Entrepreneurial Risk, Investment and Innovation*

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Abstract

I develop a general equilibrium model with risk averse entrepreneurial firms and with public firms. The simulations of the model show that an increase in uncertainty, which by construction does not affect the investment decisions of public firms, significantly reduces the propensity of entrepreneurial firms to innovate. Furthermore, they predict that the negative effect of uncertainty on innovation is stronger for the less diversified entrepreneurial firms, and is stronger in the absence of financing frictions in the economy. In the second part of the paper I test these predictions on a dataset of small and medium Italian manufacturing firms.

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Introduction

This paper studies the effect of uncertainty on entrepreneurial risky innovation. A theoretical literature has shown that entrepreneurs may be unwilling to invest in risky and highly productive projects in the present of frictions that prevent them from diversifying the risk of the investment (Obstfeld, 1994; Acemoglou, and Zilibotti, 1997; Rampini, 2004; Castro, Clementi and MacDonald, 2004). This problem is empirically relevant, because entrepreneurial households appear not to be able to diversify the risk of their business. Moskowitz and Vissing-Jørgensen (2002) analyze US data and show that 48% of all private equity is owned by households for whom it constitutes at least 75% of their total net worth. This lack of diversification seems to be driven by market imperfections rather than by risk-loving preferences. On the one hand, Bitler, Moskowitz and Vissing-Jorgensen (2005) provide evidence that agency considerations play a key role in explaining why entrepreneurs on average hold large ownership shares. On the other hand experimental studies generally find entrepreneurs to be as risk averse, and some studies find them to be even more risk averse, than non entrepreneurs (Sarasvathy, Simon and Lave, 1998; Miner and Raju, 2004; Hongwei and Ruef 2004).

The above considerations emphasise that undiversifiable entrepreneurial risk is an important factor for the decision to invest in innovative risky projects, and raise the following question: how is the relation between entrepreneurial risk and innovation affected by fluctuations in uncertainty along the business cycle? If an increase in uncertainty regarding the prospects of an industry, for example at the beginning of a recession, discourages undiversified entrepreneurs to invest in risky innovation, then this effect may have important consequences for both business cycles and growth. Despite the potential importance of this question, little is known about the empirical evidence on the relation between uncertainty and the risky innovation of entrepreneurial businesses. This paper aims at providing new evidence on this relation. More specifically, its objective is twofold: i) to develop a dynamic general equilibrium model of an economy with heterogenous entrepreneurs, and to use it to derive a series of predictions about the link between uncertainty and entrepreneurial risky innovation. ii) to verify empirically these predictions on a panel of firm-level data.

In the model, I consider many infinitely lived entrepreneurs who can invest in their own business and can borrow or lend at the risk free rate. Each entrepreneurial business generates output using a production function which is linear in technology and concave in capital, and it is also subject to exogenous profits shocks. Each entrepreneur can invest in innovation to improve the technology of her business. If she does not innovate, then her technology becomes progressively more obsolete and profits fall. If she innovates, she pays a fixed cost and upgrades the technology to the frontier. Innovation is in general risky, because the fixed cost has both a deterministic and a stochastic component.

I use the model to analyse economies with different degrees of innovation risk, as measured by the volatility of the stochastic component of the fixed innovation cost. In economies where such risk is low, I refer to the innovation decision as "*technology adoption*". Since capital and technology are complementary, the technology upgrading is always accompanied by a large fixed capital investment. Therefore this type of innovation decision can be interpreted as the decision to purchase capital which embodies a new technology that makes production more efficient, but it does not change significantly the nature of the product sold, and therefore it adds little uncertainty to the outcome of the investment.

Instead, I refer to "risky innovation" when I consider economies with a high volatility of the innovation cost. This type of innovation can be interpreted as the decision to develop and/or to sell a new product. Ex-ante the entrepreneur expects it to be profitable, but uncertainties related both to the development phase and the commercialisation phase imply that the net profits from the innovation are uncertain.

In the model I also introduce a corporate sector, where the firms are identical to the entrepreneurial firms, except that the households in this sector can fully diversify their idiosyncratic risk. Hence, despite they are risk averse, they manage their firms with the objective to maximize expected profits. I solve the general equilibrium of the model in the absence of aggregate uncertainty, but in the presence of idiosyncratic uncertainty for both the entrepreneurial firms and the risk neutral firms. I simulate the artificial economy and calibrate it so that the cross sectional variance of the income/sales ratio and the amount of undiversifiable risk in the entrepreneurial sector matches the same moments calculated for US entrepreneurial households. The simulation results determine the following predictions:

i) An increase in the volatility of the exogenous profits shock reduces the risky innovation of the entrepreneurial sector, while it does not affect the risky innovation of the corporate sector.

Uncertainty does not affect corporate firms because the exogenous profits shock enters the production function additively. On the one hand this assumption simplifies the model and the interpretation of the results, because it allows to measure the effect of uncertainty on entrepreneurial innovation with the difference between the behavior of entrepreneurial firms and the behavior of corporate firms. On the other hand I later show that the predictions of the model about the negative effect of uncertainty on entrepreneurial innovation are confirmed and reinforced by the introduction of a more standard multiplicative shock in the production function. The only difference is that, because the volatility of the multiplicative shock affects the expected profits of the innovation, all the results hold conditional on average firm profitability.

ii) The negative effect of uncertainty on the innovation of entrepreneurial firms is stronger the less diversified they are and the lower is the presence of financing frictions in the economy.

While prediction (i) refers to the average effect of uncertainty in the entrepreneurial sector, prediction (ii) clarifies that such effect is driven by the less diversified entrepreneurs in the industry. These are in the left tail of the distribution of financial wealth, as a consequence of having suffered negative shocks in the past. They are undiversified in the sense that they have no financial assets, and nearly all of their wealth is made up by the value of their business. As a consequence, their main instrument to rebalance the risk/return profile of their assets in response to a change in uncertainty, is the choice of the riskiness of the firm's investment projects. Furthermore, prediction (ii) implies that financing frictions dampen the effect of uncertainty on innovation. The intuition is as follows: the less diversified entrepreneurs are also less financially wealthy, and hence in the presence of financing frictions are more likely to face a binding borrowing constraint. Their innovation decisions then become affected by the current availability of credit rather than by the uncertainty about future profits.

iii) *A change in exogenous uncertainty does not affect the investment in "technology adoption" for all firms.*

The finding that uncertainty affects entrepreneurial risky innovation is consistent with the concept of "risk vulnerability" (Gollier and Pratt, 1996), which implies that "adding an unfair background risk to wealth makes risk averse individuals behave in a more risk averse way with respect to another independent risk".[1] The interesting result of the simulations is to show that, while the influence of uncertainty on risky innovation is negligible for entrepreneurial households that hold some financial assets and are thus at least partially diversified, such influence is instead very important for most of the entrepreneurial firms, because the model is calibrated to replicate the large concentration of risk observed for the US entrepreneurial households sector. More precisely I find that, for realistic values of the parameters in the simulated economies, a 80% increase in the volatility of profits causes on average a reduction in the frequency of risky entrepreneurial innovation in a range between 8% and 17%.

In the second part of the paper I formally test predictions i), ii) and iii) using a dataset of small and medium Italian manufacturing firms. This dataset includes detailed information about the ownership structure of the firms and the innovation content of firm investment. The estimation results are consistent with all the three predictions.

This paper is related to Czarnitzki and Kraft (2004), who study the innovation of owner-led firms versus managerial firms, and more generally to the literature on undiversifiable entrepreneurial risk and investment. In particular Heaton and Lucas (2000) study the implications of entrepreneurial undiversifiable risk for portfolio choices and asset prices. Rampini (2004), Caggetti and De Nardi (2006), Castro, Clementi and Mac Donald (2004 and 2008) develop general equilibrium models where financing imperfections and undiversifiable risk affect the decision to become an entrepreneur and/or to invest in risky projects, and illustrate the consequences for aggregate fluctuations and growth.

[1] A sufficient condition for "risk vulnerability" is decreasing and convex risk aversion, which is satisfied by CARA and CRRA utility functions. This condition is realistic, because it implies that the wealthier an agent is, the smaller is the reduction in risk premium of a small risk for a given increase in wealth.

This paper is also related to Miao and Wang (2006), who extend the standard real option approach to investment to an incomplete market environment, and analyse the effect of market incompleteness on the timing of investment decisions. Finally, this paper is related to the studies of general equilibrium economies with heterogenous entrepreneurial households and incomplete markets (Quadrini and Meh, 2006; Angeletos, 2007; Covas, 2006, among others).

This paper makes a new contribution to the literature by demonstrating that undiversifiable entrepreneurial risk is important for the relationship between uncertainty and innovation. More specifically, this paper makes a theoretical contribution by analyzing simultaneously the investment in fixed capital and in risky innovation in a dynamic general equilibrium entrepreneurial economy with incomplete markets. The general equilibrium nature of the model is important for at least two reasons. First, because it allows to quantify the average effect of uncertainty on innovation for realistic levels of risk diversification. Second, because it allows to generate predictions which refer to the entrepreneurial sector as a whole. Such predictions can thus be tested with firm data only, and do not require the knowledge of the type of assets owned by each entrepreneurial household.

The major contribution of this paper is that it provides new empirical evidence concerning the link between uncertainty and the innovation decisions of entrepreneurial firms. The dataset used is particularly interesting because it combines balance sheet data with survey data. The balance sheet data cover a large panel with more than 10000 Italian manufacturing firms. The survey data cover the same firms, and include detailed qualitative information about the property structure, about the investment in different types of innovation, and about other relevant qualitative information that can be used to control the robustness of the results, such as the presence of financing constraints, the degree of internationalization and the market structure of the firms.

The outline of this paper is as follows: section I illustrates the model. Section II shows the results of the simulations of a general equilibrium entrepreneurial economy. Section III shows the empirical analysis of the Italian manufacturing firms. Section IV summarizes the conclusions.

I The model

I consider an economy with a large number of ex-ante identical households. They have access to a technology that produces output using capital and is subject to exogenous idiosyncratic shocks to its revenues. I assume that a fraction γ of households can only invest in their own business or borrow/lend a one period riskless bond. I call these households the "entrepreneurial sector".[2]

[2] For simplicity, I do not explicitly model the reasons why these households cannot hold diversified portfolios of the other businesses in order to fully diversify their idiosyncratic risk. Other authors who follow the same strategy are Angeletos and Calvet (2006), Angeletos (2007) and Covas (2006). Alterna-

A fraction 1-γ of firms is managed by the remaining households. The difference is that these households can invest in each other's firms (but not in the entrepreneurial sector), and are able to perfectly diversify their risk. I call these households "diversified" and the corresponding firms the "corporate sector". Without loss of generality I assume that all diversified households own the same uniform portfolio in the shares of the firms in the corporate sector. They can also trade the one period riskless bond between themselves and with the entrepreneurial households. Introducing the "corporate sector" in the model allows to quantify the effect of entrepreneurial risk on investment and innovation by comparing the behavior of entrepreneurial firms with the behavior of the corporate sector firms.

A Technology

As in Abel and Eberly (2005) I assume that the firms can, by paying a fixed cost, upgrade their technology to the frontier. If a firm does not innovate, its technology becomes less productive than the frontier technology, because of obsolescence. More formally, at time t a generic firm produces output y_t using the following production function:

$$y_t = A_t k_t^{\alpha} + \varepsilon_t; 0 < \alpha < 1 \tag{1}$$

where k_t is capital, A_t is the technology level, and ε_t is a stationary and persistent revenues shock, which follows a AR(1) process, $\varepsilon_t = \rho^{\varepsilon}\varepsilon_{t-1} + \nu_t$ with $0 < \rho^{\varepsilon} < 1$, where ν_t is an independent and identically distributed shock with mean zero and standard deviation $\sigma_{\varepsilon}^2(S_t)$. I introduce exogenous uncertainty as an additive shock in order to simplify the analysis, because such shock does not affect the marginal productivity of capital for the firm. In section III, I will relax this assumption and will show that the main predictions of the model are robust to considering a multiplicative shock in the production function.

The volatility of the revenue shock σ_{ε}^2 is time varying, according to the regime S_t:

$$S_t \in \{H, L\}, \text{ with } \sigma_{\varepsilon}^2(H) > \sigma_{\varepsilon}^2(L) \tag{2}$$

$$\begin{gathered} prob\,(S_t = S_{t-1}) = \rho^s \\ prob\,(S_t \neq S_{t-1}) = 1 - \rho^s \\ 0.5 < \rho^s < 1 \end{gathered}$$

Condition (2) implies that the uncertainty about the firm's profits is higher in the H state than in the L state. For simplicity, I rule out the presence of aggregate uncertainty by assuming that the regime S_t is firm specific. The purpose of the next section of this paper is to simulate the model and to verify how the innovation of entrepreneurial firms

tively, one could model an economy with heterogenous entrepreneurs where the market incompleteness arises endogenously due to financing frictions, as for example do Meh and Quadrini (2006).

and risk neutral firms are affected by the level of exogenous uncertainty. One could argue that the introduction of the switching regime S_t is an unnecessary complication, because one could simply solve the model for a fixed value of σ_ε^2 and then compare the simulation results for different values of σ_ε^2. However such simpler exercise would compare different economies with different steady state characteristics, and would not be directly comparable to the empirical investigation performed in the second part of the paper.

I introduce in the model an indicator function I_t to denote the innovation decision. If the entrepreneur does not innovate, then $I_t = 0$ and the technology depreciates at the rate δ_A, with $A_{t+1} = (1-\delta_A)A_t$. If the firm invests in innovation then $I_t = 1$, and the technology is upgraded in the next period at the cost F_{t+1}, so that $A_{t+1} = \overline{A}$, where $\overline{A}$ is the technology frontier. I assume that such frontier is constant, in order to preserve the stationarity property of the maximization problem. The fixed cost F_{t+1} is stochastic:

$$F_{t+1} = F + \xi \text{ with probability } 0.5$$
$$F_{t+1} = F - \xi \text{ with probability } 0.5$$

Therefore the term F measures the fixed costs of innovating in period t, and the term ξ measures the uncertainty in the profits that such innovation will generate in the future. It follows that if ξ is relatively small then the $I_t = 1$ decision can be interpreted as "technology adoption": the firm pays a fixed cost to adopt a new technology which will allow it to produce more efficiently. Instead if ξ is relatively large then the $I_t = 1$ decision can be interpreted as "risky innovation". The firm develops and/or adopts a new product which, if successful, with greatly increase profits, while if unsuccessful will generate a substantial loss.

