate a partial equilibrium industry with many entrepreneurial households, all identical except for the realisation of their idiosyncratic shocks. We calibrate the parameters of the model so that the cross sectional variance of the (income/sales) and the (income/value) ratios in the simulated industry match those of US entrepreneurial households. Moreover we calibrate the initial wealth endowed to newborn entrepreneurs in order to match the distribution of the concentration of wealth across US entrepreneurial households. We then analyse the effect of a permanent increase in uncertainty in the simulated economy combined with a decrease in average productivity, such that the investment of the entrepreneurs and the aggregate capital of the simulated industry would be unaffected if all entrepreneurs were able to diversify away all the risk. We show that, for levels of undiversifiable risk comparable to those of the US entrepreneurial households, aggregate entrepreneurial capital has a large negative elasticity to aggregate uncertainty, even for low levels of risk aversion.

Because entrepreneurial firms are on average small firms, the simulation results provide a plausible explanation of the findings of Ghosal and Loungani (2000). The authors use data of four digit industries for the US, and show that the negative impact of profits uncertainty on investment is much greater in industries dominated by small firms than in those dominated by large firms.

In the remainder of the paper we provide direct evidence of the uncertainty-investment relationship for entrepreneurial firms. We consider the dataset of the Mediocredito Centrale Survey of Small and Medium Italian Manufacturing Firms. This dataset is interesting for our purpose because it includes: i) information about the ownership structure of the firms, which can be used to identify the firms where the management faces most

Table 1: Wealth concentration for US entrepreneurial households

% contribution to total private equity held by US households		
	1989	1998
Households with $\geq$ 75% net worth in private eq.	40.8%	47.9%
Households with $\geq$ 50% net worth in private eq.	76.2%	74.7%
Households with $\geq$ 25% net worth in private eq.	92.2%	91.7

Source: Moskowitz and Vissing-Jørgensen (2002)

of the business risk. More precisely, we select in the "entrepreneurial" group every firm that is controlled by one single manager-owner that owns more than 50% of its shares. ii) Detailed information about the innovation content of firms investment. In particular the survey contains information on whether or not the firms invested in innovation. We use this information to show that uncertainty affects negatively the investment in innovation of entrepreneurial firms, while it does not affect the investment in innovation of the other firms.

The outline of this paper is as follows: section 2 reviews the empirical facts that motivate the paper. Section 3 illustrates the model. Section 4 shows the results of the simulations of a partial equilibrium entrepreneurial industry. Section 5 shows the empirical analysis of the Italian manufacturing firms. Section 6 summarises the conclusions.

2 Empirical facts

In this section we briefly review the main empirical facts that motivate the analysis of this paper.

- Entrepreneurial risk.

Fact 1: *entrepreneurial households do not diversify risk.* Table 1 shows that 75% of all US private equity is owned by households for whom it constitutes at least half of their total net worth (source: Moskowitz and Vissing-Jørgensen (2002)).

Fact 2: *entrepreneurial households account for a substantial share of aggregate investment and output.* Table 2 also shows that entrepreneurial firms are on average small.

Table 2: Value of equity held by US households

	1989	1992	1995	1998
Market value of private equity	3687	3757	4293	5737
Market value of public equity	1587	2102	3439	7256
Average number of employees	18.7			

Billions US$. Source: Moskowitz and Vissing-Jørgensen (2002)

Table 3: Percentages relative to the whole of the US industry

	<20 employees	<100 employees	<500 employees
N. of firms	89.5 %	98.3 %	99.7 %
Employment	19.5 %	37.9 %	52.5 %
Est. Receipts	16.9 %	33.9 %	47 %

Source: US Census

Nonetheless they are important for aggregate employment and output. We cannot precisely quantify this claim, so we propose two indirect pieces of evidence: i) the market value of private equity held by US household has been generally higher than the market value of public equity held by them (source: Moskowitz and Vissing-Jørgensen (2002)). The only exception is 1998, when the stock market bubble inflated the value of public equity. ii) Table 3 shows that firms smaller than 100 employees accounted for almost 40% of the total employment in the US industry in 1995. Since most small firms are entrepreneurial firms, this indirectly confirms that the entrepreneurial sector accounts for a relatively large share of aggregate output and production.

- Uncertainty and investment

Fact 3: *the negative impact of uncertainty on investment is much stronger on smaller than on larger businesses.* Ghosal and Loungani (2000) use yearly data from 330 four digits US industries, for the 1958-1991 period, and estimate the elasticity of the fixed capital investment rate to profits uncertainty. They show that on average profits uncertainty negatively affects investment, but that the effect is much stronger in industries dominated by small firms. Table 4 summarises their main result. The elasticity of investment to profits uncertainty is as high (in absolute value) as -0.88 for the industries with the

Table 4: The differential impact of uncertainty on investment in small and large firms (Ghosal and Loungani, 2000)

	Elasticity of I/K to exp. volatility of profits	median n. empl.
All US industries	-0.267**	87
Small firms industries	-0.881**	23
Large firms industries	-0.168**	246
Source: Ghosal and Loungani (2000)		

highest concentration of small firms[2], and as low as -0.17 for the industries with the highest concentration of large firms[3].

