Financing Constraints, Radical versus Incremental Innovation, and Aggregate productivity.*†

Andrea Caggese
UPF, CREI, and Barcelona GSE.
March 28, 2014

Abstract

Innovation and technology adoption are fundamental forces that shape firm dynamics and aggregate productivity growth. New firms bring new ideas and are better suited to introduce radical innovations that generate permanent improvements in aggregate productivity. However new firms are also more likely to suffer financing frictions, which distort their entry, investment and innovation decisions. This paper develops the model of an industry with heterogeneous firms, and studies the effect of financing frictions and bankruptcy risk on the tradeoff between radical innovations (risky but potentially able to generate huge improvements in productivity) and incremental innovations. The model shows that financing frictions have both direct and indirect effects on innovation. First, they directly negatively affect both types of innovation, for firms that cannot innovate because they lack internal funds to invest. Second, financing friction increase bankruptcy probability for young and financially fragile firms, and reduce entry and competition. Therefore firms that survive, and accumulate enough financial wealth to become financially unconstrained, operate in a less competitive environment, are profitable also at relatively low productivity levels, and are less willing to engage in risky innovation activity. Simulation results show that, for realistic parameter values, this indirect effect dominates on the direct effect and distorts innovation decisions against radical innovation and in favor of incremental innovation, increasing the lag between industry productivity and the technological frontier by up to 25%. I test these predictions and their implications for productivity growth on a sample of Italian manufacturing firms, for which I have direct survey information on both financing frictions an on the innovation decisions of firms, and I find that: i) the life cycle and innovation decisions of firms significantly differ across groups of sectors selected according to the intensity of financing frictions; ii) these different dynamics are consistent with the predictions of the model.

* A previous version of this paper was entitled: Financing Frictions, Firm Dynamics, and Innovation.
I thank the participants to the ESSIM conference in Turkey, May 2013, and to seminars at the Vienna Graduate School of Business and at UPF for useful comments. All errors are my own responsibility.
† Keywords: Firm Dynamics, Financing Frictions, Radical innovation, Incremental Innovation.
1 Introduction

Innovation and technology adoption are fundamental forces that shape firm dynamics and aggregate productivity growth. New firms bring new ideas and are better suited to introduce radical innovations that generate permanent improvements in aggregate productivity. However new firms are also more likely to face financing frictions, which may distort their investment and innovation decisions.

This paper develops the model of an industry with heterogeneous firms, and studies the effect of financing frictions and bankruptcy risk on the trade off between radical innovations (risky but potentially able to generate huge improvements in productivity) and incremental innovations. In the model firms are monopolistically competitive, they start production by paying a fixed cost, and their technology becomes gradually obsolete relative to the frontier technology if they do not invest in innovation. Moreover firms face financing frictions, and are hit by idiosyncratic revenue shocks that generate losses and may cause inefficient liquidation.

Firms can choose two types of innovation: if they invest in incremental innovation, they pay a fixed cost and have a high probability to improve their technology by one step and keep their position relative to the frontier. If they invest in radical innovation, they also pay a fixed cost but the outcome is much more risky. With a small probability they succeed and jump to the frontier technology. However if they fail their productivity and profitability is reduced below the level they had before innovating. The intuition for this assumption is that radical innovation, because of its disruptive nature, is not complementary to the existing tangible and intangible capital of the firm. Furthermore, such innovation is irreversible, and requires the firm to replace the capital and expertise which was used to operate the old technology. Therefore in case of failure the firm
cannot easily revert back to the old technology, and its efficiency will be lower with respect to the situation before innovating. This type of innovation is similar to the concept of radical innovation as it is defined in management studies, which implies radical changes to the firm’s structure, and implies that current assets are not suitable to implement the new product or production process. For example Utterback (1996) defines radical innovation as a "change that sweeps away much of a firm’s existing investment in technical skill and knowledge, designs, production technique, plant and equipment".

In the model, despite all firms have same access to both types of innovations, young firms are more likely to engage in radical innovation. Old firms are endogenously larger and more likely to do incremental innovation, because they are those who successfully introduced a radical innovation in the past, and having reached a high level of productivity choose incremental innovation to maintain it.