B The entrepreneurial sector

Each entrepreneur at the beginning of time t produces y_t, repays b_t, the debt contracted in the previous period, and pays the innovation cost F_t, if it innovated in period $t-1$. Net worth w_t is:

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

where δ is the depreciation rate of fixed capital. After producing, the entrepreneur decides consumption c_t, the level of fixed capital that will be productive in the next period k_{t+1}, the amount to be borrowed or lent b_{t+1}, and wether or not to innovate and upgrade the technology. The budget constraint is the following:

$$k_{t+1} + c_t = w_t + \frac{b_{t+1}}{R} \tag{4}$$

where $R \equiv 1 + r$ and b_{t+1}/R is the net present value of the face value of debt b_{t+1}, to be repaid in the next period. In the benchmark case I assume that there are no financing frictions, and hence the entrepreneur is only subject to the "natural" borrowing constraint:

she cannot borrow more than the amount that guarantees nonnegative consumption with certainty in the next period. Simulation results show that, for reasonable parameter values, such constraint is almost never binding in equilibrium. Later, in section III, I will compare the benchmark results with the results from a simulated economy with tighter borrowing constraints.

The entrepreneurial household chooses b_{t+1}, k_{t+1} and I_t in order to maximize the value function (5) subject to the budget constraint (4) and the natural borrowing constraint (8):

$$V\left(S_t, w_t, A_t\right) = \max_{I_t,} \left\{V^{up}\left(S_t, w_t, A_{t+1}\right), V^{noup}\left(S_t, w_t, A_{t+1}\right)\right\} \tag{5}$$

where:

$$V^{up}\left(S_t, w_t, A_t\right) = \left\{\max_{k_{t+1}, b_{t+1}} u\left(c_t\right) + \beta^e [E_t V\left(S_{t+1}, w_{t+1}, A_{t+1}\right) \mid I_t = 1]\right\} \tag{6}$$

$$V^{noup}\left(S_t, w_t, A_t\right) = \left\{\max_{k_{t+1}, b_{t+1}} u\left(c_t\right) + \beta^e [E_t V\left(S_{t+1}, w_{t+1}, A_{t+1}\right) \mid I_t = 0]\right\} \tag{7}$$

$$b_{t+1} \leq b^{nat}\left(w_t, A_t, S_t\right) \tag{8}$$

The natural borrowing limit $b^{nat}\left(w_t, A_t, S_t\right)$ is endogenous because it depends on the stream of profits generated by the business, and is therefore a function of the state variables w_t, A_t and S_t. Conditional on the upgrade decision, the marginal productivity of capital in the next period is known with certainty. Therefore by taking the first order condition of (6) and (7) with respect to k_{t+1} and b_{t+1} it is possible to derive the following first order conditions for k_{t+1} and b_{t+1}:

$$u'\left(c_t\right) = \beta^e \left\{\left(\frac{\partial y_{t+1}}{\partial k_{t+1}} + 1 - \delta\right) E_t \left[u'\left(c_{t+1}\right)\right] \mid I_t\right\} \tag{9}$$

$$u'\left(c_t\right) = R\beta^e E_t \left[u'\left(c_{t+1}\right) \mid I_t\right] \tag{10}$$

The risk of innovation is reflected in the term $E_t[V\left(S_{t+1}, w_{t+1}, A_{t+1}\right) \mid I_t = 1]$ in equation (6). The higher is ξ, the higher is the variance of future consumption, conditional on the innovation outcome, the lower is the expected utility from consumption and the value of $E_t[V\left(S_{t+1}, w_{t+1}, A_{t+1}\right) \mid I_t = 1]$. This effect reduces the incentive to innovate for an entrepreneurial firm with respect to a risk neutral firm. In the next section we will study how variations in the volatility of the exogenous risk $\sigma_\varepsilon^2\left(S_t\right)$ affect entrepreneurial innovation.

C The corporate sector

Households in the corporate sector are identical to those in the entrepreneurial sector except that, because they fully diversify their risk, they manage their business with the objective to maximize the net present value of the stream of profits V_t^d:

$$V_t^d\left(S_t^d, A_t^d\right) = \max_{k_{t+1}^d, I_t^d} E_t\left(\pi_{t+1}^d\right) + \frac{1}{R} E_t\left[V_{t+1}^d\left(S_{t+1}^d, A_{t+1}^d\right)\right] \tag{11}$$

where:

$$E_t\left(\pi_{t+1}^d\right) = E\left(y_{t+1}^d\right) - UKk_{t+1}^d - RI_t^dF \tag{12}$$

Therefore their optimal investment is as follows:

$$k_{t+1}^d = \left\{\frac{E_t\left(A_{t+1}^d \mid I_t^d\right)}{UK}\right\}^{\frac{1}{1-\alpha}} \tag{13}$$

Because all firms are ex ante identical, and each household owns an equally weighted portfolio, the dividends d received each period are equal to the average of the profits $\pi_t^d\left(S_t^d, A_t^d\right)$:

$$d = \int \pi_t^d\left(S_t^d, A_t^d\right) d\Gamma^d\left(S_t^d, A_t^d\right) \tag{14}$$

The absence of aggregate uncertainty implies that $\Gamma^d\left(S_t^d, A_t^d\right)$, the density function of risk neutral firms, is constant, and therefore also d is constant over time. Therefore the problem of a generic diversified household is the following:

$$\max_{c_t^d, b_{t+1}^d} \sum_{j=0}^{\infty} \left(\beta^d\right)^j u\left(c_{t+j}^d\right) \tag{15}$$

such that:

$$c_t^d = w_t^d + d + \frac{b_{t+1}^d}{R} \tag{16}$$

Finally, b_{t+1}^d is bounded by the following condition:

$$b_{t+1}^d \leq \frac{Rd}{r} \tag{17}$$

Equation (17) is equivalent to a transversality condition. It states that the diversified households cannot borrow more than the net present value of their flow of dividends.

II General Equilibrium

In the following definitions, I use the subscripts i and j to indicate the $i-th$ entrepreneurial household and the $j-th$ risk neutral firm, respectively. The equilibrium of the economy is: a value function for the entrepreneurial household $V_{i,t}\left(\theta_{i,t}, w_{i,t}, A_{i,t}\right)$, and for the risk neutral firm $V_{j,t}^d\left(S_{j,t}^d, A_{j,t}^d\right)$; the policy functions $k_{i,t+1}\left(S_{i,t}, w_{i,t}, A_{i,t}\right)$, $b_{i,t+1}\left(S_{i,t}, w_{i,t}, A_{i,t}\right)$ $c_{i,t}\left(S_{i,t}, w_{i,t}, A_{i,t}\right)$, $I_{i,t}\left(\theta_{i,t}, w_{i,t}, A_{i,t}\right)$, $k_{i,t+1}^d\left(\theta_{i,t}, w_{i,t}, A_{i,t}\right)$ and $I_{i,t}^d\left(\theta_{i,t}, w_{i,t}, A_{i,t}\right)$; the diversified households' borrowing b^d and consumption c^d; the cross sectional distribution of entrepreneurs' characteristics $\Gamma\left(S_{i,t}, w_{i,t}, A_{i,t}\right)$ and of risk neutral firms' characteristics $\Gamma\left(S_{i,t}^d, A_{i,t}^d\right)$, and the interest rate r_t such that:

i) Given r_t, the entrepreneur's policy functions solve the entrepreneur's decision problem (5), the risk neutral firm's policy function solves the decision problem (11), and the diversified household borrowing and consumption decisions solve the diversified household's decision problem (15).

ii) The interest rate r ensures that the bond market is in equilibrium:

$$\gamma \int b_{t+1}\left(S_{i,t}, w_{i,t}, A_{i,t}\right) d\Gamma\left(S_{i,t}, w_{i,t}, A_{i,t}\right) + (1-\gamma)\, b^d = 0 \tag{18}$$

iii) The cross sectional distribution of entrepreneurs' characteristics $\Gamma\left(S_{i,t}, w_{i,t}, A_{i,t}\right)$ and of risk neutral firms' characteristics $\Gamma^d\left(S^d_{j,t}, A^d_{j,t}\right)$ are constant over time.

In order to ensure that in equilibrium entrepreneurial households face a non negligible amount of undiversifiable risk, I assume that entrepreneurs are relatively impatient:

Assumption 1: $\beta^d > \beta^e$

When equation (18) holds, the consumption path of the diversified households is constant over time and the equilibrium interest rate is $R^* = \frac{1}{\beta^d}$. In order to explain why assumption 1 is necessary, suppose that it does not hold, because $\beta^d = \beta^e$, and that $R = \frac{1}{\beta^d}$. For this value of the interest rate the entrepreneurs, as long as they face idiosyncratic risk, are willing to invest in the risk free bond for precautionary reasons. This reduces R below $\frac{1}{\beta^d}$, and it incentives the diversified households to borrow in order to increase consumption. This accumulation of debt by the diversified households continues until either the entrepreneurial sector has saved so much that is able to fully diversify the risk, or until the diversified households have reached their maximum borrowing allowed by equation (17). On the contrary assumption 1 ensures that entrepreneurs save up to the point that their desire to save in order to diversify their risk is counterbalanced by their desire to consume due to their relatively low discount factor.

III Simulation results

I solve the maximization problem of the entrepreneurial firm and of the risk neutral firm using a numerical method (see appendix 1 for details), and I simulate 5000 firms in the artificial economy for 1000 periods. I model utility with a C.E.S. function:

$$u\left(c_t\right) = \frac{c_t^{1-\eta}}{1-\eta} \tag{19}$$

Table I illustrates the choice of benchmark parameters. A first set of parameters is calibrated by matching one to one a set of empirical moments. The depreciation rate of fixed capital δ is set equal to 14.5%. β^d is set to match an average real interest rate of 2%. The fraction γ of entrepreneurial households in the economy is equal to 0.4.[3] The parameters

[3] The value of γ does not affect the results as long as it is not too large. If the fraction of diversified households $1-\gamma$ is to small, constraint (17) may be binding in equilibrium, and it may become impossible to match the degree of diversification of entrepreneurial households observed in the data.

$\sigma_\varepsilon^2(L)$, α and β^e are calibrated on annual data of the entrepreneurial households in the 1989, 1992, 1995 and 1998 US Surveys of Consumer Finances (SCF). The parameter α determines the curvature of the production function and can be interpreted as the degree of market power of the firm. I calibrate it to match the average of the net profits/sales ratio for the entrepreneurial businesses in the SCF. The parameter $\sigma_\varepsilon^2(L)$ matches the standard deviation of the net income/sales ratio for the entrepreneurial businesses in the SCF. The parameter β^e matches the wealth distribution of the entrepreneurial sector. Following Moskowitz and Vissing-Jørgensen (2002) I measure it as the ratio between the value of the business and the total net worth of the household. The larger the ratio is, the more the profits of the business are an important component of the permanent wealth of the household, the more the household is sensitive to changes in business risk for its consumption and investment decisions. I choose β^e in order to match the fraction of total private equity that is owned by households for which the value of the business, measured as the net present value of future expected profits, constitutes at least 75% of their total net worth. Moskowitz and Vissing-Jørgensen (2002) calculate this fraction to be around 48%. The assumptions of the model establish a direct mapping between this moment and the value of β^e. If β^e decreases, entrepreneurial households are willing to consume more and to borrow more, and their distribution of financial wealth shifts to the left.

The frontier technology $\overline{A}$ is normalised to 1. The parameters δ_A, F and ξ are calibrated using the innovation data available for the Italian firms analysed in the empirical section of this paper. The depreciation rate of technology δ_A directly affects the size of the technological upgrade (the difference $\overline{A} - A_t$) for an innovating firm, and the size of the associated fixed capital investment $k_{t+1} - k_t$, because technology and fixed capital are complementary. This mapping suggests to calibrate δ_A so that the discrete fixed capital investment directed to innovation in the empirical data matches the same moment in the simulated economy. The parameter F is calibrated in order to match the average frequency of innovation for all firms. The baseline value of the parameter ξ matches the difference in the average frequency of innovation between entrepreneurial and non entrepreneurial firms. However, because this empirical moment is also driven by other firm characteristics, I also perform a sensitivity analysis of the value of ξ.

Regarding the remaining parameters, their value cannot be identified by one specific empirical moment. Therefore, I first assign to these parameters a reasonable value for the base calibration. Later, in section III.A, I verify the sensitivity of the results to changing such values. Among these parameters, the relative risk aversion coefficient η is set equal to 2 in the base calibration. Later I verify the sensitivity of the results for a range of values between 0.8 and 2.6. The parameter $\sigma_\varepsilon^2(H)$ is chosen so that in the high volatility state the standard deviation of the profits/sales ratio is 80% higher than in the low volatility state. This range of variation is consistent with the cross-industry variation observed in the empirical data analysed in the next section. The benchmark value of ρ^ε, the AR(1) coefficient of the exogenous shock ε, is calibrated to 0.95. This is consistent with the empirical evidence that productivity shocks are very persistent. The benchmark value of ρ^s, the persistency coefficient of the regime S_t, is calibrated to 0.9.

Figure 3 illustrates the relationship between innovation risk on the x-axis, and the frequency of innovation on the y-axis. Innovation risk is measured according to its contribution to the volatility of profits. A value close to zero corresponds to the "technology adoption case", while higher values correspond to the "risky innovation" case. The value of ξ in the base calibration implies that the innovation risk accounts for 15.8% of the total volatility of profits.