3 A model of an entrepreneurial household

We consider an industry composed by many risk averse entrepreneurial households (from now on simply called "entrepreneurs"). These are born with an endowment of wealth w_0^i, where i indicates the ith entrepreneur, that they can either invest in their own risky technology or in a riskless asset.

Markets are incomplete and the entrepreneurs cannot insure against the idiosyncratic risk of their technology. Moreover the entrepreneurs cannot own shares of the businesses of other entrepreneurs. We assume that there are no financing imperfections and we rule out bankruptcy. Entrepreneurs are all ex ante identical, and they only differ for the initial endowment w_0^i and for the realisation of their idiosyncratic shock. Each period they die with probability $1-\gamma$. We assume that death takes place just after consumption, before next period decisions are taken. The technology of each entrepreneur requires the use of fixed capital k_t and of variable inputs l_t. In what follows we omit the subscript i, because we describe the investment decision of one generic entrepreneur. Capital k_t takes one period to become productive, while variable inputs l_t are immediately productive. We assume that all prices are constant and normalize them to one. Output net of variable

[2] These are industries that satisfy two criteria: i) at least 60% of the employment of the industry is in firms with less than 500 employees. ii) al least 90% of the firms are with less than 100 employees.

[3] These are industries where: i) less than 60% of the employment of the industry is in firms with less than 500 employees. ii) less than 78% of the firms are with less than 100 employees.

inputs is:

$$y_t = e^{\theta_t} k_t^{\alpha} l_t^{\beta} - l_t$$

$$\alpha + \beta < 1$$

θ_t is a stationary stochastic process. At the beginning of time t, after having observed the productivity shock θ_t, the entrepreneur chooses l_t, k_{t+1} and c_t in order to maximise the following value function:

$$V(\theta_t, w_t) = \max_{l_t, k_{t+1}, c_t} u(c_t) + \gamma\beta E_t V(\theta_{t+1}, w_{t+1}) \tag{1}$$

The budget constraint is the following:

$$c_t = w_t + \frac{b_{t+1}}{R} - k_{t+1} \tag{2}$$

And:

$$w_t = y_t + (1-\delta) k_t - b_t \tag{3}$$

δ is the depreciation rate of fixed capital. c is consumption. $u(c_t)$ is a concave utility function that satisfies the assumption of decreasing absolute risk aversion. β is the intertemporal discount factor. $R = 1 + r$, where r is the risk free interest rate. For simplicity we assume that $R = \frac{1}{\gamma\beta}$. $\frac{b_{t+1}}{R}$ is the net present value of one period debt with face value b_t. From the maximisation problem it is possible to derive the following Euler equation for fixed capital investment:

$$u'(c_t) = \frac{1}{R} E_t \left[\left(\frac{\partial y_{t+1}}{\partial k_{t+1}} + 1 - \delta \right) u'(c_{t+1}) \right] \tag{4}$$

By using the result that $E_t[u'(c_{t+1})] = u'(c_t)$, we can rearrange the Euler equation as follows:

$$E_t \left(\frac{\partial y_{t+1}}{\partial k_{t+1}} \right) = UK + \Psi_t \tag{5}$$

$$\Psi_t = -R \frac{cov\left[\left(\frac{\partial y_{t+1}}{\partial k_{t+1}} \right), u'(c_{t+1}) \right]}{u'(c_t)} > 0 \tag{6}$$

$E_t \left(\frac{\partial y_{t+1}}{\partial k_{t+1}} \right)$ is the expected marginal productivity of fixed capital. $UK = R - (1-\delta)$ is the user cost of capital. The sign and the magnitude of the term Ψ_t depend on the covariance between the marginal productivity of capital and the marginal utility of consumption. The presence of idiosyncratic risk implies that this covariance is negative, because a positive shock at time $t+1$ increases marginal productivity of capital, permanent wealth and consumption, thereby reducing $u'(c_{t+1})$. Therefore Ψ_t is greater than zero, and its magnitude is positively related to three factors: i) the degree of risk aversion; ii) the volatility of the idiosyncratic shock; iii) the fraction of net worth of the entrepreneur invested in the business. The simulations performed in the next section show that (iii) is the critical factor that determines the negative relationship between investment and uncertainty. If most of the wealth of the entrepreneur is concentrated in the business, then Ψ_t is very sensitive to changes in the volatility of the idiosyncratic shock, even if the entrepreneur has a low risk aversion. Instead if the entrepreneur is well diversified, then uncertainty does not significantly affect investment, even if the entrepreneur has an high risk aversion.