I calibrate the model and simulate several industries with different degrees of financing frictions. I shows that such frictions have both direct and indirect effects on innovation. First, they directly negatively affect both types of innovation, for firms that cannot innovate because they lack internal funds. Second, financing friction increase bankruptcy probability for young and financially fragile firms, and reduce entry and competition. Simulation results show that, for realistic parameter values, this indirect effect dominates on the direct effect and distorts innovation decisions against radical innovation and in favour of incremental innovation. This happens because financing frictions increase the chances that firms go bankrupt in the early stages of their life. Firms that survive this phase and accumulate enough financial wealth to become financially unconstrained, operate in a less competitive environment, are profitable also at relatively low productivity levels, and have a lower propensity to attempt a risky innovation process.
I test these predictions and their implications for productivity growth on a panel of
more than 10000 Italian manufacturing firms, for which I have direct survey information
on both financing frictions an on the innovation decisions of firms, and I find that: i) the
life cycle and innovation decisions of firms significantly differ across groups of sectors
selected according to the intensity of financing frictions; ii) these different dynamics
are consistent with the predictions of the model.

This paper is related to several strands of literature. Firms dynamics are modeled
in an monopolistic competition setting as in Melitz (2003), with financing frictions
causing inefficient default as in Caggese and Cunat (2013). Financing frictions affect
entry and exit and the reallocation of resources, as in Caggese and Cunat (2013), Buera,
Kaboski, and Shin (2011) and Midrigan and Xu (2014). However the model’s emphasis
is primarily on innovation as the driving force of productivity growth during the firm’s
life-cycle. Therefore the paper is related to Hsieh and Klenow (2012), who compare the
life cycle of manufacturing plants in the USA, Mexico and India. Hsieh and Klenow
(2012) show that the average size and total factor productivity of surviving plants
strongly increases along the plants life cycle in the USA, while such positive relation
is much more tenuous in Mexico and absent in India. They thus emphasize that to
understand aggregate productivity, the process of accumulation of knowledge at the
unit level is a key factor, as important as reallocation. This paper provides support to
the hypothesis that financing frictions are important in understanding these dynamics.

The paper is also related to the literature on competition, firm dynamics, and inno-
vation (Among others, see Klette and Kortum, 2004; Lentz and Mortensen, 2008;
Aghion et al., 2005), and to the recent literature on radical versus incremental inno-
vation (see for example Acemoglu, Akcigit and Celik, 2014). Finally, in emphasizing
the risk component of innovation, this paper is related to Dorastzelsky Jaumandreu
(2013), who notice that R&D increases the volatility of productivity growth, to Caggese
(2012), who estimate a negative effect of uncertainty on the riskier innovation decisions of entrepreneurial firms, and to Gabler and Poschke (2013), who also consider the importance of innovation risk for selection, reallocation, and productivity growth.

2 Model

I consider an industry model of firm dynamics and monopolistic competition, with profits uncertainty and financing frictions as in Caggese and Cunat (2013). The novelty of this model is to introduce endogenous innovation decisions and different innovation types.

In the model firms pay a fixed cost to enter the industry and a fixed cost to operate each period. They are subject to financing frictions, and they can increase their productivity by engaging in innovation activity which has an uncertain outcome. More formally, each firm in an industry produces a variety \( w \) of a consumption good. There is a continuum of varieties \( w \in \Omega \). Consumers preferences for the varieties in the industry are C.E.S. with elasticity \( \sigma > 1 \). The C.E.S. price index \( P_t \) is then equal to:

\[
P_t = \left[ \int_w p_t(w)^{1-\sigma} \right]^{\frac{1}{1-\sigma}}
\]

And the associated quantity of the aggregated differentiated good \( Q_t \) is:

\[
Q_t = \left[ \int_w q_t(w)^{\frac{\sigma-1}{\sigma}} \right]^{\frac{1}{\sigma-1}}
\]

where \( p_t(w) \) and \( q_t(w) \) are the price and quantity consumed of the individual varieties \( w \), respectively. The overall demand for the differentiated good \( Q_t \) is generated by:

\[
Q_t = AP_t^{1-\eta}
\]

where \( A \) is an exogenous demand parameter and \( \eta < \sigma \) is the industry price elasticity.
of demand. From (2) and (3) the demand for an individual variety \( w \) is:

\[
q_t(w) = A \frac{F_t^{\sigma-\eta}}{p_t(w)^\sigma}
\]  

(4)

Each variety is produced by a firm using labour, which is paid a unitary wage equal to 1. Therefore total labour cost for one firm is equal to:

\[
\text{Labour cost} = \frac{q_t(w)}{v}
\]  

(5)

Where \( \frac{1}{v} \) is the labour cost to produce one unit of output. I assume that the marginal productivity of labour for the frontier technology is equal to \( \frac{\bar{v}}{v} \), and it grows every period at the gross rate \( g > 1 \). To normalize the model, I assume that labour cost also grows at the same rate and is equal to \( \frac{\bar{v}}{v} \). It is then straightforward to notice that \( v \) in equation (5) is equal to \( \frac{\bar{v}}{v} \), the productivity of the firm relative to the frontier technology. The profits for a firm with relative productivity \( v_t \) and variety \( w \) are given by:

\[
\pi_t(v_t, \varepsilon_t) = p_t(w)q_t(w) - \frac{q_t(w)}{v_t} - F_t
\]  