The frequency of innovation of corporate sector firms is constant and equal to 33%, and is not affected neither by the uncertainty state, nor by the innovation risk, as these firms are managed by risk neutral managers who only care about expected profitability. Conversely, innovation risk reduces the frequency of innovation of entrepreneurial firms. Importantly, this negative effect, which is measured by the difference between corporate sector firms and entrepreneurial firms, is much stronger in the high uncertainty state than in the low uncertainty state, despite the exogenous profits shock and the innovation shock are independent. Intuitively, consider at a certain time t a cross section of entrepreneurs who are in the high uncertainty state. These entrepreneurs are heterogeneous in terms of their current financial wealth, which depends on their history of idiosyncratic shocks. Those who were successful in the past have accumulated financial wealth and can use it to smooth consumption. Conversely, those who were unlucky have a lower amount of financial wealth, and most of their permanent wealth is represented by the value of their business. For these "less diversified" entrepreneurs an increase in the volatility of profits reduces the willingness to take on the additional innovation risk, even when such risk is small. In order to understand this effect, consider the "worst case" scenario, where an exogenous negative profits shock is compounded by a higher than expected cost of innovation. The profits shock is persistent, and leads to a reduction in the value of the business and in current consumption. In this context, the negative shock to the cost of innovation further reduces entrepreneurial wealth and causes a further drop in consumption. The likelihood of this event significantly reduces the expected utility ex ante conditional on innovating. The implication is that entrepreneurs in the high uncertainty state prefer to delay innovation, at the cost of producing less efficiently. Instead, when background uncertainty is low, an increase in innovation risk initially does not affect much average entrepreneurial innovation, even for the less diversified entrepreneurs. This happens for two reasons: i) when both risks are small, their impact on expected utility is negligible. ii) Even if some of the least diversified entrepreneurs delay innovation, this effect is compensated by those entrepreneurs who just switched from the high uncertainty to the low uncertainty state, and find it optimal not to delay innovation any more.

The implications of these effects are summarised in figure 4, which illustrates the relationship between exogenous uncertainty and innovation, for different values of the innovation risk. It shows that an increase in the exogenous uncertainty significantly lowers the propensity of entrepreneurial firms to innovate. Such effect initially increases with the innovation risk, so that for the base calibration the frequency of entrepreneurial innovation on average increases by 9.7% when a firm moves from the high uncertainty to the low uncertainty state. This average effect is entirely driven by the less diversified entrepreneurial firms in the economy, as shown in figure 5. The first observation on the left of figure 5 refers to the whole of the entrepreneurial sector. The observations to the right instead refer to groups of entrepreneurial firm-year observations selected according to their degree of diversification, measured as the ratio between financial wealth and the total value of the firm. Figure 5 shows that the less diversified are the firms, the more their innovation is sensitive to exogenous uncertainty, so that the average difference in the frequency of innovation across states can become as large as 42.5%. On the contrary, the innovation of more diversified firms is not sensitive to the uncertainty regime.

Summing up, figures 3, 4 and 5 determine the following results: first, in an economy the risky innovation of the entrepreneurial firms is on average negatively affected by the amount of uncertainty, the more so the riskier innovation is. Second, this negative effect is much stronger for the less diversified firms. It is important to note that these results do not depend on the presence of borrowing constraints, but only on some type of imperfection that limit the ability of entrepreneurial firms to diversify risks.

The consequence of financing frictions is instead analysed in figure 6, which considers simulations of the model where the following exogenous borrowing limit is introduced:

$$b_t \leq \overline{b} \tag{20}$$

In figure 6 the first observation to the left refers to the base calibration, where firms are not financially constrained. Then on the x-axis are shown economies with progressively smaller $\overline{b}$, which implies that more firms have a binding financing constraint in equilibrium, and cannot invest optimally, so that their average fixed capital investment decreases. The implication is that the average frequency of entrepreneurial innovation also declines in these economies, for two reasons. First, there is a direct effect: a negative innovation shock implies that the firm may face a binding constraint in financing both consumption and capital investment, and this discourages innovation ex-ante. Second, there is an indirect effect: innovation is only profitable if after innovating the firm can also increase its fixed capital investment, but this is not possible if financing constraints are binding. Hence, as constraint (20) becomes more tight, then both the average fixed capital investment (on the x-axis) and the average frequency of innovation decline. More interestingly, figure 6 also shows that aggregate entrepreneurial innovation becomes less sensitive to a change in the uncertainty state. Intuitively, consider again the investment decision of the less diversified firms. In the absence of binding financing constraints, these firms allocate resources between consumption, investment and innovation according to an internal solution of their optimisation problem. An increase in exogenous uncertainty reduces the net present value of the expected utility of consumption conditional on innovating, and it makes it optimal to delay innovation. Conversely, in the presence of financing frictions these firms allocate resources according to a binding resource constraint. Hence the tighter the financing constraint, the less relevant is exogenous uncertainty for their innovation decisions.

All the results illustrated so far maintain the assumption that the profits shock enters the production function additively. In other words, the term ε in equation (1) can be interpreted as the outcome of some uncertainty concerning the firm's profits which is unrelated to the outcome of the innovation process. This assumption simplifies the analysis, because it implies that uncertainty affects the innovation decision only indirectly through its effect on expected utility, but is clearly unrealistic. I relax this assumption below, by assuming the following production function:

$$y_t = e^{\tau \varepsilon_t} A_t k_t^{\alpha} + \varepsilon_t; 0 < \alpha < 1 \tag{21}$$

where τ is a positive constant. In this new formulation, ε_t also enter as a multiplicative shock, and directly affects the outcome of the innovation process. The magnitude of τ determines the relative importance of the multiplicative component of the shock. In figure 7 we increase progressively τ, starting from a value of $\tau = 0$, which corresponds to the base calibration. With respect to the base model, the presence of the multiplicative shock has two additional effects. First, because the profits function is convex in $e^{\tau \varepsilon_t}$, when a firm switches from the low uncertainty to the high uncertainty state its expected profits increase. This effect increases risky innovation. Second, the outcome of the innovation is now positively correlated to the exogenous profits shock, through the term $e^{\tau \varepsilon_t}$. This effect further decreases the innovation of the least diversified entrepreneurs.

These two counteracting effects help to explain the simulation results illustrated in figure 7. As τ increases, the increase in entrepreneurial innovation following a decline in uncertainty becomes smaller, because firms experience also a decline in the expected profits from the innovation. However, after controlling for average firm profitability in each state, the figure shows that the "conditional" increase in entrepreneurial innovation following a decline in uncertainty becomes actually larger in τ, because of the second effect mentioned above. These findings suggest that, in order to empirically estimate the importance of undiversifiable risk for the negative effect of uncertainty on entrepreneurial innovation, it may be important to control for average firm profitability.

A Sensitivity analysis

In the following figures 8-12 I verify that the above results are robust to variations in the parameters which are not calibrated with observable empirical moments.

Figure 8 considers different degrees of relative risk aversion. It shows that, if the innovation risk is non negligible, then the negative effect of uncertainty on innovation is substantial also for low levels of risk aversion. In other words, the key factor driving the negative effect of uncertainty on innovation is not that entrepreneurs are very risk averse, but rather that a substantial amount of entrepreneurial households do not diversify their business risk. Furthermore, figure 8 shows that the effect of uncertainty on innovation does not necessarily decline with the degree of risk aversion. For large levels of innovation risk, the innovation decision is actually more sensitive to uncertainty when risk aversion is low. This point is illustrated more in details in figure 9, which shows that in an economy with low entrepreneurial risk aversion ($\eta = 0.8$), the innovation risk still has a large negative effect on risky innovation in the high uncertainty state, while its effect is, if anything, slightly positive for entrepreneurs in the low uncertainty state.

Figure 10 considers the effect of uncertainty on innovation when the change in volatility across states becomes more pronounced. The result here is quite intuitive. When the change from the low uncertainty to the high uncertainty state implies a larger increase in profits volatility, the associated decline in entrepreneurial innovation is also larger.

Finally, figures 11 and 12 consider different values of persistency of the exogenous profit shocks (figure 11) and of the uncertainty state (figure 12). They show that the effect of uncertainty on innovation is higher the more persistent the profits shock is, but they also imply that the effect is still significant also for lower persistency levels.

IV Empirical analysis

The simulations of the general equilibrium entrepreneurial economy illustrated above determine the following testable predictions:

Prediction I: An increase in uncertainty, as measured by the volatility of profits, negatively affects the risky innovation of entrepreneurial firms, while it does not affect the risky innovation of non entrepreneurial firms.

prediction II: An increase in uncertainty does not affect the risky innovation of diversified entrepreneurial firms and/or of financially constrained entrepreneurial firms.

Prediction III: An increase in uncertainty does not affect the technological adoption of both entrepreneurial and non entrepreneurial firms.

I test these predictions on a panel of small and medium Italian manufacturing firms based on the 1995, 1998 and 2001 Mediocredito Centrale Surveys. Each Survey covers the activity of a sample of more than 4400 small and medium manufacturing firms in the three previous years. Mediocredito Centrale selected these samples balancing the criteria of randomness and continuity. Each survey contains three consecutive years of data. After the third year, most of the sample is replaced and the new sample is then kept for the three following years. The combined sample of the three surveys includes 11417 firms and 13601 firm-year observations. The surveys provide detailed qualitative information on property structure, employment, R&D and innovation, internationalization and financial structure. In addition to this qualitative information, Mediocredito Centrale also provides, for most of the firms in the sample, an unbalanced panel with balance sheet data items going back in time as far as 1989.

This dataset has several useful features. First, it includes qualitative information not only on the amount spent by each firm in R&D, but also on the type of fixed investment and R&D expenditure.[4] This information can be used to identify which firms are investing in projects that involve risky innovation. Second, it includes information about the property structure of the firms, which allows to identify which firms are "entrepreneurial", in the sense that they are owned and managed by the same individual. Third, it includes additional information that can be used to control for the effect of other factors that are potentially important for innovation, such as financing constraints, market structure and internationalization.

The main limitation of this dataset is the lack of information about the assets of the entrepreneurial households that are not included in the balance sheet of the firm. On the one hand this is not a problem for the test of predictions (*i*) and (*iii*). On the other hand prediction (*ii*) implies that the negative relationship between risk and innovation is driven by the less diversified firms in the sample. In section IV.D.1 I will show some empirical evidence in support of this prediction using the information about the financial assets of the firms.

A Construction of the dataset

I select the sample of entrepreneurial firms using the following property structure information from the surveys. Firms are asked if their three largest shareholders: i) are individuals, financial companies or industrial companies; ii) have the "direct control" of the firm. For each of these shareholders is also specified their share of ownership in the firm.

Using this information I select as "entrepreneurial" those firms that: a) have one individual who owns at least 50% of the shares of the firm; b) are actively managed by this individual.

In the model the entrepreneurial households own 100% of the shares of their firms. Therefore criterion (a) may seem too inclusive. However I argue that this is not the case, and that this selection criterion is the most efficient in identifying firms that effectively are fully owned and managed by a single entrepreneurial household. This claim can be verified using the information provided by the 1995 survey, where firms also indicate, in case more than one shareholder is an individual, whether there are family ties among them (unfortunately this information is not included in the 1998 and 2001 surveys). I

[4] Other authors have been analysing the innovation data of the Mediocredito Surveys. Hall, Lotti and Mairesse (2006) study the relationship between employment, innovation and productivity. Parisi, Schiantarelli and Sembebelli (2006) study the relationship between productivity, innovation and R&D. Benfratello, Schiantarelli and Sembenelli (2008) analyse the effect of banking development on firm innovation.

consider the firms classified as entrepreneurial firms in the 1995 survey, according to the criteria (a) and (b). Among all the entrepreneurial firms that have more than one shareholder, 94% have other individuals as shareholders, and 71% have family ties among all the shareholders.

In the full sample composed of the three surveys, 33.2% of the firms are classified as entrepreneurial. The sorting criterion is fairly stable over time, so that if I exclude from the entrepreneurial group those firms that are present in more than one survey, and are not selected as entrepreneurial firms in all the surveys, the ratio falls very little, from 33.2% to 30.2%. Table II illustrates some summary statistics about the firms in the dataset. Entrepreneurial firms are on average younger, smaller, and they have a marginally higher return on capital.

B Estimation strategy

I identify the investment in innovation using the direct questions in the Mediocredito Surveys. In the section with the heading "Technological innovation and R&D", firms are asked whether they engaged, in the previous three years, in R&D expenditure. The firms that answer yes (37% of the total) are asked what percentage of this expenditure was directed to: i) improve existing products; ii) improve existing productive processes; iii) introduce new products; iv) introduce new productive processes; v) other objectives.

Furthermore, in the section of the survey with the heading "Investment", firms are asked if they undertook new investment in plant and/or equipment in the three previous years. The firms that answer yes (89% of the total) are asked to specify to what extent the fixed investment had the following objectives: i) improve existing products; ii) increase the production of existing products; iii) produce new products; iv) other objectives. For each chosen answer the firm indicates three possible degrees of intensity: low, medium and high.

I use the questions above to construct indicators of risky innovation activity. It is plausible to assume that on average the innovation related to the introduction of new products is likely to be risky, because of demand uncertainty. Conversely the innovation directed either to improve existing products or to innovate the productive processes is less risky, and analogous to the technology adoption case considered in the theoretical model. It is important to notice that this mapping between the innovation decision in the model and in the empirical data is consistent with the view that product innovation may be chosen by firms as part of a diversification strategy. Also in the model the investment in risky innovation is a diversification opportunity, because its outcome is independent from the exogenous revenues shock. However, the simulations of the model show that, for realistic levels of concentration of entrepreneurial wealth and of risk aversion, an increase in the exogenous profits uncertainty significantly reduces the willingness to take on the innovation risk.

I summarize the information about innovation and technology adoption in the following four dichotomous variables. The variable that identifies risky innovation is $r\&d\_inn_{i,p}$, which is equal to 1 if more than 50% of $R\&D$ spending of firm i in survey p is directed to develop new products, and zero otherwise. $r\&d\_t.a._{i,p}$, the variable that identifies "technology adoption" (less risky innovation) is equal to 1 if firm i did $R\&D$ activity in survey p but $r\&d\_inn_{i,p} = 0$, and zero otherwise. An alternative indicator of risky innovation is $fix\_inn_{i,p}$, which is equal to 1 if fixed investment spending of firm i is partly or fully directed to the introduction of new products, and is equal to 0 otherwise. Finally $fix\_t.a_{i,p}$ is equal to 1 if firm i undertook a new fixed investment project but $fix\_inn_{i,p} = 0$ and 0 otherwise. Table III reports the percentage of firms selected according to the four criteria above. It shows that entrepreneurial firms on average engage less in R&D than non entrepreneurial firms. Moreover a similar proportion of firms in both groups invests in fixed capital in order to improve existing products or to introduce new productive processes, while entrepreneurial firms on average are less likely to introduce new products.