4 Numerical solution

We solve numerically the model described above and we simulate an industry with many entrepreneurs. We consider a CES consumption function:

$$u(c_t) = \frac{c_t^{1-\eta}}{1-\eta} \tag{7}$$

For the baseline simulation results we choose a value of $\eta = 2$. The productivity shock is a two state symmetric Markow process:

$$\begin{gathered} \theta_t \in \{\theta_L, \theta_H\} \\ pr(\theta_{t+1} = \theta_t) = \rho \\ pr(\theta_{t+1} \neq \theta_t) = 1-\rho \end{gathered}$$

The parameters are calibrated on annual data from the 1989, 1992, 1995 and 1998 US Surveys of Consumer Finances, and are reported in table 5. The key objective of this calibration is to match, in the simulated entrepreneurial industry, the degree of concentration of risk of US entrepreneurial households as calculated from the Surveys of Consumers Finances. Therefore we match both the cross sectional volatility of profits and the cross sectional distribution of the amount of wealth invested in the entrepreneurial business. This calibration requires the calculation of the market value of the entrepreneurial businesses. It is not obvious what such value should be, since by definition "private equity" shares are not traded. For the empirical data we follow the studies that calculate the value of entrepreneurial businesses by using the question in the Survey of Consumer Finance where entrepreneurs are asked at what price they would be able to sell their share of their own business.

There is no unambiguous way to determine this value in the theoretical model because the valuation of the future expected stream of profits generated by the technology may generally differ for the buyer and the seller, even if both have the same degree of relative risk aversion. In other words, the value of the stream of profits generated by the business will be higher the more diversified is the owner, because she will require a lower risk premium and will invest more in the business. Therefore we define a lower bound of the value of the business as the net present value of the expected stream of profits for the current entrepreneur/owner, and an upper bound as the value of the business for a fully diversified investor. In the simulations we assume that the market value is the average between the upper and the lower bound. This is equivalent to assume that: i) there exist many diversified investors that are willing to buy the businesses of the entrepreneurs. ii) The entrepreneurs receive a large private benefit from running their businesses. In this case the entrepreneurs expect to be able to sell their businesses at the average between their reservation value and the investors valuation, but in practice their private benefits are large enough so that no entrepreneur is ever willing to sell her own business in equilibrium[4].

We assume that new entrepreneurs are born "rich" with probability κ and poor with probability $1-\kappa$, with $w_0^{rich} > w_0^{poor}$. κ, w_0^{rich} and w_0^{poor} are chosen in order to calibrate the

[4]This simplifying assumption is not essential, and in any case the presence of private benefits from the entrepreneurial activity is consistent with Hamilton (2000), who estimates that: "*Most entrepreneurs enter and persist in business despite the fact that they have both lower initial earnings and lower earnings growth than in paid employment, implying a median earnings difference of 35% for individuals in business for 10 years*".

Table 5: Calibrated Parameters

	Value	Matched moment	Data	Simulations
θ_L	1.57	Average size of the entrepreneurial firms		
θ_H	1.99	st. dev (net income/sales)*	0.183	0.202
ρ	0.75	st. dev (net income/value business)*	0.160	0.166
α	0.35	average (net income/value business)*	0.133	0.111
β	0.58	capital/variable inputs*	0.6	0.6
w_0^{poor}	0.01**	% of total private equity from entrepreneurs with concentration $\geq$ 75%	46%	45%
w_0^{rich}	0.2**	% of total private equity from entrepreneurs with concentration $\geq$50%	75%	72%
κ	0.05	% of total private equity from entrepreneurs with concentration $\geq$ 25%	92%	88%
δ	14.5%	Average depreciation of capital	14.5%	14.5%
r	4%	average real interest rate	4%	4%
γ	6%	average firms exit rate	6%	6%
		Other moments	Data	Simulations
		Average(net income/sales)*	0.136	0.179

All the statistics are computed using the 1989, 1992, 1995 and 1998 Surveys of Consumers Finances. *) Only entrepreneurs that own and manage a manufacturing company are included. We calculate the first and second moment of the (net income/sales) ratio and of the (net income/value of the business) ratio after excluding from the analysis the observations greater than one in absolute value.