(6)

Since all the formulas are identical for all varieties, we drop the indicator \( w \) from now on. \( F_t > 0 \) are the overhead fixed costs of production that have to be paid every period. They are subject to an idiosyncratic shock \( \varepsilon_t \) which is uncorrelated across firms and possibly correlated over time for each firm:

\[
F_t = F + \varepsilon_t
\]

Firms are heterogeneous in terms of productivity \( v_t \). The shock \( \varepsilon_t \) introduces uncertainty in profits, and it plays an important role in the presence of financing frictions. By affecting the accumulation of wealth and the the probability of default, the shock also affects both the entry decision, the exit decision, and the equilibrium productivity in the industry. The idiosyncratic shock enters additively in \( \pi_t(v_t, \varepsilon_t) \) so that it does
not affect the firm decision on the optimal price $p_t$ and quantity produced $q_t$. This makes the model both easier to solve and more comparable to the basic model without financing frictions.\(^1\)

The firm is risk neutral and chooses $p_t$ in order to maximize $\pi_t (v_t, \varepsilon_t)$. The first order condition yields the standard pricing function:

$$p_t = \frac{\sigma - 1}{\sigma - 1 v_t} \quad (7)$$

It then follows that:

$$\pi_t (v_t, \varepsilon_t) = \left(\frac{\sigma - 1}{\sigma}\right)^{\sigma - 1} \left( A P^{\sigma} - \eta v_t^{\sigma - 1} - F_t \right)$$

The timing of the model for a firm which was already in operation in period $t - 1$ is the following. At the beginning of period $t$ with probability $\delta$ its technology becomes useless forever, and the firm liquidates all its assets and stops activity. With probability $1 - \delta$ the firm is able to continue with the current technology. It observes the realization of the shock $\varepsilon_t$, which determines $\pi_t (v_t, \varepsilon_t)$ and realizes financial wealth $a_t$:

$$a_t = R (a_{t-1} - K (I_{t-1}) - d_{t-1}) + \pi_t (v_t, \varepsilon_t) \quad (8)$$

$I_{t-1} \in \{0, 1, 2\}$ is an indicator function that is equal to 1,2 if the firm decided to invest in type 1 or type 2 innovation, respectively, in period $t - 1$. These two innovation types are described below. It is equal to 0 if the firm did not innovate in period $t - 1$. $K (I_{t-1})$ is the cost of innovation. Financing frictions are introduced by following Caggese and Cuñat (2013) and assuming that the firm cannot borrow to finance the fixed cost of its operations. While it can pay workers with the stream of revenues generated by their

\(^1\)A multiplicative shock of the type $\varepsilon_t p_t q_t$ would not change the qualitative results of the model, but it would have two main consequences. First, it would imply that the optimal quantity produced $q_t$ would be a function of the intensity of financing frictions, thus making the solution of the problem more complicated. Second, it would imply that expected profits are a function of the volatility of the shock $\varepsilon_t$. 

7
labour input, it has to pay in advance for a fraction $\gamma$ of the other costs of production. Therefore continuation is feasible only if:

$$a_t \geq \gamma F$$

(9)

where $\gamma$ is a coefficient greater than zero and proxies for the efficiency of the financial system. It is natural to assume that $\gamma$ is $\leq 1$, but it should be possible to argue that $\gamma > 1$ is simply a shortcut to more severe levels of financing frictions. If the constraint (9) is not satisfied, then the firm cannot continue its activity and is forced to liquidate.\(^2\)

Conditional on continuation, innovation is feasible if:

$$a_t \geq \gamma (F + K)$$

(10)

Given the presence of financing frictions, and the fact that the firm discounts future profits at the constant interest rate $R$, it is trivial to show that it is never optimal for the firm to distribute dividends while in operation, since accumulating wealth reduces future expected financing constraints. Hence dividends $d_t$ are always equal to zero. Profits increase wealth $a_t$, which is distributed as dividends when the firm is liquidated.

After observing $\xi_t$ and realizing profits, the firm decides whether or not to continue activity the next period. It may decide to voluntarily exit if it is not profitable enough to cover the fixed per period cost $F$. In this case the firm voluntarily liquidates and ceases to operate forever. Conditional on continuation, it decides whether or not to innovate in period $t$ to improve productivity in period $t + 1$.