Before testing the predictions of the model, I provide some anecdotal evidence in support of the claim that the intensity of risky innovation is positively correlated with the average riskiness of the firms in the sample. The model predicts that conditional on innovating a firm expects an higher volatility of its future revenues. Figures 1 and 2 pool the data for each 3 digit sector for the whole of the sample period (1992-2000). They show the correlation between the dispersion of profits across firms for each sector, and the ratio of the frequency of product innovation relative to the frequency of innovation directed to improve the current production. The figures show that the dispersion of returns is significantly increasing in such ratio. These unconditional correlations are consistent with the claim that product innovation is on average more risky than the innovation directed to improve the current production.

C Estimation results

I test predictions *(i)*, *(ii)* and *(iii)* by regressing the innovation decision on a measure of idiosyncratic uncertainty:

$$\begin{aligned} y_{i,p} &= \alpha_0 + \alpha_1 sdroa\_1_{s.p} + \alpha_2 export_{i,p} + \alpha_3 supply_{i,p} + \alpha_4 constrained_{i,p} + \\ &\quad + \alpha_5 return_{i,p} + \alpha_6 \ln(size_{i,p}) + \alpha_7 age_{i,p} + \alpha_8 age^2_{i,p} + d^{2digits}_{i,p} + d^{survey}_{i,p} + u_{i,p} \end{aligned} \tag{22}$$

The dependent variable $y_{i,p}$ is one of the indicators of innovation described above, namely the two dichotomous variables representing the "risky innovation" decision $r\&d\_inn$ and fix_inn, and the two dichotomous variables representing the "technology adoption" decision $r\&d\_t.a.$ and fix_t,a. The independent variable that measures uncertainty is $sdroa\_1_{s.p}$. This variable is equal to the cross sectional standard deviation of the return on assets (operating profits divided by total assets) for the firms in the three digit sector

s in the most recent year of survey p (e.g. year 1994 for the 1995 Survey).[5] $sdroa\_1_{s,p}$ has 191 different observations in total.

The advantage of using a sectorial measure of uncertainty is that it is exogenous from the point of view of the single firm, thereby reducing possible biases caused by a reverse causality problem. However, the coefficient of $sdroa\_1_{s.p}$ may still be biased by the presence of sector specific omitted variables. The robustness of the results to this potential problem are analyzed in the next section. It is instead not a problem the fact that $sdroa\_1_{s.p}$ is sector specific while exogenous uncertainty is instead firm specific in the simulated data analysed in the previous section. It is possible to show that all the predictions of the model are also confirmed by a richer model where firms belong to different sectors, and where exogenous uncertainty arises at the sectorial rather than at the firm level.

I include in the regression also the following control variables: $avgroa\_1_{s,p}$, the cross sectional mean of the return on assets for sector s in survey p, is an indicator of the average profitability of firms. This explanatory variable is important because, as noted in the previous section, it controls for the possibility that higher uncertainty may affect innovation also by increasing expected returns. $export_{i,p}$ is equal to 1 (69% of total) if firm i exports part of its production outside Italy, and is equal to 0 otherwise. The variable capturing market structure is $supply_{i,p}$, which is equal to 1 (44%) if firm i produces 100% of its output based on the order placed by downstream firms, and equal to zero otherwise. The variable capturing financing constraints is $constrained_{i,p}$, which is equal to one if firm i declares financing constraints (14%), and zero otherwise.[6] The other control variables are $size_{i,p}$, which is the number of employees of firm i, and $age_{i,p}$, which is the age of firm i (relative to the year of the survey) measured in years. Finally, $d_{i,p}^{2digits}$ is a series of two digit sector dummy variables, and $d_{i,p}^{survey}$ is a series of survey dummy variables.

Table IV reports the estimation of equation (22). Consistently with predictions (i) and (iii), it shows that an increase in uncertainty, as measured by the $sdroa\_1_{s,p}$ variable, has a significant and negative effect on the investment in risky innovation of the entrepreneurial firms, while it does not affect the investment in risky innovation of the other firms. Importantly, while entrepreneurial and non entrepreneurial firms differ with respect to the correlation between risk and innovation, they do not differ much with respect to the significance of the other control variables. With respect to the regressions that use the product innovation variables $r\&d\_inn_{i,p}$ and $fix\_inn_{i,p}$ as dependent variables, I

[5] I consider the most recent available year of each survey because it includes an higher number of observations. This is because not all firms have balance sheet data for all the three years in the survey. Nonetheless the results do not differ substantially if I consider a cross sectional measure of risk that covers all the three years in the survey instead.

[6] Firms are asked the three following questions about financing problems: 1) "during the last year, did the firm desire to borrow more at the interest rate prevailing on the market?". 2) "If the previous answer was yes: was the firm willing to pay and higher interest rate in order to get additional credit?". 3) "During the last year, did the firm ask for more credit without obtaining it?". The variable $constrained_{i,p}$ is equal to one if the answer to any of the three previous questions is positive.

find that firms that export more and larger firms innovate more. Conversely firms that produce based on orders of downstream firms rather than for the market innovate less. These findings may be explained by the fact that large firms that produce for the market and that export abroad are more pressured to innovate by their competitors.

Conversely, the regressions that uses $fix\_t.a._i$ as the dependent variable show that firms that install new fixed capital to improve the existing production have opposite characteristics: they export less and they produce more upon orders and less for the market.

D Robustness checks

In this section I perform several robustness checks of the consistency between the predictions of the model and the empirical evidence.

D.1 Financing constraints and diversification

The first robustness check is related to the prediction of the model that the presence of financing constraints reduces the negative effect of uncertainty on the risky innovation of entrepreneurial firms. Table V replicates the analysis in table IV after excluding the 14% of firms that declare financing problems in any of the three surveys. The results are consistent with the predictions of the model. The comparison between tables IV and V shows that excluding financially constrained firms increases the negative effect of uncertainty on risky innovation. Moreover the bottom part of table V shows that such negative effect disappears when the model is estimated for financially constrained firms only.

The second robustness check is related to the prediction of the model that the negative relation between uncertainty and innovation only holds for undiversified entrepreneurial households. More precisely, simulation results show that the entrepreneurial households that hold an amount of financial assets relatively large with respect to the size of their business are not affected by changes in uncertainty. In order to verify this prediction, I construct the measure of financial wealth $fin\_a_{i,t}$, which is equal to the ratio between the net financial assets of firm i (financial investment + liquidity + short term financial credit - short term financial debt) divided by the total assets of firm i in period t. I eliminate the largest 1% and smallest 1% values as outliers. The measure of diversification I consider is $divers_{i,p}$, which is the average of $fin\_a_{i,t}$ across the three years of survey p. The mean of $divers_{i,p}$ is equal to 0.38, and its standard deviation is equal to 0.21. I verify prediction (ii) in table VI, where I estimate equation (22) using the risky innovation indicators $r\&d\_inn_{i,p}$ and $fix\_inn_{i,p}$ as dependent variables and separating firms according to wether the value of the variable $divers_{i,p}$ is below or above the 0.5 cutoff point. This threshold for identifying diversified entrepreneurial firms is higher than the threshold indicated by the simulated data. The difference is that in the simulated data the measure of diversification is computed using the value of the firm's future profits at the denominator, while in the empirical data the denominator is the book value of the assets, which is likely to underestimate the real value of the firm. The estimation results confirm the prediction that the negative effect of risk on innovation is driven by the undiversified entrepreneurial firms, because the coefficient of $sdroa\_1_{s,p}$ is only significant for the firms with a low value of $divers_{i,p}$. Importantly, also in this case there are few substantial variations in the coefficients of the other main determinants of innovation across the different regressions. Furthermore, these results are unlikely to be driven by the fact that low $divers_{i,p}$ firms are financially constrained firms, because both the model and the regression results show that financing constraints reduce rather than increase the negative effect of risk on the entrepreneurial innovation decisions. This is confirmed by table VII, which splits the sample in the same way as table VI but also it excludes from the sample financially constrained firms. In this case the coefficient of $sdroa\_1_{s,p}$ becomes more significant and larger in absolute value for "low $divers_{i,p}$" firms.

D.2 Endogeneity problems

In the previous sections I argued that the measure of profits uncertainty $sdroa\_1_{s,p}$ is exogenous from the point of view of the firms, while it may still be correlated to sectorial characteristics that may matter for the innovation decisions, and thus bias the estimation results.

This section verifies that the observed negative relationship between uncertainty and entrepreneurial innovation is not driven by such unobserved characteristics. It is worthwhile to notice that the results presented above already provide two argument to reject such claim. First, the test of the model is based on finding a differential effect of uncertainty on the different types of innovation decisions of entrepreneurial versus non entrepreneurial firms. The results confirm this differential effect, and find that the only significant negative effect of uncertainty on innovation regards the innovation to develop new products by entrepreneurial firms, as predicted by the model. Therefore, any endogeneity problem that biases the coefficient of $sdroa\_1_{s,p}$ in the same direction for both types of firms does not affect the validity of this result.

Second, the most likely endogeneity problem in the estimation of equation (22) is that some firms may belong to more dynamic sectors, with more innovation on average and also higher volatility and cross sectional dispersion of profits. However, this type of endogeneity should bias the coefficient of $sdroa\_1_{s,p}$ upwards rather than downwards, and therefore it should bias the estimations towards rejecting rather than accepting prediction (i). This claim is confirmed by table VIII, which estimates the effect of uncertainty with and without including the set of control variables. The first five columns estimate the model with $r\&d\_inn_{i,p}$ as dependent variable. In column (1) no control variable is included. In column (2) I include only the sector and survey dummies. In column (3) I include the control variables representing internationalization and market structure, in column (4) the variable that controls for the average profitability of the firms in the sectors, and finally in column (5) the full specification. The coefficient of $sdroa\_1_{s,p}$ is negative and significant in all specifications except than in column (1). In this case the coefficient of $sdroa\_1_{s,p}$ becomes positive, because the volatility of profits and the frequency of innovation are positively correlated across 2 digit sectors and across surveys, and therefore if these dummies are omitted the coefficient of $sdroa\_1_{s,p}$ is biased upwards. The presence of this bias is confirmed by the fact that the increase in the coefficient of $sdroa\_1_{s,p}$ also happens for non entrepreneurial firms (see the last row of table VIII). Similar results are found when I use $fix\_inn_{i,p}$ as dependent variable, in the second part of the table, in columns (6) to (10). Moreover, column (9) shows that average profitability significantly increases the probability of product innovation, and that after controlling for such variable the coefficient of $sdroa\_1_{s,p}$ becomes more negative and significant. These results are consistent with the predictions of the model (see the discussion at page 14).

Therefore, for the results presented above to be explained by an endogeneity problem, it should be that some other factor, which varies across three digits sectors, is at the same time negatively correlated with the risky innovation of entrepreneurial firms and positively correlated with the volatility of profits in the sector.

In tables IX and X, I provide two further robustness checks that control for this hypothesis. In table IX, I include in the estimation 3 digit sector dummies. This implies that the coefficient of $sdroa\_1_s$ is identified only by variations in uncertainty in each sector over time rather than by changes across sectors. The combined presence of 3 digit sector fixed effects and survey fixed effects controls for the impact of any sector specific unobserved variable and for any survey specific effect. Moreover I substitute the control variables $supply_{i,p}, constrained_{i,p}, avgroa\_1_{i,p}, \ln(size_{i,p}), age_{i,p}$ and $age_{i,p}^2$ with sector specific variables. For example, I substitute $constrained_{i,p}$ with $constrained_{s,p}$, the latter being the fraction of constrained firms in sector s and survey p. This change takes into account the fact that such variables at the firm level are also possibly endogenous. Table IX shows that the coefficient of $sdroa\_1_{s,p}$ is very similar, across the different groups, to the coefficient estimated in the regressions that included only 2 digit sector dummies (see table IV). At the bottom of table IX, I report the estimated coefficient of $sdroa\_1_{s,p}$ for the groups of firms selected according to diversification and to financing constraints. These results are also broadly consistent with those in the previous tables. Finally, table X proposes an instrumental variable estimation where, in addition to introducing three digit sector dummies, I also instrument the variable $sdroa\_1_{s,p}$. I use as instruments two lagged variables related to the riskiness of each sector p. $sdroa\_1_{s,p-1}$, which is the cross sectional volatility of return on assets for the sector s in the previous survey, and $sd\_output_{s,p-1}$, which is the standard deviation of the trend deviations of an index of revenues for sector s during the last year of survey $p-1$.[7] The latter variable is computed using monthly data from the Italian Statistical Institute (ISTAT) for all 3 digit manufacturing sectors. Therefore

[7]Before detrending, the indexes have been deseasonalised.

is based on a sample larger than the sample of the Mediocredito Surveys. Furthermore, I use a contemporaneous instrument called $sdNA_{s,p}$, which is a measure of cross sectional uncertainty for North American firms in the manufacturing sector s during the three years of survey p.[8] This instrument has the advantage of being orthogonal to any unobservable factor which is specific to the Italian firms and which may drive the observed correlation between uncertainty and entrepreneurial innovation. I estimate the model using a two step instrumental variable probit estimator. Table X reports, for brevity, only the estimates of the coefficient of $sdroa\_1_{s,p}$ for all the different regressions, and the $p-value$ of the Amemiya-Lee-Newey Overidentification test of the orthogonality of the instruments. The α_1 coefficient measuring the sensitivity of innovation to uncertainty follows the same pattern observed in the previous tables, even though is generally more noisily estimated, and not always significant. This is partly due to the fact that the sample is further reduced because, in order to use the instrument $sdNA_{s,p}$, I had to drop the observations of several sectors, either because the instrument was not available for those sectors, or because the mapping between the NAICS classification of north American Firms and the ATECO classification of Italian firms was ambiguous. Nonetheless the results are still broadly consistent with the predictions of the model. First, the decisions to improve the existing production, $r\&d\_t.a.$ and $fix\_t.a$, are not affected by uncertainty for all firm. Second, the negative effect of uncertainty on the risky innovation of entrepreneurial firms increases for less diversified firms, especially after excluding financially constrained firms. Indeed among the less diversified and not financially constrained firms, the effect of uncertainty on risky innovation is negative and significant for entrepreneurial firms for the fix_inn indicator, while is much smaller and not significant for the other firms.