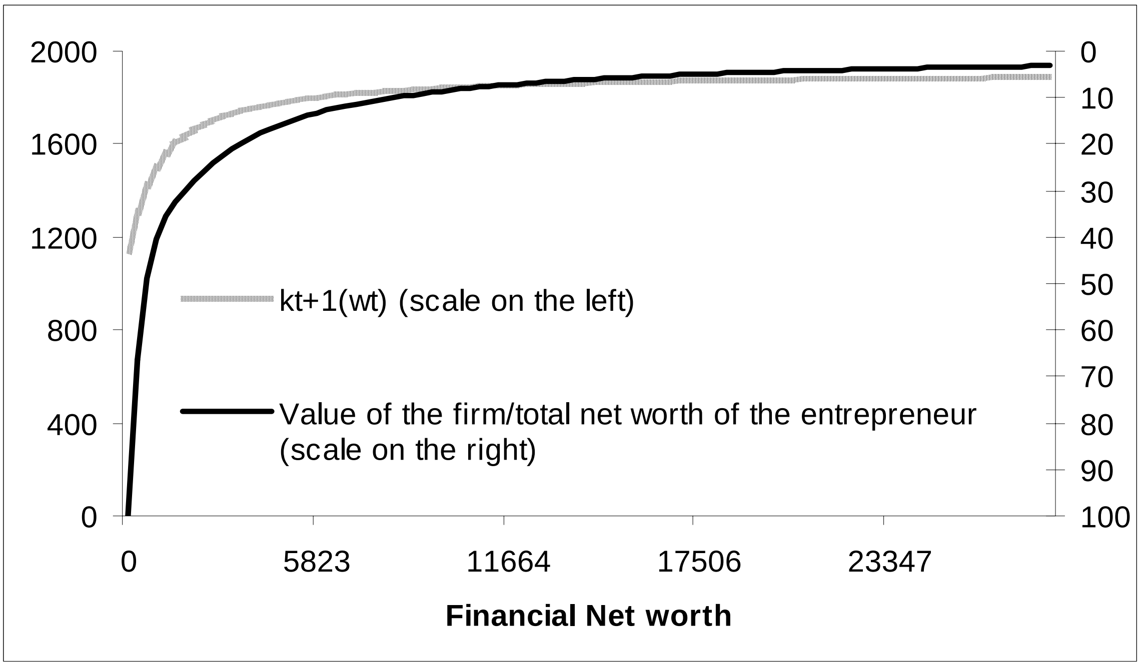
**) Ratio w_0/k^{ss}, where k^{ss} is the average optimal capital of a fully diversified entrepreneur.

cross sectional distribution of the concentration of risk, as shown in table 5. The volatility and persistency of the idiosyncratic shock are chosen to match the cross sectional variances of the profits/sales ratio and of the profits/value ratio of the entrepreneurial households in the Survey of Consumers Finances[5].

Figure 1 shows the policy function $k_{t+1}(w_t)$ conditional on $\theta_t = \theta_H$. w_t is on the horizontal axis. When w_t is very large then the optimal capital k_{t+1} approaches the profit maximising capital chosen by a risk neutral agent, because the term Ψ_t goes to zero. For smaller values of w_t the undiversifiable business risk affects the expected consumption of the entrepreneur, and she requires an higher return on investment. This implies a lower optimal capital level k_{t+1}.

[5]In order to reduce the amount of heterogeneity present in the empirical data, we compute these volatilities using only the data about the entrepreneurs that operate in the manufacturing sector.

Figure 1: Concentration of wealth and optimal capital conditional on $\theta_t = \theta_H$ (constant elasticity of substitution coefficient $\eta = 2$)