If the firm does not innovate ($I_t = 0$ and $K(0) = 0$), with probability $1 - \xi^{NI}$ its technology remains constant and therefore its relative technology level $\nu$ depreciates at the rate $g$. With probability $\xi^{NI} > 0$ the firm can imitate firms with the technological level one step ahead. In this case its productivity increases at the rate $g > 0$ and

\(^2\)Constraint (9) is a simple way to introduce financing frictions in the model. Nonetheless it generates realistic firm dynamics, and can be interpreted as a shortcut for more realistic models of firm dynamics with financing frictions, such as, for instance, Clementi and Hopenhayn (2006).
its relative productivity \( v \) remains constant. This stochastic imitation probability is not essential for the qualitative results of the model, but it is necessary to properly calibrate it with empirical data.

If the firm chooses type 1 \((I_t = 1)\) or "incremental" innovation, invests an amount equal to \( K(1) > 0 \) to improve its technology by one step. If successful, with probability \( \xi^{INC} > \xi^{NI} \) the firm's relative productivity \( v \) remains constant, otherwise it depreciates at the rate \( g \) with probability \( 1 - \xi^{INC} \). Incremental innovation is a type of innovation that tries to improve on the current technology without radical changes to the products and production processes. If innovation is not successful it means that the innovation process generated new ideas and knowledge which were not useful in increasing productivity, and therefore were not applied to the firm production process.

If the firm chooses type 2 \((I_t = 2)\) or "radical" innovation, it will invests an amount equal to \( K(2) > K(1) \) and will reach the frontier technology \((v = 1)\) with probability \( \xi^I \), while it will depreciate at the rate \( g^{fail} \) with probability \( 1 - \xi^I \), where \( g^{fail} > g \). The intuition for the high depreciation in case of default is the following: \( K(2) \) is the cost of investment in a new type of capital in which the new technology is embodied. Such investment is irreversible, and requires the firm to replace the capital and expertise which was used to operate the old technology. Therefore in case of failure the firm cannot easily revert back to the old technology, and its efficiency will be lower with respect to the situation before innovating. This type of innovation is similar to the concept of radical innovation as it is defined in management studies, which implies radical changes to the firm’s structure, and implies that current assets are not suitable to implement the new product or production process. For example Utterback (1996) defines Radical Innovation as a "change that sweeps away much of a firm’s existing investment in technical skill and knowledge, designs, production technique, plant and equipment". The following table summarizes the law of motion of productivity conditional on \( I_t \):
if \( I_t = 0 \):

(No innovation)

\[ v_{t+1} = v_t \text{ with prob. } \xi^{NI} \]
\[ v_{t+1} = \frac{v_t}{g} \text{ with prob. } 1 - \xi^{NI} \]
\[ K(0) = 0 \]

if \( I_t = 1 \):

(Incremental Innovation)

\[ v_{t+1} = v_t \text{ with prob. } \xi^{INC} > \xi^{NI} \]
\[ v_{t+1} = \frac{v_t}{g} \text{ with prob. } 1 - \xi^{INC} \]
\[ K(1) > 0 \]

if \( I_t = 2 \):

(Radical Innovation)

\[ v_{t+1} = 1 \text{ with prob. } \xi^I > 0 \]
\[ v_{t+1} = \frac{\nu}{g} \text{ with prob. } 1 - \xi^I \]
\[ K(2) > K(1) \]

In order to characterize the innovation decision, I define \( V^1_t (a_t, \varepsilon_t, v_t) \) as the value function today conditional on doing incremental innovation:³

\[
V^1_t (a_t, \varepsilon_t, v_t) = -K(1) + \frac{1 - \delta}{R} \left\{ \xi^{INC} E_t \left[ V_{t+1} (a_{t+1}, \varepsilon_{t+1}, v_t) + \pi_t + \varepsilon_t \right] + \left( 1 - \xi^{INC} \right) E_t \left[ V_{t+1} \left( a_{t+1}, \varepsilon_{t+1}, \frac{v_t}{g} \right) + \pi_t + \varepsilon_t \right] \right\}
\]

Then I define \( V^2_t (a_t, \varepsilon_t, v_t) \) as the value function today conditional on doing radical innovation:

\[
V^2_t (a_t, \varepsilon_t, v_t) = -K(2) + \frac{1 - \delta}{R} \left\{ \xi^I E_t \left[ V_{t+1} (a_{t+1}, \varepsilon_{t+1}, 1) + \pi_t + \varepsilon_t \right] + \left( 1 - \xi^I \right) E_t \left[ V_{t+1} \left( a_{t+1}, \varepsilon_{t+1}, \frac{v_t}{g} \right) + \pi_t + \varepsilon_t \right] \right\}
\]