V Conclusions

This paper develops a model of an economy where undiversifiable entrepreneurial risk matters in equilibrium for the investment decisions of entrepreneurial firms. In this context

[8] This variable is computed starting from the panel of 7070 North American Firms analysed in Castro, Clementi and Mac Donald (2008). The authors run a panel regression of net sales on a series of explanatory variables such as industry and year dummies, age and size. The residual from this estimate, called ε_{ist}, represents the unexplained part of the growth rate of sales from year t and year $t+1$ for firm i in sector s. Then the following second stage regression is run separately for each Mediocredito Survey subperiod:

$$\ln \widehat{\varepsilon}_{ist}^2 = \theta_s + u_{ist} \tag{23}$$

where t goes from 1992 to 1994, from 1995 to 1997 and from 1998 to 2000 for the second, third, and fourth Mediocredito Survey respectively. The variable $sdN_{s,p}$ is then computed as follows:

$$sdN_{s,p} = \sqrt{\exp(\widehat{\theta}_{s,p})}$$

where $\widehat{\theta}_{s,p}$ is the point estimate of θ_s in the regression relative to the period of survey p. I am very grateful to Rui Castro for his help in providing the data to construct this variable.

I analyze the implications of this risk for the relationship between uncertainty and risky innovation. I show that an increase in uncertainty adversely affects the investment in risky innovation of entrepreneurial firms, while it does not affect the innovation decisions of risk neutral firms. The predictions of the model are confirmed by the empirical analysis of a sample of small and medium Italian manufacturing firms.

The main message of this paper is that the effect of uncertainty on entrepreneurial innovation is quantitatively significant. The estimation results imply that if the cross sectional volatility of profits increases from 0.078 (the median value) to 0.097 (the 90% percentile), the probability to do R&D to introduce new products for an entrepreneurial firm decreases from 14.7% to 11.8%. If one believes that the level of uncertainty faced by firms varies significantly in the business cycle, and that entrepreneurial innovation may be a source of growth and positive externalities for the economy, then this finding implies that the effect of entrepreneurial risk on innovation may be an important factor for both business cycle fluctuations and growth.

The second message of the paper relates to the previous literature on entrepreneurial households. Many authors have been focusing on borrowing constraints as an important factor that influences entry in the entrepreneurial sector, the wealth distribution and capital accumulation in the economy (see for example Caggetti and De Nardi, 2006). In contrast, this paper shows that undiversifiable risk is also important to understand the investment decisions of entrepreneurial firms, even in the absence of other market imperfections.

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VI Appendix 1

The dynamic investment problem of the entrepreneurial firm is solved with a numerical method. First, I discretise the state space of the state variables w_t and A_t in grids of 600 points and 10 points, respectively. Then I formulate an initial guess of

$E_t\left[V\left(S_{t+1}, w_{t+1}, A_{t+1}\right)\right]$, and I use it to compute the value functions $V_t^{up}\left(S_t, w_t, A_t\right)$ and $V_t^{noup}\left(S_t, w_t, A_t\right)$. Then I compare the two function and determine the new guess of $V\left(S_t, w_t, A_t\right)$. I iterate again this process until the value function converges. The final outcome is the optimal policy functions of consumption $c_t\left(S_t, w_t, A_t\right)$, capital $k_{t+1}\left(S_t, w_t, A_t\right)$, borrowing $b_{t+1}\left(S_t, w_t, A_t\right)$ and innovation decision $I_t\left(S_t, w_t, A_t\right)$. The dynamic investment problem of the risk neutral firm is solved using a similar procedure.

Figure 1: Cross sectional dispersion of the profits/sales ratio (3 digit manufacturing sectors) as a function of R&D composition.

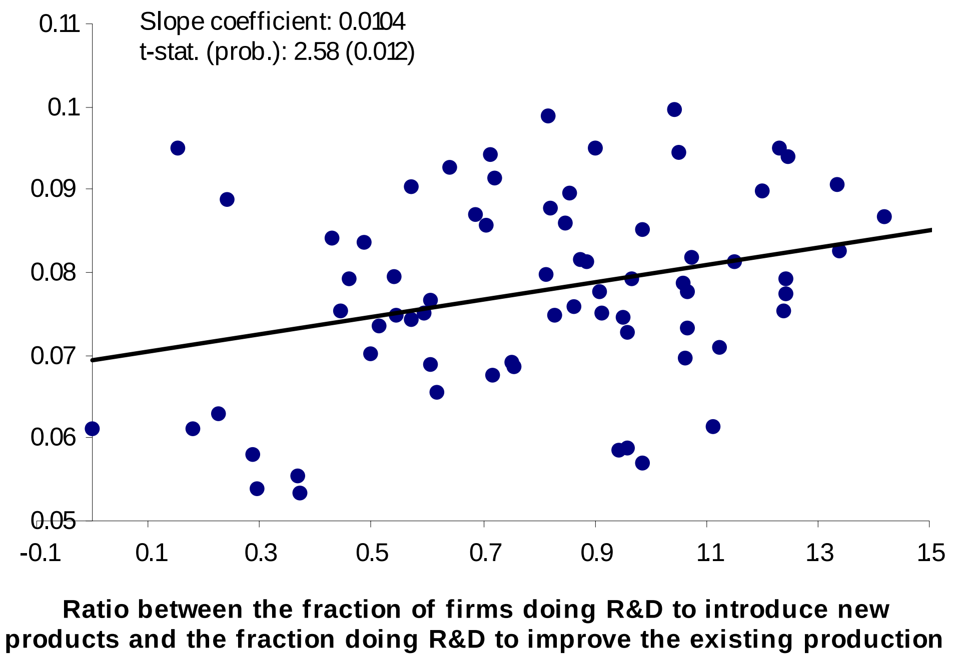

Figure 2: Cross sectional dispersion of the profits/sales ratio (3 digit manufacturing sectors) as a function of fixed investment composition.

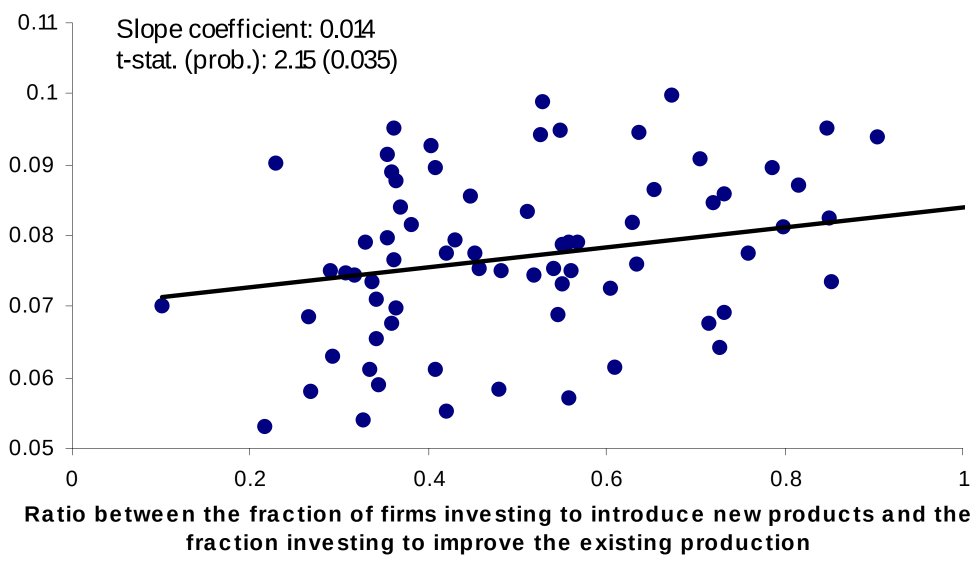

Figure 3: Frequency of innovation conditional on exogenous uncertainty in the simulated economy.

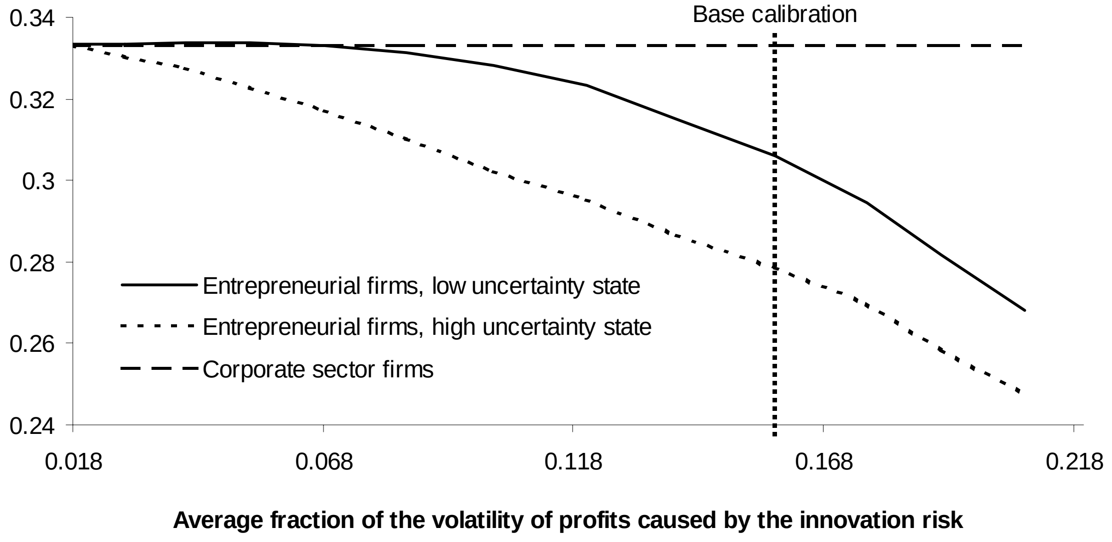

Figure 4: Percentage increase in entrepreneurial innovation in the low uncertainty state relative to the high uncertainty state.

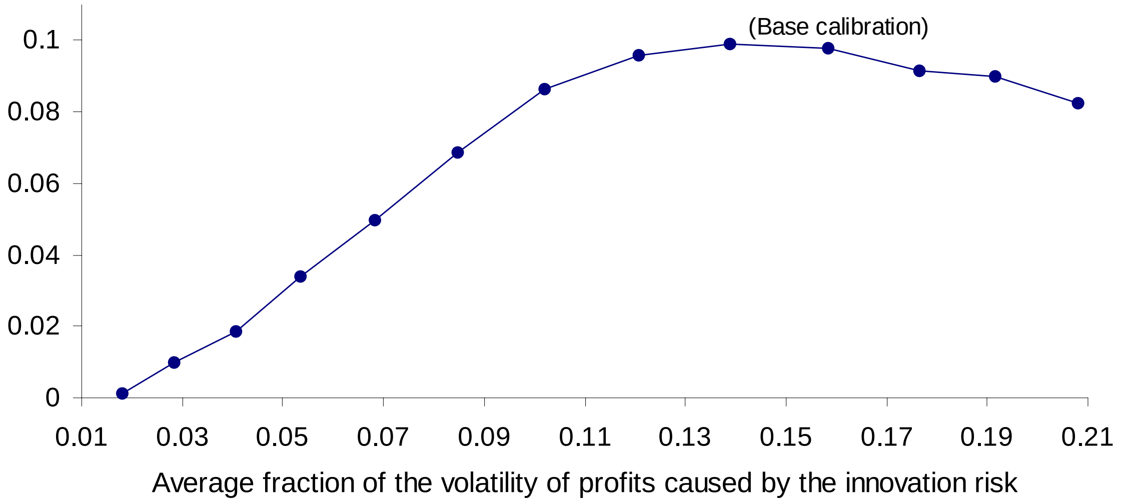

Figure 5: Percentage increase in entrepreneurial innovation in the low uncertainty state relative to the high uncertainty state, for groups of firms with different degrees of diversification.

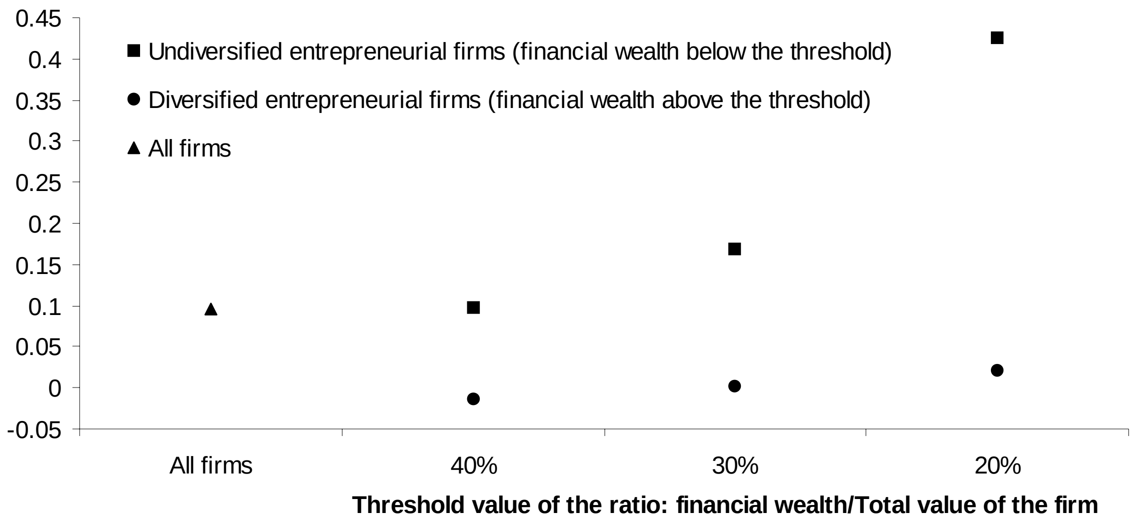

Figure 6: Entrepreneurial innovation in simulated economies with different degrees of financing constraints.