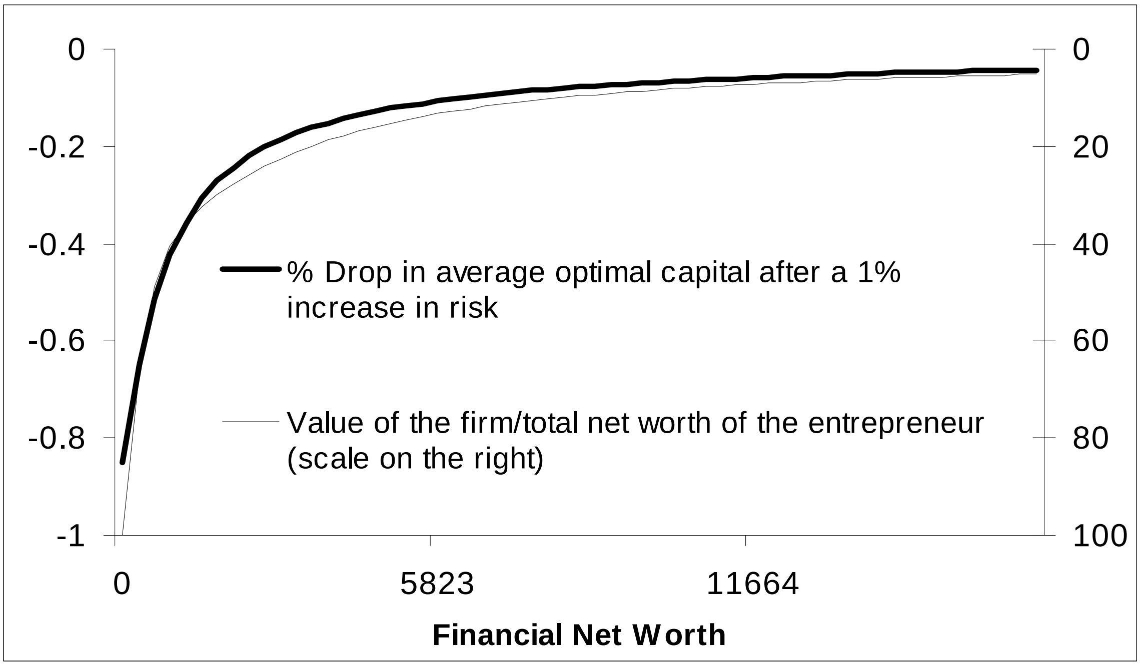
4.1 Change in uncertainty

Figure 1 suggests that undiversifiable risk is potentially important for aggregate investment dynamics because most of the US entrepreneurial households have more than 50% of their wealth invested in their business (see table 1). Figure 1 shows that if the idiosyncratic risk of the business is not insurable, then these entrepreneurs significantly underinvest with respect to the optimal capital chosen by a fully diversified entrepreneur.

More importantly, the investment of these households becomes very sensitive to small changes in uncertainty. We consider the following experiment: the standard deviation of the idiosyncratic shock permanently increases by 1% for all entrepreneurs. At the same time average productivity decreases so that the optimal capital choice of a fully diversified entrepreneur would not change[6]. This allows us to abstract from the other factors that influence the relationship between uncertainty and investment, and to focus on the effects

[6]A risk averse entrepreneur that is able to diversify away the idiosyncratic risk would choose the level of capital that maximises the net present value of expected profits. Since capital is not subject to adjustment costs, and given that the revenue function is convex with respect to the realisation of the shock, the profit maximising level of capital increases with uncertainty (Abel, 1983).

Figure 2: Elasticity of optimal entrepreneurial capital to an increase in risk conditional on $\theta_t = \theta_H$ (constant elasticity of substitution coefficient $\eta = 2$)



of the concentration of risk. Figure 2 shows the elasticity of $k_{t+1}(w_t \mid \theta_t = \theta_H)$ with respect to this change in risk. This elasticity is negative and large when the wealth is very concentrated in the business.

Table 6 shows the response of aggregate capital in the entrepreneurial industry to the 1% permanent increase in risk. The first column shows the benchmark case with $\eta = 2$. Aggregate output of the entrepreneurial sector decreases by 0.93%. This large and negative elasticity of investment to uncertainty is the consequence of the concentration of risk. In fact the elasticity is much smaller for the largest 20% entrepreneurial businesses in the industry. These are risk averse but diversified entrepreneurs. The idiosyncratic risk affects less their consumption path, thanks to the amount of financial wealth they own, and as a consequence their investment decisions are more similar to those of a risk neutral investor, which by construction is unaffected by the permanent increase in uncertainty.

This result is important, because it shows that, for levels of diversification and of idiosyncratic uncertainty analogous to those estimated for the US entrepreneurial households, entrepreneurial investment is strongly negatively related to uncertainty. A natural objection to this conclusion is that the model is very simple, and therefore it abstracts with respect to other factors that may reduce the magnitude of this finding. However, before we discuss such factors, it is important to note that there are also factors not considered in the model that are instead likely to increase the magnitude of this finding. For example, in the model we assume that fixed capital is fully reversible. This means that an entrepreneur that invested in period t can fully recover the replacement value of fixed capital in period $t+1$, if such capital turns out to be unproductive. This assumption is of course not realistic, and if we allow capital to be fully or partly irreversible, then the increase in uncertainty would have an even greater effect on an undiversified entrepreneur, because the presence of irreversibility would increase the expected fluctuations of her consumption path if she invests in her risky business.

Among the factors that instead are likely to reduce the effect of uncertainty on investment, the most important one is the fact that in reality individuals choose between entrepreneurship and paid employment. The latter option generates expected wages that are less risky than the expected profits from the entrepreneurial activity. Therefore it may be that only individuals with very low levels of risk aversion choose to become entrepreneurs. We believe that this factor does not affect the quantitative importance of our finding, for at least two reasons: i) the empirical evidence shows that entrepreneurial households are not substantially less risk averse than non entrepreneurial ones (see for example Hartog *et al., 2002).* ii) We still find a significant negative effect of uncertainty on entrepreneurial investment even for an industry where all entrepreneurs have a coefficient of relative risk aversion as low as 0.5. Table 2 shows that US entrepreneurial firms are on average small. Therefore the simulation results in table 6 demonstrate that entrepreneurial risk provides a plausible explanation of the findings of Ghosal and Loungani (2000), who estimate that the negative reaction of investment to uncertainty is very strong only in industries dominated by small firms. The difference in the elasticity between small and large businesses estimated by Ghosal and Loungani is around -0.61 (see table 4).