And finally, the value function conditional on not innovating is:

\[
V^0_t (a_t, \varepsilon_t, v_t) = \frac{1 - \delta}{R} \left\{ \xi^{NI} E_t \left[ V_{t+1} (a_{t+1}, \varepsilon_{t+1}, v_t) + \pi_t + \varepsilon_t \right] + \left( 1 - \xi^{NI} \right) E_t \left[ V_{t+1} \left( a_{t+1}, \varepsilon_{t+1}, \frac{v_t}{g} \right) + \pi_t + \varepsilon_t \right] \right\}
\]

The firm then makes the innovation decision \( I_t \) which maximizes the firms’ value:

\[
V^*_t (a_t, \varepsilon_t, v_t) = \arg \max_{I_t \in \{0,1,2\}} \{ V^0_t (a_t, \varepsilon_t, v_t), V^1_t (a_t, \varepsilon_t, v_t), V^2_t (a_t, \varepsilon_t, v_t) \} \quad (11)
\]

such that

\[
a_t \geq \gamma [F + K (I_t)].
\]

³I define the value of the firm as the net present value of future profits. Since the discount factor of the firm is 1/R, and the firm is risk neutral, this value coincides with the net present value of expected dividends.
Given the optimal innovation decision conditional on continuation, the value of the firm at the beginning of time $t$, $V_t(a_t, \varepsilon_t, v_t)$, is:

$$V_t(a_t, \varepsilon_t, v_t) = 1(a_t \geq \gamma F) \left\{ \max \left[ V^*_t(a_t, \varepsilon_t, v_t), 0 \right] \right\}$$  \hspace{1cm} (12)

Equation 12 implies that the value of the firm is equal to zero in two cases. First, when the indicator function $1(a_t \geq \gamma F)$, which is equal to one if the argument is true, is equal to zero because the liquidity constraint (9) is not satisfied. Second, when the firm is not profitable enough, and the value in the curly brackets is equal to zero.

2.1 Entry decision

Every period there is free entry. There is a large amount of new potential entrants with a constant endowment of wealth $a_0$. They draw their type $v$ (their productivity relative to the frontier) from a uniform distribution with support $[v, 1]$, after having paid an initial cost $S^C$. Once they learn their type they decide whether or not to start activity. If they start, then draw $\varepsilon_0$ from an initial normal distribution. The free entry condition requires that ex ante the expected value of paying $S^C$ and constituting a firm, conditional on the expectation of the initial value of the shock $\varepsilon_0$, is zero:

$$\mathbb{E}^{\varepsilon_0} \left\{ \max \left[ V_0(a_0, v_0, \varepsilon_0), 0 \right] \right\} f(v_0)dv_0 - S^C = 0$$  \hspace{1cm} (13)

2.2 Aggregate equilibrium

In the steady state the aggregate price $P_t$, the aggregate quantity $Q_t$, and the distribution of firms over the values of $v_t, \varepsilon_t$ and $a_t$ are constant over time. The presence of technological obsolescence and the exogenous exit probability $\delta$ imply that the age of firms is finite and that the distribution of wealth across firms is non-degenerate. Aggregate price $P_t$ is set to ensure that the free entry condition (13) is satisfied. The number
of firms in equilibrium ensures that $P_t$ also satisfies the aggregate price equation (1). Aggregation is very simple because all operating firms with productivity $v$ choose the same price $p(v)$, as determined by (7).

3 Model’s solution and simulations.

In the next subsections I calibrate the model, solve it, and illustrate firm dynamics in the simulated industries.

3.1 Calibration

The calibrated parameters are chosen to match a set of simulated moments with the moments estimated from the panel of Italian manufacturing firms analyzed in section 4. The parameters are illustrated in table 1. The rate of exogenous depreciation $\delta$ matches the employment share of exiting firms. The average real interest rate is equal to two percent, which is consistent with the average short-term real interest rates in Italy in the sample period. Regarding the distribution of productivity of new firms, it is assumed to be lognormally distributed, with mean $\tau$, calibrated to match the average profits of young firms (from 6 to 10 years old) relative to unconditional average profits, and variance $\sigma^2_v$, calibrated to match the cross sectional dispersion in profitability across firms. The initial entry cost $S^C$ matches the average profitability of firms, while the liquidity shock $\xi$ matches the time series volatility of firm profits. The depreciation rate of technology $g$ is set to 1.0035, to match the expected yearly decline in profits for firms which do not innovate. The frontier productivity is normalized to 1. The innovation probabilities $\xi^{NI}, \xi^{INC}$, and $\xi^f$, the innovation costs $K(1)$ and $K(2)$ and the depreciation rate of firms failing in radical innovation $g^{fail}$ jointly match the following moments: the average expenditure in r&d, the percentage of firms making losses, the average age of firms, and the distribution of innovation over the age of firms. Finally,
The parameter $a_0$, the initial wealth of new firms, affects the intensity of financing frictions and the probability of bankruptcy. I set a benchmark value such that 0.5% of firms go bankrupt in the simulations. This corresponds to a relatively low value for the Italian industry.\footnote{As a comparison, business bankruptcies in Italy in the recent deep 2009-2012 recession have been around 2-3\% per year.} Later on I compare simulation results across industries with different values of $a_0$. The fixed per period cost $F$ matches the ratio of fixed overhead costs over labor cost, which in our empirical sample is estimated to be around 30\% (Caggese and Cuñat, 2013).