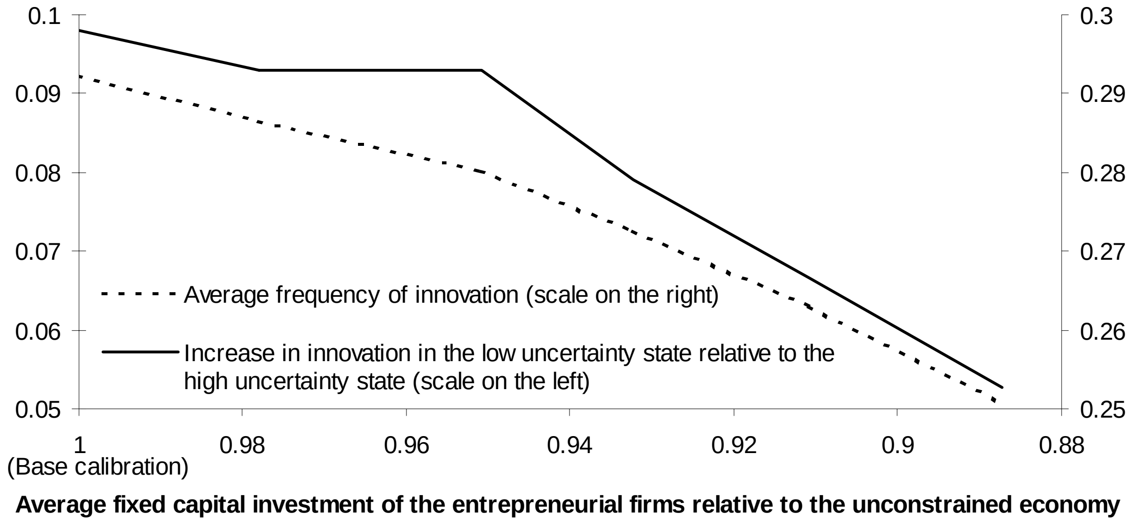

Figure 7: Percentage increase in entrepreneurial innovation in the low uncertainty state relative to the high uncertainty state, simulated economies with a multiplicative shock in the production function.

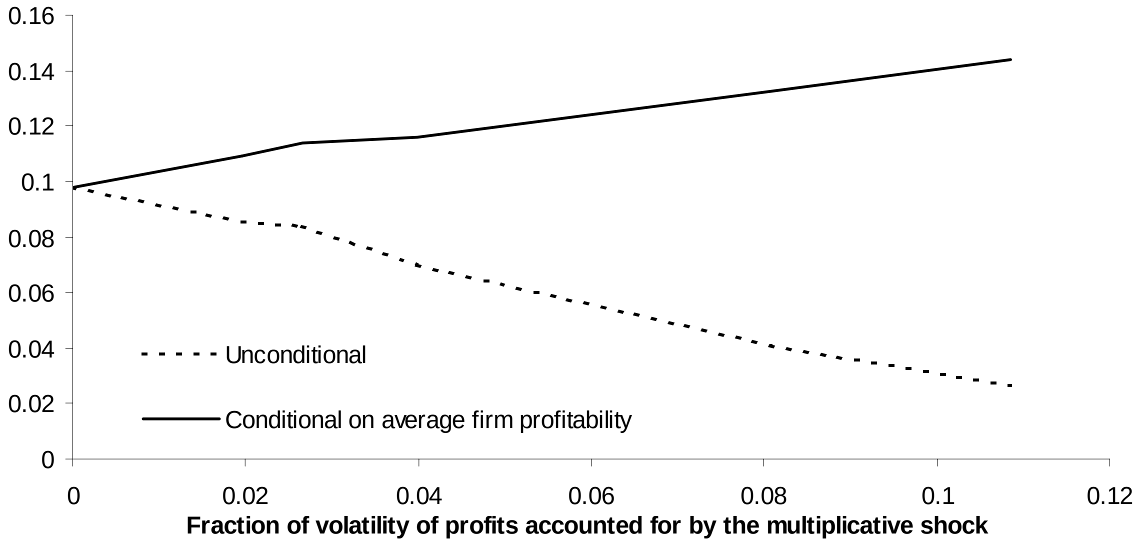

Figure 8: Percentage increase in entrepreneurial innovation in the low uncertainty state relative to the high uncertainty state: sensitivity to the degree of constant relative risk aversion.

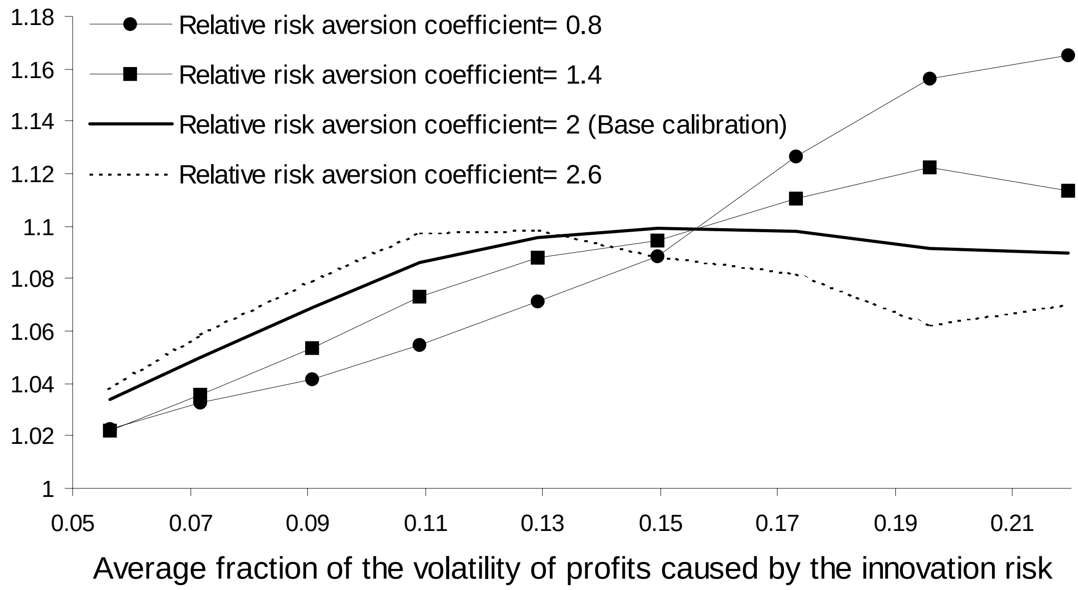

Figure 9: Frequency of innovation conditional on the uncertainty state, economies with low degree or risk aversion ($\eta = 0.8$).

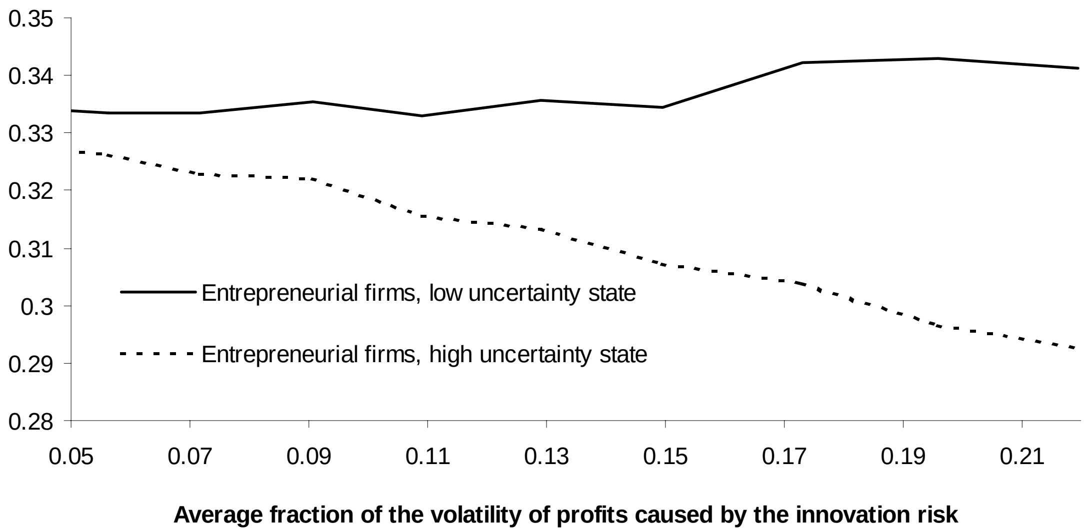

Figure 10: Percentage increase in entrepreneurial innovation in the low uncertainty state relative to the high uncertainty state. Sensitivity to the difference in volatility of profits across states.

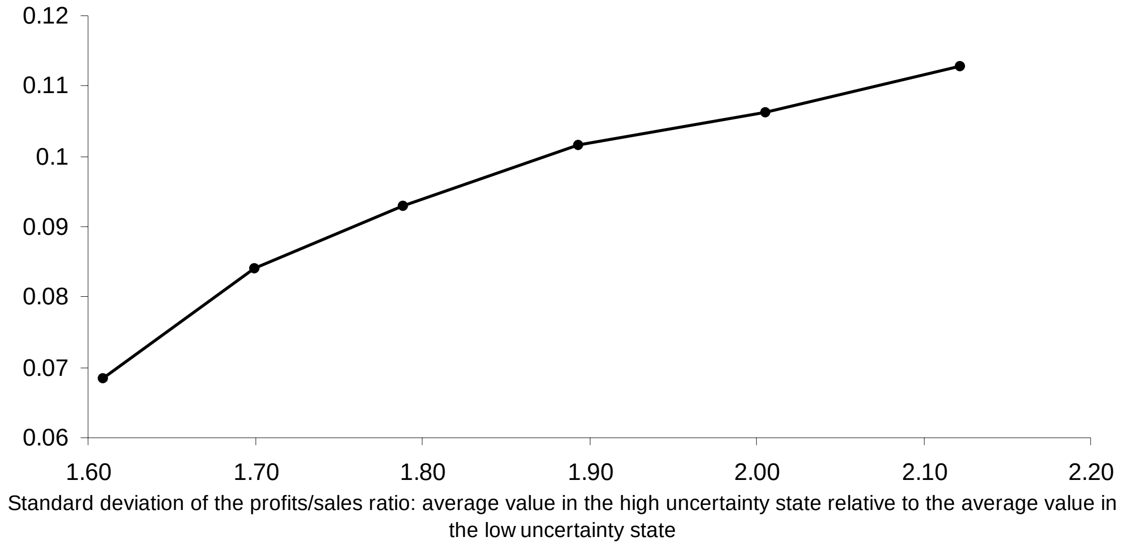

Figure 11: Percentage increase in entrepreneurial innovation in the low uncertainty state relative to the high uncertainty state. Sensitivity to the persistency of the exogenous profits shock.

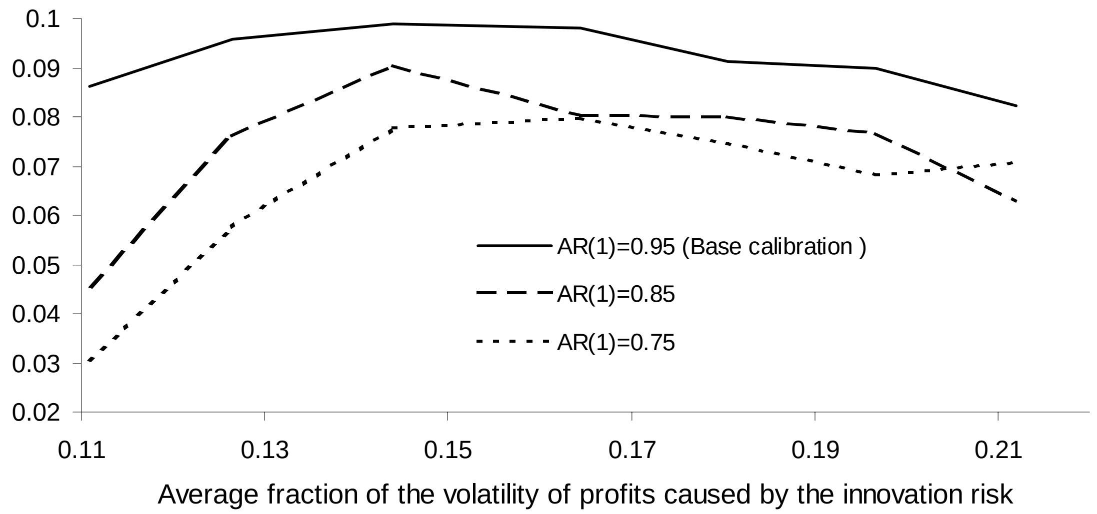

Figure 12: Percentage increase in entrepreneurial innovation in the low uncertainty state relative to the high uncertainty state. Sensitivity to the persistency of the exogenous states.

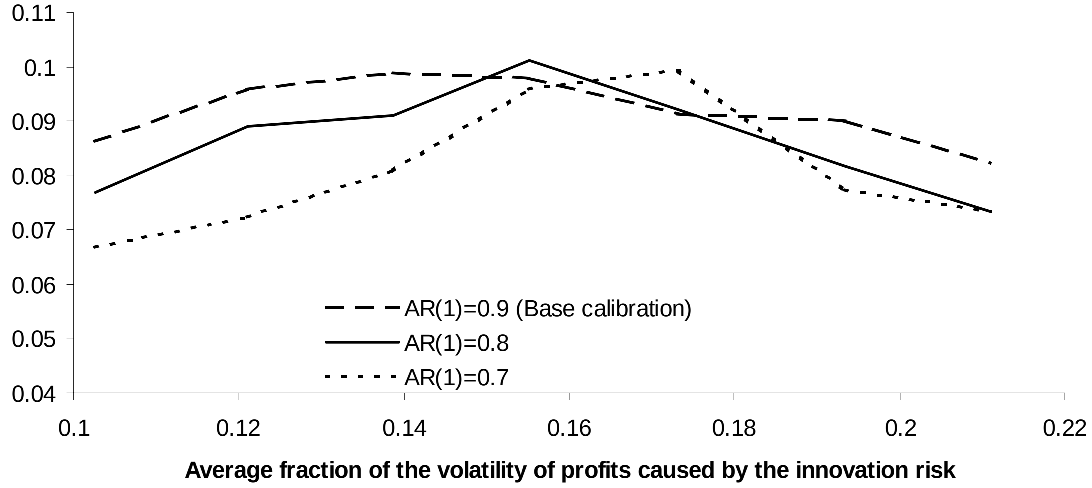

Table I: Calibrated parameters

	Value	Matched moment	Data	Simulations
α	0.865	Average(net income/sales)*	0.136	0.135
δ	0.145	Average depreciation of capital	14.5%	14.5%
$\sigma_\varepsilon(L)$	0.83	st. dev (net income/sales)*	0.09	0.10
β^d	0.9804	real interest rate	2%	2%
β^e	0.952	% of private equity from entrepreneurial households with concentration $\geq$ 75%	48%	48%
F^{***}	0.7%	Average frequency of innovation**	31%	31%
ξ^{***}	22.8%	Difference in avg. frequency of innovation between manager led firms versus entrepreneurial firms	5%	4%
δ_A	0.0013	Fixed investment related to innovation as a % of sales	10%	11%
		Non calibrated parameters (sensitivity analysis)		
$\sigma_\varepsilon(H) - \sigma_\varepsilon(L)$	1.53	from 1.15 to 1.80		
ρ_θ	0.95	from 0.75 to 0.95		
ρ_s	0.9	from 0.7 to 0.9		
η	2	from 0.8 to 2.6		

*Statistics computed using the 1989, 1992, 1995 and 1998 Surveys of Consumers Finances, where only entrepreneurs that own and manage a manufacturing company are included, and also excluding as outliers the observations greater than one in absolute value. **Fraction of entrepreneurial firms that declare to perform R&D in order to introduce new products. ***Measured as a fraction of the net present value of the total profits expected from the innovation.