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Table 6: Elasticity of aggregate investment to uncertainty

	$\eta = 2$	$\eta = 1.25$	$\eta = 0.5$
All firms	-0.93	-0.68	-0.29
80% smaller firms	-1.17	-0.90	-0.44
20% larger firms	-0.19	-0.11	-0.03
Difference small-large	-0.98	-0.79	-0.41

5 Entrepreneurial risk and innovation: an empirical analysis

In the previous section we have shown that entrepreneurial risk is quantitatively important in explaining the relationship between uncertainty and investment. In this section we illustrate some direct empirical evidence of the different impact of uncertainty on entrepreneurial versus non entrepreneurial firms. In particular we focus on the decisions to innovate, because typically the investment in innovation, to develop a new product or to enter in a new market, is generally more risky than the investment in the current production, because its return is more uncertain. Therefore the presence of undiversifiable entrepreneurial risk implies that uncertainty should have a large negative effect on the investment in innovation of entrepreneurial firms, more so than on the investment in innovation of non entrepreneurial firms.

In this section we illustrate a test of this hypothesis. We use a dataset of 4497 firms provided by the Mediocredito Centrale Survey of Small and Medium Italian manufacturing firms. The survey asks several questions related to the activity of the firms in the 1995-1997 period. In particular it reports the following information about the three largest shareholders of the firm: i) if they are individuals, financial companies or industrial companies; ii) if they have the direct control of the firm; iii) their share of ownership in the firm.

Out of the 4497 firms we focus on a subsample of 1505 firms for which also 8 years of balance sheet data, from 1990 to 1997, are available. Using the information in the survey we select firms in two groups:

1) "entrepreneurial" firms. We select in this category every firm that has the majority of its shares owned by a single person that also directly manages it. 407 firms, 27% of the total, are selected in this group. Even though we do not know how diversified the entrepreneurs in this group are, we assume that on average they should face an high concentration of risk, because Italian entrepreneurial households show a similar concentration of risk than US entrepreneurial households **(must prove it!).**

2) "public firms**":** this is the control group, composed by firms with a more diversified ownership structure. The idea is that the presence of separation between ownership and management, or the presence of more than one owner/manager, indicates that the managers of these firms should bear less of the firm's idiosyncratic risk. We select in this category firms that:

- are owned by one or more individuals, but the combined share of ownership of the individuals with an active management role is less than 50%.
- Are owned by another industrial company.

337 firms, 22% of the total, are classified as "public firms". The above criteria that determine the two groups of entrepreneurial and public firms are not mutually exclusive, and therefore many firms do not fall in either group. For example it is difficult to classify firms owned by a financial firm. These could be firms with separation between ownership and management, but more often are firms in which the owner of the financial holding directly manages the controlled firm, but does not directly own it for tax purposes. The 761 firms that do not fit in any of the previous two groups are called "other firms". Table 7 illustrates some summary statistics about the firms in the three groups.

In the following analysis we want to investigate on the relationship between uncertainty and innovation for these three groups of firms. We identify the decisions to invest in innovation using the direct questions in the Mediocredito Survey. In a section of the survey with the heading "Technological innovation and research and development", firms are asked the following question:

Table 7: Summary statistics

	Entrepreneurial firms	Public firms firms	Other firms
Mean n. employees	114	259	291
Median n. employees	55	85	104
Mean age (in 1998)	31	33	32
Median growth rate of sales	7.5%	6.8%	7.9%
Mean profits/sales ratio	6.2%	6.4%	4.7%
% of financially constrained firms	16%	11%	12%
% of firms with R&D spending	38%	45%	48%
Average % of sales from export	33%	32%	32%

1) Did the firm engage, in the 1995-97 period, in any of the following types of innovation?

- Product innovation.
- Process innovation.
- Organizational innovation.

2) Did the firm engage, in the 1995-97 period, in R&D expenditure? If yes, what percentage of this expenditure was directed to

- Improve existing products.
- Improve existing productive processes.
- Introduce new products.
- Introduce new productive processes.
- Other objectives.

It is interesting to note that questions 1 and 2 generate two independent sets of information. 1171 firms out of 1505 declared to engage in some type of innovation. Out of these 1171 firms only 621 firms also engaged in R&D expenditure. Furthermore in the section of the survey with the heading "Investment" firms are asked:

3) To what extent the fixed (plant and equipment) investment done during the 1995-1997 period had the following objectives?

- Improve existing products.
- Increase the production of existing products.
- Produce new products.
- Other objectives.

For each option of question 3 the firm indicates, in case of a positive answer, three possible degrees of intensity (low, medium and high).