A remaining set of parameters cannot be directly matched to the Italian Dataset. For these I assume values consistent with related studies. The value of $\sigma$, the elasticity of substitution between varieties, is equal to 4, in line with Bernard, Eaton, Jensen and Kortum (2003), who calculate a value of 3.79 using plant level data. The value of $\eta$, the industry price elasticity of demand, is set equal to 1.5, following Constantini and Melitz (2007).\footnote{This is also consistent with Broda and Weinstein (2006), who estimate that the elasticity of substitution falls between 33\% to 67\% moving from the highest to the lowest level of disaggregation in industry data.} The value of $\gamma$, the fraction of fixed costs that need to be financed with internal finance, is equal to 1.

\section*{3.2 Simulation results}

The benchmark calibration represents an industry with an average level of financing frictions. In order to match the empirical exercise illustrated in the next section, where I compare groups of four digit sectors selected according to the intensity of financing frictions, I simulate two industries identical to the benchmark industry, except that they have different values of $a_0$, the initial endowment of firms. For the constrained industry the value of $a_0$ is set to 0.5, so that 1.9\% of firms go bankrupt every year, versus 0.5\% in the benchmark calibration. In the unconstrained industry $a_0$ is set equal
### Table 1: Calibration

<table>
<thead>
<tr>
<th>Matched parameters</th>
<th>Value</th>
<th>Moment to match</th>
<th>Data</th>
<th>Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\delta$</td>
<td>0.03</td>
<td>share of exiting firms</td>
<td>5%</td>
<td>5.2%</td>
</tr>
<tr>
<td>$r$</td>
<td>1.02</td>
<td>average real interest rate</td>
<td>2%</td>
<td>2%</td>
</tr>
<tr>
<td>$F$</td>
<td>0.2</td>
<td>average ratio fixed costs/labour costs</td>
<td>0.3</td>
<td>0.15</td>
</tr>
<tr>
<td>$\sigma^2$</td>
<td>0.969</td>
<td>avg. cross sect. dispersion of profits/added value</td>
<td>0.064</td>
<td>0.053</td>
</tr>
<tr>
<td>$S^{\text{C}}$</td>
<td>0.6</td>
<td>mean profits/added value</td>
<td>0.037</td>
<td>0.037</td>
</tr>
<tr>
<td>$\xi$</td>
<td>0.15</td>
<td>average of time series vol of profits/ad.v. at the firm level</td>
<td>0.084</td>
<td>0.085</td>
</tr>
<tr>
<td>$g$</td>
<td>1.0035</td>
<td>average yearly decline in profits/sales. for a non inn. firm</td>
<td>3%</td>
<td>2%</td>
</tr>
<tr>
<td>$K^{\text{road}}$</td>
<td>0.05</td>
<td>average r&amp;d/added value</td>
<td>3%</td>
<td>1.8%</td>
</tr>
<tr>
<td>$K^{\text{keep}}$</td>
<td></td>
<td>Average innovation of firms aged 35–40</td>
<td>37%</td>
<td>38%</td>
</tr>
<tr>
<td>$\alpha^{\text{top}}$</td>
<td></td>
<td>normalized to 1</td>
<td>n.a.</td>
<td>n.a.</td>
</tr>
<tr>
<td>$\alpha^{\text{not}}$</td>
<td>0.6</td>
<td>average age of firms</td>
<td>24</td>
<td>24</td>
</tr>
<tr>
<td>$\alpha^{\text{inn}}$</td>
<td>0.8</td>
<td>% of innovating firms aged 20-25</td>
<td>32%</td>
<td>28%</td>
</tr>
<tr>
<td>$g^{\text{fail}}$</td>
<td>0.1</td>
<td>Average innovation of firms with age 0-5</td>
<td>29%</td>
<td>29%</td>
</tr>
<tr>
<td>$a_0$</td>
<td>1.2</td>
<td>% of firms going bankrupt every period</td>
<td>0.5%</td>
<td>0.5%</td>
</tr>
</tbody>
</table>

Other parameters: $\gamma = 1; \eta = 1.5; \sigma = 4$

To 2, so that 0.01% of firms go bankrupt every year. I simulate both industries for 500 periods and compute firm level and aggregate statistics. Figure 1 shows the percentage of firms innovating in each industry as a function of their age. To make it comparable with the empirical data analysed in the next section, I consider total innovation and the interval between 6 to 40 years of age. The figure shows that innovation is more frequent on average and grows faster over time in the unconstrained industry than in the constrained one.