Table II: Summary statistics

	Entrepreneurial firms	Other firms
Mean n. employees	45	183
Median n. employees	25	41
Mean age	23	27
Median age	19	21
Mean operative income / total assets	7.4%	6.8%
% of exporting firms	66%	71%
Number of firm-survey observations	4505	9084

Table III: Share of firms that invest in innovation

	Entrepreneurial firms	Other firms
	r&d	
No *r&d*	69%	59%
$r\&d\_innov = 1$	15%	20%
$r\&d\_t.a = 1$	16%	21%
	New fixed investment	
No new fixed inv.	15%	9%
fix_innov	26%	31%
$fix\_t.a.$	59%	60%

Table IV: The relationship between risk and innovation.

Regression: $y_{i,p} = \alpha_0 + \alpha_1 sdroa\_1_{s,p} + \alpha_2 export_{i,p} + \alpha_3 supply_{i,p} + \alpha_4 constrained_{i,p} +$
$+ \alpha_5 avgroa\_1_{s,p} + \alpha_6 \ln(size_{i,p}) + \alpha_7 age_{i,p} + \alpha_8 age^2_{i,p} + d^{2digits}_{i,p} + d^{survey}_{i,p} + u_{i,p}$

	$y_{i,p} = r\&d\_inn_{i,p}$		$y_{i,p} = r\&d\_t.a_{i,p}$		$y_{i,p} = fix\_inn_{i,p}$		$y_{i,p} = fix\_t.a._{i,p}$	
	entr.	other	entr.	other	entr.	other	entr.	other
α_1	-5.04**	-1.87	3.31	1.16	-4.62**	-1.01	2.16	-0.22
	(-2.3)	(-1.3)	(1.5)	(0.9)	(-2.5)	(-0.8)	(1.2)	(-0.2)
α_2	0.37***	0.52***	.26***	0.32***	0.19***	0.24***	-0.07	-0.11***
	(5.4)	(10.4)	(4.4)	(7.6)	(3.4)	(6.1)	(-1.3)	(-3.0)
α_3	-.24***	-0.15***	0.07	-0.03	-0.10**	-0.15	0.14***	0.17***
	(-4.0)	(-4.0)	(1.3)	(-0.8)	(-2.0)	(-4.4)	(2.9)	(5.5)
α_4	0.06	0.18***	0.042	0.013	0.09	0.18***	-0.04	-0.12***
	(0.9)	(3.6)	(0.6)	(0.3)	(1.5)	(4.0)	(-1.5)	(-2.6)
α_5	-1.62	-0.78	-2.98	-0.09	4.36**	2.40*	-2.13	-0.04
	(-0.7)	(-0.5)	(-1.4)	(-0.1)	(2.2)	(1.8)	(-1.2)	(-0.1)
α_6	.25***	0.24***	.18***	0.13***	0.27***	0.18***	-0.05	-0.05***
	(7.0)	(15.4)	(5.4)	(8.8)	(8.4)	(12.8)	(-1.5)	(-3.3)
α_7	0.003	0.006*	-0.002	-0.002	0.007**	0.006**	-0.01***	-0.004*
	(0.8)	(1.7)	(-0.5)	(-1.0)	(2.0)	(2.2)	(-2.8)	(-1.8)
α_8	-.0001	-.0001***	.0004	.0001***	-.0001**	-.0001***	.0001***	.00001***
	(-1.1)	(-3.2)	(0.6)	(3.2)	(-2.5)	(-3.7)	(3.2)	(3.1)
n.obs	3627	7703	3631	7708	3638	7710	3636	7710
Pseudo R^2	0.11	0.13	0.04	0.06	0.06	0.05	0.04	0.03

All regressions are estimated with a maximum likelihood Probit estimator. I use a Huber/White/sandwich estimator of the variance to correct for heteroskedasticity. Standard errors are clustered at the 3 digit sector level. *Significant at the 90% confidence level; **significant at the 95% confidence level; *** significant at the 99% confidence level. $sdroa\_1_{i,s}$: standard deviation of the cross section of the gross income/assets ratio for the firms in the three digit sector s in the most recent year of each survey. $export_{i,p}$: equal to 1 (69% of total) if firm i exports part of its production outside Italy, and is equal to 0 otherwise. $supply_{i,p}$: equal to 1 (44%) if firm i produces 100% of its output based on the order placed by downstream firms. and equal to zero otherwise. $constrained_{i,p}$: equal to one if the firm declares financing constraints (14%), and zero otherwise. $avgroa\_1_{i,s}$: cross sectional mean of the return on assets for sector s in the most recent year of the survey. $size_{i,p}$: number of employees of firm i. $age_{i,p}$: age of the firm (relative to the year of the survey) in years. $d^{2digits}_{i,p}$ is a series of two digit sector dummy variables, and $d^{survey}_{i,p}$ is a series of dummy variables that are equal to 1 if firm i is surveyed in Survey p, and equal to zero otherwise.

Table V: The relationship between risk and innovation. Financially constrained firms excluded.

Regression: $y_{i,p} = \alpha_0 + \alpha_1 sdroa\_1_{s,p} + \alpha_2 export_{i,p} + \alpha_3 supply_{i,p} +$
$+\alpha_5 avgroa\_1_{s,p} + \alpha_6 \ln(size_{i,p}) + \alpha_7 age_{i,p} + \alpha_8 age^2_{i,p} + d^{2digits}_{i,p} + d^{survey}_{i,p} + u_{i,p}$

	$y_{i,p} = r\&d\_inn_{i,p}$		$y_{i,p} = r\&d\_t.a_{i,p}$		$y_{i,p} = fix\_inn_{i,p}$		$y_{i,p} = fix\_t.a._{i,p}$	
	entr.	other	entr.	other	entr.	other	entr.	other
α_1	-7.36***	-1.77	4.44**	0.78	-5.21**	-0.94	2.89	-0.19
	(-3.0)	(-1.1)	(1.9)	(0.6)	(2.5)	(-0.7)	(1.5)	(-0.2)
α_2	0.40***	0.51***	0.30***	0.35***	0.16***	0.25***	-0.05	-0.13***
	(5.2)	(9.3)	(4.4)	(7.5)	(2.6)	(-2.9)	(-1.0)	(-3.2)
α_3	-0.20***	-0.16***	0.08	-.04	-0.10*	-0.13***	0.15***	0.16***
	(-3.2)	(-3.7)	(1.4)	(-1.1)	(-1.8)	(-3.6)	(2.8)	(4.6)
α_5	-0.49	-2.01	-4.16*	0.80	5.56***	1.39	-2.75	0.80
	(-0.2)	(-1.2)	(-1.8)	(0.5)	(2.6)	(1.0)	(-1.4)	(0.6)
α_6	0.25***	0.25***	0.19***	0.13***	0.27***	0.18***	-0.04	-0.04***
	(6.5)	(14.6)	(5.2)	(8.2)	(7.9)	(12.0)	(-1.1)	(-2.7)
α_7	0.001	0.006	-.0002	-0.002	0.006*	0.004	-0.009**	-0.002
	(0.2)	(1.6)	(-0.1)	(-0.8)	(1.6)	(1.4)	(-2.4)	(-1.0)
α_8	-.00003	-.0001***	.00003	.0001***	-.0001**	-.0001***	.0001***	.0001**
	(-0.6)	(-3.0)	(0.7)	(2.8)	(-2.1)	(-2.9)	(2.6)	(2.4)
n.obs	3014	6698	3006	6703	3024	6705	3022	6705
Pseudo R^2	0.12	0.14	0.04	0.06	0.06	0.05	0.04	0.03
Coefficient of $sdroa\_1_s$ estimated for the group of financially constrained firms only								
α_1	4.93	-1.36	-1.74	4.66	-2.26	-0.23	-3.06	-0.81
	(1.0)	(-0.3)	(-0.4)	(1.3)	(-0.5)	(-0.1)	(-0.7)	(-0.2)
n.obs	599	1002	613	997	590	1002	590	1002
Pseudo R^2	0.12	0.13	0.13	0.07	0.07	0.10	0.05	0.06

All regressions are estimated with a maximum likelihood Probit estimator. I use a Huber/White/sandwich estimator of the variance to correct for heteroskedasticity. Standard errors are clustered at the 3 digit sector level. *Significant at the 90% confidence level; **significant at the 95% confidence level; *** significant at the 99% confidence level. $sdroa\_1_{i,s}$: standard deviation of the cross section of the gross income/assets ratio for the firms in the three digit sector s in the most recent year of each survey. $export_{i,p}$: equal to 1 (69% of total) if firm i exports part of its production outside Italy, and is equal to 0 otherwise. $supply_{i,p}$: equal to 1 (44%) if firm i produces 100% of its output based on the order placed by downstream firms. and equal to zero otherwise. $constrained_{i,p}$: equal to one if the firm declares financing constraints (14%), and zero otherwise. $avgroa\_1_{i,s}$: cross sectional mean of the return on assets for sector s in the most recent year of the survey. $size_{i,p}$: number of employees of firm i. $age_{i,p}$: age of the firm (relative to the year of the survey) in years. $d^{2digits}_{i,p}$ is a series of two digit sector dummy variables, and $d^{survey}_{i,p}$ is a series of dummy variables that are equal to 1 if firm i is surveyed in Survey p, and equal to zero otherwise.

Table VI: The relationship between risk and innovation. Entrepreneurial firms selected according to the degree of diversification.

$$y_{i,p} = \alpha_0 + \alpha_1 sdroa\_1_{s,p} + \alpha_2 export_{i,p} + \alpha_3 supply_{i,p} + \alpha_4 constrained_{i,p} + \\ + \alpha_5 avgroa\_1_{s,p} + \alpha_6 \ln(size_{i,p}) + \alpha_7 age_{i,p} + \alpha_8 age^2_{i,p} + d^{2digits}_{i,p} + d^{survey}_{i,p} + u_{i,p}$$

	$y_{i,p} = r\&d\_inn_{i,p}$		$y_{i,p} = fix\_inn_{i,p}$	
	$divers_{i,p}$ ≤ 0.5	$divers_{i,p}$ > 0.5	$divers_{i,p}$ ≤ 0.5	$divers_{i,p}$ > 0.5
α_1	-7.88***	-1.77	-5.10**	-3.97
	(-2.7)	(-0.5)	(-2.1)	(-1.3)
α_2	0.40***	0.33***	0.26***	0.10
	(4.3)	(3.2)	(3.5)	(1.2)
α_3	-0.25***	-0.22**	-0.12*	-0.08
	(-3.3)	(-2.3)	(-1.8)	(-1.0)
α_4	0.16*	-0.14	0.07	0.12
	(1.7)	(-1.1)	(0.9)	(1.2)
α_5	-0.39	-2.55	2.88	6.88**
	(-0.14)	(-0.7)	(1.1)	(2.2)
α_6	0.24***	0.23***	0.22***	0.30***
	(5.3)	(3.6)	(5.3)	(5.4)
α_7	.002	.003	.01**	.002
	(0.3)	(0.6)	(2.2)	(0.4)
α_8	-.00004	-.00005	-.0001**	-.00006
	(-0.7)	(-0.8)	(-2.4)	(-1.1)
n.obs	1958	1669	1954	1679
Pseudo R^2	0.11	0.12	0.06	0.05

All regressions are estimated with a maximum likelihood Probit estimator. I use a Huber/White/sandwich estimator of the variance to correct for heteroskedasticity. Standard errors are clustered at the 3 digit sector level. *Significant at the 90% confidence level; **significant at the 95% confidence level; *** significant at the 99% confidence level. $divers_{i,p}$ is the average of the ratio between the net financial assets and total assets for firm i in survey p. $sdroa\_1_{i,s}$: standard deviation of the cross section of the gross income/assets ratio for the firms in the three digit sector s in the most recent year of each survey. $export_{i,p}$: equal to 1 (69% of total) if firm i exports part of its production outside Italy, and is equal to 0 otherwise. $supply_{i,p}$: equal to 1 (44%) if firm i produces 100% of its output based on the order placed by downstream firms. and equal to zero otherwise. $constrained_{i,p}$: equal to one if the firm declares financing constraints (14%), and zero otherwise. $avgroa\_1_{i,s}$: cross sectional mean of the return on assets for sector s in the most recent year of the survey. $size_{i,p}$: number of employees of firm i. $age_{i,p}$: age of the firm (relative to the year of the survey) in years. $d^{2digits}_{i,p}$ is a series of two digit sector dummy variables, and $d^{survey}_{i,p}$ is a series of dummy variables that are equal to 1 if firm i is surveyed in Survey p, and equal to zero otherwise.