We want to use questions 1, 2 and 3 to construct indicators of risky innovation activity, and therefore we focus on product rather than process innovation, because the future revenues coming from the investment in a new product should be more uncertain. We summarize the information about product innovation in the four following variables:

- $product\_inn_i = 1$ if firm i declared to engage in product innovation, and 0 otherwise.
- $r\&d_i = 1$ if firm i declared $R\&D$ spending and 0 otherwise.
- $fix\_newp_i = 1$ if fixed investment spending of firm i is partly or fully directed to the introduction of new products.
- $r\&d\_newp_i = 1$ if more than 20% of $R\&D$ spending of firm i is directed to the development of new products.

Table 8 reports the percentage of firms in the three classes that declare the four types of innovation[**must justify why we do not use categorical data**]. We investigate on the effect of risk on innovation by performing the following regression:

$$\begin{aligned} depvar_i = \alpha_0 + \alpha_1 risk_i + \alpha_2 export_i + \alpha_3 \ln(size_i) + \alpha_4 constrained_i + \\ + \alpha_5 growth_i + \alpha_6 avgreturn_i + \alpha_7 supply_i + d_s + u_i \end{aligned} \tag{8}$$

Table 8: Share of firms that invest in product innovation

	Entrepreneurial firms	Public firms	Other firms
$product\_inn_i = 1$	39%	42%	41%
$r\&d_i = 1$	38%	45%	48%
$r\&d\_newp_i$	16%	23%	21%
fix_newp_i	36%	40%	39%
Both $product\_inn_i = 1$ and $fix\_newp_i = 1$	28%	33%	30%
Both $product\_inn_i = 1$ and $r\&d_i = 1$	22%	26%	25%

$depvar_i$ is a binary variable, and corresponds to the four variables described above. $risk_i$ is the standard deviation of the profits/sales ratio for firm i in the 1990-1994 period divided by the average of the same standard deviation for all the firms in the two digit industry to which firm i belongs. $export_i$ is the share of output that is exported. $constrained_i$ is equal to 1 if the firm declared financing constraints in financing investment in the 1995-97 period, and zero otherwise[**insertfootnoteonconstraints**]. $growth_i$ is equal to the average growth rate of sales in the 1990-1994 period. $avgreturn_i$ is the average profits/sales ratio for firm i in the 1990-1994 period. $supply_i$ is a dummy variable that is equal to 1 if firm i is a supplier that produces all its output based on the order placed by downstream firms (19% of all the sample). It is equal to zero if firm i produces part or all its output for the market (78% of the firms in the sample produced all their output for the market). d_s is equal to one if firm i belongs to the $s-th$ two digit industrial sector and zero otherwise. Our test is based on comparing the value and significance of the coefficient of $risk_i$ across entrepreneurial and public firms. All the included regressors except $constrained_i$ are predetermined, because they refer to the 1990-1994 period, while the dependent variable refers to the 1995-1997 period. This may still not be sufficient to ensure that these regressors are orthogonal to the error term u_i. However we argue that despite this potential problem the estimation results are still useful because, as tables 7 and 8 show, the groups of public and private firms are quite similar in terms of their characteristics (**introduce a table with the means of the regressors**). Therefore it is reasonable to assume that any bias in the estimation of the coefficient of risk should be similar across groups, and therefore that the between-groups difference in the estimated coefficient of $risk_i$ is a consistent test of our hypothesis [**should also add a comment on Italy as an entrepreneurial economy**].

Table 9 reports the results of the probit estimation of equation (8) using the variables $product\_inn_i$, $r\&d_i$ and fix_newp_i as dependent variables. The results are consistent with the hypothesis that risk negatively affect the investment in innovation of entrepreneurial firms, while it does not affect the investment in innovation of the other firms. The coefficient of the variable $risk_i$ is negative and significant for the entrepreneurial firms, while is either not significant or positive and significant for the other firms. Therefore for all the three variables used as dependent variable we find that the negative effect of uncertainty on innovation is stronger for entrepreneurial firms than for public firms. Two considerations support the significance of this result: i) the estimated coefficients of the other regressors, when they are significant, have always the same sign across the groups of public and private firms. This reduces the possibility that the heterogenous response of innovation to risk is caused by a bias factor that has a different impact on entrepreneurial and non entrepreneurial firms. ii) among the other regressors the variable $supply_i$ should be negatively related to risk. This is because firms with $supply_i = 1$ face less demand uncertainty than firms with $supply_i$=0. Consistently with the hypothesis we find that the $supply_i$ coefficient is significantly higher for entrepreneurial firms than for public firms in two out of three regressions. Table 10 repeats the analysis of table 9 using $r\&d\_newp_i$ as dependent variable. In this case no significant relationship is found between risk and the decision to invest in R&D for the development of new products.