In order to understand why this is the case, figure 2 shows the percentage of firms doing radical innovation as a function of their productivity. On the horizontal axis is the current productivity index, which measures the distance to the frontier. A lower value indicates a better technology, and a firm that fails to keep up with the frontier increases its index by one. Radical innovation is chosen when the technology state and profits are sufficiently low. Since profits are generally higher in the constrained industry,
because of the competition effect, firms wait until they reach a lower technology level before starting to innovate. This is the indirect negative effect of financing frictions. The direct negative effect of financing frictions is implied by the fact that not all firms that reach the technology state 72 in the constrained industry are able to finance innovation. But the fraction of these firms is relatively small. Moreover there is also a direct positive effect of financing frictions. Some firms in the constrained industry actually innovate before state 72. These are firms with little financial wealth, which innovate earlier because of a "gambling for resurrection" effect. If they do no innovate now, they will be unable to do it in the future conditional on a negative profits shock, and will very likely go bankrupt in the near future. Overall, figure 2 implies that the indirect effect of financing frictions is much more important than the direct effect in determining radical innovation.

Figure 3 shows the consequences of radical innovation for the firms lifecycle. In the unconstrained industry a much larger number of young firms perform radical innovation than in the constrained industry. As a consequence more of these firms reach the frontier technology, at which point they start to engage in incremental innovation,
The implications of this higher intensity of risky innovation for productivity dynamics over the firms life cycle are shown in figure 4. Productivity steadily declines in the constrained industry, while it increases over time for firms in the unconstrained industry.

Table 2 summarizes the implications of these different dynamics for aggregate productivity. Average total factor productivity is 4.7% higher in the unconstrained industry than in the constrained one. Since the frontier technology is exogenous in the model, perhaps a better measure of efficient allocation of resources is the distance from such frontier. Firms are on average closest to the frontier in the unconstrained industry. Instead the average distance increases by almost 25% for the constrained industry.
Figure 3: Fraction of firms doing radical innovation as a function of firm’s age

Figure 4: Total factors productivity over the firm’s life cycle.
4 Empirical evidence

The model developed in the previous section yields two testable predictions on the relation between financing frictions, innovation and productivity along the life cycle:

Prediction 1: firms in less financially constrained industries innovate more than firms in more financially constrained industries.

Prediction 2: firms in less financially constrained industries have a growing productivity over the life cycle, more so than firms in more financially constrained industries.

In this section I provide empirical evidence on these two predictions for a sample of Italian manufacturing firms. This panel is drawn from the Mediocredito/Capitalia surveys of small and medium manufacturing firms. It is an unbalanced panel of more than 10,000 firms with annual balance-sheet data and profit and loss statements from 1989 to 2000, as well as qualitative information from three surveys conducted in 1995, 1998 and 2001. Each survey reports information about the activity of the firms in the three previous years and, in particular, it includes detailed information on financing constraints and innovation.

4.1 Identification of financially constrained firms.

I use the information about financing frictions included in the surveys to create a binary variable "\(\text{constrained}_{i,s}\)", which is equal to one if firm \(i\) declares to face financing frictions in survey \(s\), and is equal to zero otherwise.\(^6\) Ideally this indicator of financial constraints should satisfy two properties. First, it should be positively related to the probability that the firm faces problems in accessing external finance because

\(^6\)Firms report whether they had a loan application turned down recently, whether they desire more credit at the market interest rate and whether they would be willing to pay a higher interest rate than the market rate to obtain credit. I aggregate these three variables into a single variable \(\text{constrained}\) that takes value one if the firm answers yes to any of these three questions. According to this measure, 17 percent of the firms declare themselves to be financially constrained.
of informational or enforceability problems with lenders. Second, it should be unrelated to growth opportunities that directly affect innovation decisions and productivity dynamics.