Table VII: The relationship between risk and innovation, entrepreneurial firms selected according to the degree of diversification. Financially constrained firms excluded

Regression: $y_{i,p} = \alpha_0 + \alpha_1 sdroa\_1_{s,p} + \alpha_2 export_{i,p} + \alpha_3 supply_{i,p} +$
$+\alpha_5 avgroa\_1_{s,p} + \alpha_6 \ln(size_{i,p}) + \alpha_7 age_{i,p} + \alpha_8 age^2_{i,p} + d^{2digits}_{i,p} + d^{survey}_{i,p} + u_{i,p}$

	$y_{i,p} = r\&d\_inn_{i,p}$		$y_{i,p} = fix\_inn_{i,p}$	
	$divers_{i,p} \leq 0.5$	$divers_{i,p} > 0.5$	$divers_{i,p} \leq 0.5$	$divers_{i,p} > 0.5$
α_1	-12.6***	-1.98	-6.32**	-3.78
	(-3.8)	(-0.6)	(-2.3)	(-1.2)
α_2	0.47***	0.33***	0.27***	0.03
	(4.3)	(3.0)	(3.2)	(0.4)
α_3	-0.24***	-0.18*	-0.09	-0.11
	(-2.8)	(-1.8)	(-1.3)	(-1.3)
α_5	2.15	-3.09	4.35	7.90**
	(0.7)	(-0.9)	(1.5)	(2.4)
α_6	0.25***	0.22***	0.22***	0.29
	(4.9)	(3.3)	(4.8)	(4.9)
α_7	-.0008	.002	0.01*	.002
	(-0.1)	(0.3)	(1.7)	(0.4)
α_8	-.00002	-.00003	-.0001*	-.00005
	(-0.27)	(-0.5)	(-1.9)	(-1.0)
n.obs	1581	1397	1578	1439
Pseudo R^2	0.13	0.12	0.06	0.06

All regressions are estimated with a maximum likelihood Probit estimator. I use a Huber/White/sandwich estimator of the variance to correct for heteroskedasticity. Standard errors are clustered at the 3 digit sector level. *Significant at the 90% confidence level; **significant at the 95% confidence level; *** significant at the 99% confidence level. $divers_{i,p}$ is the average of the ratio between the net financial assets and total assets for firm i in survey p. $sdroa\_1_{i,s}$: standard deviation of the cross section of the gross income/assets ratio for the firms in the three digit sector s in the most recent year of each survey. $export_{i,p}$: equal to 1 (69% of total) if firm i exports part of its production outside Italy, and is equal to 0 otherwise. $supply_{i,p}$: equal to 1 (44%) if firm i produces 100% of its output based on the order placed by downstream firms. and equal to zero otherwise. $constrained_{i,p}$: equal to one if the firm declares financing constraints (14%), and zero otherwise. $avgroa\_1_{i,s}$: cross sectional mean of the return on assets for sector s in the most recent year of the survey. $size_{i,p}$: number of employees of firm i. $age_{i,p}$: age of the firm (relative to the year of the survey) in years. $d^{2digits}_{i,p}$ is a series of two digit sector dummy variables, and $d^{survey}_{i,p}$ is a series of dummy variables that are equal to 1 if firm i is surveyed in Survey p, and equal to zero otherwise.

Table VIII: The relationship between risk and innovation: equation selection

Regression: $y_{i,p} = \alpha_0 + \alpha_1 sdroa\_1_{s,p} + \alpha_2 export_{i,p} + \alpha_3 supply_{i,p} +$
$+\alpha_5 avgroa\_1_{s,p} + \alpha_6 \ln(size_{i,p}) + \alpha_7 age_{i,p} + \alpha_8 age^2_{i,p} + d^{2digits}_{i,p} + d^{survey}_{i,p} + u_{i,p}$

	$y_{i,p} = r\&d\_inn_{i,p}$ (entrepreneurial firms)					$y_{i,p} = fix\_inn_{i,p}$ (entrepreneurial firms)				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
α_1	5.01***	-7.58***	-7.62***	-7.38***	-7.36***	2.79*	-3.21*	-3.19*	-5.18**	-5.21**
	(3.0)	(-3.4)	(-3.4)	(-3.1)	(-3.0)	(1.8)	(-1.7)	(-1.7)	(-2.5)	(2.5)
α_2			0.49***	0.49***	0.40***			0.27***	0.26***	0.16***
			(6.5)	(6.6)	(5.2)			(4.6)	(4.4)	(2.6)
α_3			-0.22***	-0.22***	-0.20***			-0.11**	-0.12**	-0.10*
			(-3.4)	(-3.4)	(-3.2)			(-2.0)	(-2.1)	(-1.8)
α_5				-0.62	-0.49				4.99**	5.56***
				(-0.3)	(-0.2)				(2.4)	(2.6)
α_6					0.25***					0.27***
					(6.5)					(7.9)
α_7					0.001					0.006*
					(0.2)					(1.6)
α_8					-.00003					-.0001**
					(-0.6)					(-2.1)
$d^{2digits}_{i,p}$ and $d^{survey}_{i,p}$	no	yes	yes	yes	yes	no	yes	yes	yes	yes
n.obs	3063	3023	3022	3022	3014	3063	3023	3033	3033	3024
Pseudo R^2	0.003	0.08	0.10	0.10	0.12	0.001	0.03	0.03	0.04	0.06
	$y_{i,p} = r\&d\_inn_{i,p}$ (non entrepreneurial firms)					$y_{i,p} = fix\_inn_{i,p}$ (non entrepreneurial firms)				
α_1	6.12***	-0.90	-1.69	-0.92	-1.77	4.06***	0.25	-0.07	-0.48	-0.95
	(5.9)	(-0.7)	(-1.2)	(-0.6)	(-1.1)	(4.2)	(0.2)	(-0.1)	(-0.4)	(-0.7)

All regressions are estimated with a maximum likelihood Probit estimator. I use a Huber/White/sandwich estimator of the variance to correct for heteroskedasticity. Standard errors are clustered at the 3 digit sector level. *Significant at the 90% confidence level; **significant at the 95% confidence level; *** significant at the 99% confidence level. $sdroa\_1_{i,s}$: standard deviation of the cross section of the gross income/assets ratio for the firms in the three digit sector s in the most recent year of each survey. $export_{i,p}$: equal to 1 (69% of total) if firm i exports part of its production outside Italy, and is equal to 0 otherwise. $supply_{i,p}$: equal to 1 (44%) if firm i produces 100% of its output based on the order placed by downstream firms. and equal to zero otherwise. $constrained_{i,p}$: equal to one if the firm declares financing constraints (14%), and zero otherwise. $avgroa\_1_{i,s}$: cross sectional mean of the return on assets for sector s in the most recent year of the survey. $size_{i,p}$: number of employees of firm i. $age_{i,p}$: age of the firm (relative to the year of the survey) in years. $d^{2digits}_{i,p}$ is a series of two digit sector dummy variables, and $d^{survey}_{i,p}$ is a series of dummy variables that are equal to 1 if firm i is surveyed in Survey p, and equal to zero otherwise.

Table IX: The relationship between risk and innovation. Fixed effects at the three digit sector level included

Regression: $y_{i,p} = \alpha_0 + \alpha_1 sdroa\_1_{s,p} + \alpha_2 export_{s,p} + \alpha_3 supply_{s,p} + \alpha_4 constrained_{s,p} + \alpha_5 avgroa\_1_{s,p} + \alpha_6 \ln(size_{s,p}) + \alpha_7 age_{s,p} + \alpha_8 age^2_{s,p} + d^{3digits}_s + d^{survey}_p + u_{s,p}$

	$y_{i,p} = r\&d\_inn_{i,p}$		$y_{i,p} = r\&d\_t.a_{i,p}$		$y_{i,p} = fix\_inn_{i,p}$		$y_{i,p} = fix\_t.a._{i,p}$	
	entr.	other	entr.	other	entr.	other	entr.	other
α_1	-5.19**	-1.42	5.04	1.07	-5.13**	-0.26	2.69	-0.19
	(-2.1)	(-0.9)	(1.5)	(0.6)	(-2.3)	(-0.1)	(1.4)	(-0.1)
α_2	0.71	0.74	0.51	0.52**	0.26	0.35	0.15	0.03
	(1.5)	(2.5)	(1.2)	(2.0)	(0.6)	(1.4)	(0.4)	(0.1)
α_3	-0.45	0.20	-0.35	0.12	0.09	0.25	0.27	-0.33
	(-0.9)	(0.7)	(-1.0)	(0.5)	(0.2)	(1.0)	(0.8)	(-1.3)
α_4	-1.04	0.40	0.85	-0.50	0.37	0.63	-0.07	-0.38
	(-1.3)	(0.8)	(1.0)	(-1.1)	(0.4)	(1.3)	(-0.1)	(-0.9)
α_5	1.00	-0.67	-2.92	-1.60	3.74	3.86**	-0.64	-1.86
	(0.3)	(-0.4)	(-1.1)	(-0.9)	(1.3)	(2.1)	(-0.3)	(-1.2)
α_6	0.06	-0.03	0.12	0.21	0.40**	0.08	-0.26	-0.15
	(0.6)	(-0.2)	(0.6)	(1.4)	(2.2)	(0.7)	(-1.4)	(-1.3)
α_7	0.025	0.063**	-0.12*	-0.09***	0.12**	0.03	-0.17	-0.02
	(0.5)	(2.1)	(-1.7)	(-3.5)	(2.3)	(1.1)	(-3.2)	(-0.6)
α_8	-.0001	-.001**	.002	.001***	-.002	-.0005	.003	.0003
	(-0.1)	(-2.3)	(1.7)	(4.0)	(-2.0)	(-1.2)	(3.1)	(0.7)
n.obs	3507	7703	3601	7753	3591	7759	3620	7759
Pseudo R^2	0.095	0.080	0.048	0.040	0.044	0.033	0.047	0.03
Estimate of α_1 for firms selected according to diversification and financing constraints								
$divers_{i,p} \leq 0.5$	-7.06**	-2.10	3.73	1.96	-4.08*	-2.18	-1.90	0.39
	(-2.1)	(-1.2)	(1.1)	(0.9)	(-1.7)	(-1.0)	(-0.8)	(0.25)
$divers_{i,p} \leq 0.5$ and no constrained	-14.01***	-4.09**	3.06	2.81	-5.12	-3.24	-1.05	1.41
	(-3.2)	(-2.2)	(1.0)	(1.1)	(-1.5)	(-1.4)	(-0.3)	(0.8)

All regressions are estimated with a maximum likelihood Probit estimator. I use a Huber/White/sandwich estimator of the variance to correct for heteroskedasticity. Standard errors are clustered at the 3 digit sector level. *Significant at the 90% confidence level; **significant at the 95% confidence level; *** significant at the 99% confidence level. $divers_{i,p}$ is the average of the ratio between the net financial assets and total assets for firm i in survey p. $sdroa\_1_{i,s}$: standard deviation of the cross section of the gross income/assets ratio for the firms in the three digit sector s in the most recent year of each survey. $export_{i,p}$: equal to 1 (69% of total) if firm i exports part of its production outside Italy, and is equal to 0 otherwise. $supply_{i,p}$: equal to 1 (44%) if firm i produces 100% of its output based on the order placed by downstream firms. and equal to zero otherwise. $constrained_{i,p}$: equal to one if the firm declares financing constraints (14%), and zero otherwise. $avgroa\_1_{i,s}$: cross sectional mean of the return on assets for sector s in the most recent year of the survey. $size_{i,p}$: number of employees of firm i. $age_{i,p}$: age of the firm (relative to the year of the survey) in years. $d^{2digits}_{i,p}$ is a series of two digit sector dummy variables, and $d^{survey}_{i,p}$ is a series of dummy variables that are equal to 1 if firm i is surveyed in Survey p, and equal to zero otherwise.

Table X: The relationship between risk and innovation. Fixed effects at the three digits level and instrumental variable estimation. Estimate of α_1 for firms selected according to diversification and financing constraints.

Regression: $y_{i,p} = \alpha_0 + \alpha_1 sdroa\_1_{s,p} + \alpha_2 export_{s,p} + \alpha_3 supply_{s,p} + \alpha_4 constrained_{s,p} + \alpha_5 avgroa\_1_{s,p} + \alpha_6 \ln(size_{s,p}) + \alpha_7 age_{s,p} + \alpha_8 age^2_{s,p} + d_s^{3digits} + d_p^{survey} + u_{s,p}$								
	$y_{i,p} = r\&d\_inn_{i,p}$		$y_{i,p} = r\&d\_t.a_{i,p}$		$y_{i,p} = fix\_inn_{i,p}$		$y_{i,p} = fix\_t.a._{i,p}$	
Estimate of α_1 from an instrumental variable probit estimation								
	entrep.	other	entrep.	other	entrep.	other	entrep.	other
All firms	-17.89	1.52	0.88	-11.67	-17.25	-1.83	11.40	4.81
	(-1.02)	(0.11)	(0.04)	(-0.7)	(-0.89)	(-0.1)	(0.6)	(0.32)
Overid. Test (P.value)	0.36	0.64	0.89	0.02	0.24	0.56	0.18	0.88
$divers_{i,p} \leq 0.5$	-17.61	-1.46	-2.32	4.02	-44.73*	-4.69	36.27	-2.65
	(-0.78)	(-0.1)	(-0.1)	(0.18)	(-1.71)	(-0.23)	(1.43)	(-0.11)
Overid. Test (P.value)	0.18	0.94	0.96	0.03	0.38	0.87	0.62	0.61
$divers_{i,p} \leq 0.5$	-38.67	7.18	19.92	0.81	-48.55*	-0.96	33.04	-12.49
constrained excluded	(-1.47)	(0.4)	(0.5)	(0.04)	(-1.76)	(-0.1)	(1.27)	(-0.53)
Overid. Test (P.value)	0.32	0.62	0.94	0.02	0.38	0.94	0.66	0.55

All regressions are estimated with an instrumental variable two-step probit estimator. The variable $sdroa\_1_{s,p}$ is instrumented using $sdroa\_1_{s,p-1}$, $sd\_output_{s,p-1}$ and $sdNA_{s,p}$. The The p-value of the Amemiya-Lee-Newey test of overidentifying restrictions is also reported. $divers_{i,p}$ is the average of the ratio between the net financial assets and total assets for firm i in survey p. *Significant at the 90% confidence level; **significant at the 95% confidence level; *** significant at the 90% confidence level. $sdroa\_1_{i,s}$: standard deviation of the cross section of the gross income/assets ratio for the firms in the three digit sector s in the most recent years of each survey. $export_{i,p}$: equal to 1 (69% of total) if firm i exports part of its production outside Italy, and is equal to 0 otherwise. $supply_{i,p}$: equal to 1 (44%) if firm i produces 100% of its output based on the order placed by downstream firms. and equal to zero otherwise. $constrained_{i,p}$: equal to one if the firm declares financing constraints (14%), and zero otherwise. $avgroa\_1_{i,s}$: cross sectional mean of the return on assets for sector s in the most recent year of the survey. $size_{i,p}$: number of employees of firm i. $age_{i,p}$: age of the firm (relative to the year of the survey) in years. $d_{i,p}^{3digits}$ is a series of three digit sector dummy variables, and $d_{i,p}^{survey}$ is a series of dummy variables that are equal to 1 if firm i is surveyed in Survey p, and equal to zero otherwise. Among the instruments, $sd\_output_{s,p-1}$ is the standard deviations of the trend deviations of an index of revenues for sector s during the last year of survey $p-1$. $sdNA_{s,p}$, is a measure of the cross sectional volatility of sales for North American firms in the manufacturing sector s during the three years of survey p.