6 Conclusions

This paper studies the effect of entrepreneurial risk on the relationship between uncertainty and investment. Meh and Quadrini (2004) and Angeletos (2003) show that undiversifiable entrepreneurial risk reduces investment and capital accumulation. The main contribution of this paper is to shows that entrepreneurial risk is quantitatively important

Table 9: The relationship between risk and innovation, Italian manufacturing firms

$$depvar_i = \alpha_0 + \alpha_1 risk_i + \alpha_2 export_i + \alpha_3 constrained_i + \alpha_4 avgreturn_i + \alpha_5 \ln(size_i) + \\ + \alpha_5 \ln(size_i) + \alpha_6 growth_i + \alpha_7 supply_i + d_s + u_i$$

	$depvar_i = product\_inn_i$			$depvar_i = r\&d_i$			$depvar_i = fix\_newp_i$		
	entrep.	public	other	entrep.	public	other	entrep.	public	other
α_1	-0.21**	0.09	0.008	-0.15*	0.20*	0.015	-0.26***	-0.07	-0.04
	(0.10)	(0.10)	(0.05)	(0.09)	(0.11)	(0.06)	(0.10)	(0.10)	(0.05)
α_2	0.003	0.001	0.003*	0.004*	0.009***	0.007***	0.0001	-0.003	0.001
	(0.004)	(0.003)	(0.002)	(0.002)	(0.003)	(0.002)	(0.002)	(0.003)	(0.002)
α_3	0.20	-0.05	0.20	0.34*	0.04	-0.05	-0.15	0.11	-0.05
	(0.33)	(0.24)	(0.15)	(0.19)	(0.24)	(0.15)	(0.19)	(0.24)	(0.15)
α_4	2.10	0.37	0.77	1.50	1.87	1.01	-0.26	-1.18	0.99
	(2.99)	(1.28)	(0.82)	(1.51)	(1.32)	(0.84)	(1.57)	(1.35)	(0.84)
α_5	0.06	0.22***	0.09**	0.29***	0.44***	0.26***	0.24***	0.19***	0.03
	(0.13)	(0.07)	(0.04)	(0.09)	(0.07)	(0.04)	(0.08)	(0.07)	(0.04)
α_6	0.25	0.32	0.03	-0.33	0.018	0.036	-0.07	0.13	0.18
	(0.39)	(0.29)	(0.18)	(0.23)	(0.32)	(0.18)	(-0.26)	(0.29)	(0.18)
α_7	-0.17	-0.29	-0.38***	0.23	-0.31	-0.43***	0.22	-0.33*	-0.34**
	(0.29)	(0.20)	(0.13)	(0.19)	(0.21)	(0.13)	(0.19)	(0.20)	(0.13)
n. obs	399	312	738	399	315	738	399	315	738
Pseudo R^2	0.12	0.11	0.06	0.16	0.25	0.15	0.08	0.07	0.05

Table 10: The relationship between expenditure on the development of new products and uncertainty

$$r\&d\_newp_i = \alpha_0 + \alpha_1 risk_i + \alpha_2 export_i + \\ + \alpha_3 constrained_i + \alpha_4 avgreturn_i + \alpha_5 \ln(size_i) + \\ + \alpha_5 \ln(size_i) + \alpha_6 growth_i + \alpha_7 supply_i + d_s + u_i$$

	entrep.	public	other
α_1	0.025	0.18	0.003
	(0.22)	(0.16)	(0.08)
α_2	0.003	-0.007	-0.0001
	(0.003)	(0.005)	(0.002)
α_3	0.02	-0.05	0.14
	(0.33)	(0.47)	(0.23)
α_4	2.10	0.18	1.36
	(2.99)	(1.75)	(1.30)
α_5	0.06	0.34***	0.19***
	(0.13)	(0.11)	(0.06)
α_6	0.25	-0.11	-0.49*
	(0.39)	(0.44)	(0.28)
α_7	-0.17	-0.55*	-0.36*
	(0.29)	(0.32)	(0.22)
n. obs	145	139	357
Pseudo R^2	0.04	0.15	0.13

in explaining the relationship between uncertainty and aggregate investment, and especially in explaining the empirical fact that uncertainty affects significantly more small rather than large firms (Ghosal and Loungani (2000)). This finding is important because a recent theoretical and empirical literature has mainly focused on the presence of sunk costs and irreversibility as the driving force behind the observed negative relationship between investment and uncertainty. This paper is the first one, to the best of our knowledge, to show that entrepreneurial risk is also important in explaining the empirical evidence about investment dynamics.

This finding has also implications for the growth of the economy, because entrepreneurial firms are an important source of innovation. The other contribution of this paper is to show that profit uncertainty negatively affects the decisions to innovate of entrepreneurial firms, while it does not affect the decisions to innovate of non entrepreneurial firms.

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