The direct survey answers used in this paper are likely to satisfy the first property, more so than indirect measures of financing frictions based on balance sheet data. However, they may not satisfy the second criterion, because less productive and profitable firms are at the same time more likely to claim difficulties in accessing loans and have worse investment and innovation opportunities. This bias is present in the Mediocre-dito sample, because firms that declare financing frictions are less profitable than the other firms, both in absolute value and also relative to the average profitability in their sector. I correct for this problem in three ways:

i) I consider as constrained only firms that complain about problems in accessing external finance while at the same have average operative profits over added value larger than 0.1. This threshold excludes the 25% least profitable firms.

ii) I use the firm-level variable \( \text{\textit{constrained}}_{i,s} \) to calculate the frequency of financially constrained firms in each 4 digit manufacturing sector and I select sectors in different groups. One group is composed by the 50% four digit sectors with most constrained firms, called the "Constrained" group, and the other group is composed of the 50% four digit sectors with least constrained firms, called the "Unconstrained" group. Thus the constrained group includes all firms more likely to face financing problems because sector specific factors.

iii) When analyzing the results, as a further robustness check I eliminate all firms declaring financing frictions, thus further reducing selection problems. In other words, I perform the analysis on firms which are not currently declaring financing problems, but which are more likely to face these problems in the future because they belong to a sector where on average more firms face financing frictions. This procedure reduces
Table 3: Frequency of constrained and unconstrained firms in each 2 digit manufacturing sector

<table>
<thead>
<tr>
<th>Sector</th>
<th>Class</th>
<th>n. observations</th>
<th>% of firms in the &quot;Constrained&quot; group</th>
<th>% of firms in the &quot;Unconstrained&quot; group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Food and Drinks</td>
<td>15</td>
<td>960</td>
<td>25%</td>
<td>75%</td>
</tr>
<tr>
<td>Textiles</td>
<td>17</td>
<td>1150</td>
<td>30%</td>
<td>70%</td>
</tr>
<tr>
<td>Shoes and Clothes</td>
<td>18</td>
<td>551</td>
<td>38%</td>
<td>62%</td>
</tr>
<tr>
<td>Wood Furniture</td>
<td>20</td>
<td>343</td>
<td>65%</td>
<td>35%</td>
</tr>
<tr>
<td>Paper</td>
<td>21</td>
<td>379</td>
<td>72%</td>
<td>28%</td>
</tr>
<tr>
<td>Printing</td>
<td>22</td>
<td>457</td>
<td>51%</td>
<td>49%</td>
</tr>
<tr>
<td>Chemical, Fibers</td>
<td>24</td>
<td>614</td>
<td>43%</td>
<td>57%</td>
</tr>
<tr>
<td>Rubber and Plastic</td>
<td>25</td>
<td>717</td>
<td>44%</td>
<td>56%</td>
</tr>
<tr>
<td>Non metallic products</td>
<td>26</td>
<td>823</td>
<td>76%</td>
<td>24%</td>
</tr>
<tr>
<td>Metals</td>
<td>27</td>
<td>614</td>
<td>49%</td>
<td>51%</td>
</tr>
<tr>
<td>Metallic products</td>
<td>28</td>
<td>1183</td>
<td>69%</td>
<td>31%</td>
</tr>
<tr>
<td>Mechanical Products</td>
<td>29</td>
<td>2031</td>
<td>42%</td>
<td>58%</td>
</tr>
<tr>
<td>Electrical Products</td>
<td>31</td>
<td>522</td>
<td>90%</td>
<td>10%</td>
</tr>
<tr>
<td>Television and comm.</td>
<td>32</td>
<td>303</td>
<td>45%</td>
<td>55%</td>
</tr>
<tr>
<td>Precision instruments</td>
<td>33</td>
<td>191</td>
<td>75%</td>
<td>25%</td>
</tr>
<tr>
<td>Vehicles</td>
<td>34</td>
<td>261</td>
<td>75%</td>
<td>25%</td>
</tr>
<tr>
<td>other manufacturing</td>
<td>36</td>
<td>664</td>
<td>62%</td>
<td>38%</td>
</tr>
</tbody>
</table>

the possibility of mistakes in selecting firms that declare financing frictions because they face negative productivity shocks. Furthermore, it is fully consistent with the theoretical model illustrated in the previous section, which predicts that the most important effect of financing frictions on innovation dynamics are the indirect ones, via the effect of frictions on competition.

Table 3 reports the distribution of firms in the two groups for each two digit manufacturing sector. It shows that financial frictions are present in all industries and not concentrated in few sectors only.

Figure 5 shows the percentage of financially constrained firms conditional on age for the whole sample and for the Constrained and Unconstrained groups. I smooth the age profiles with 9 year moving averages. The figure shows that financing frictions decrease with age for all firms. Importantly, the reduction is larger for the Constrained
group. That is, this group identifies firms that are much more constrained when young related to the Unconstrained group, while the difference between groups is much reduced among older firms. These dynamics are consistent with the model, where firms face financing frictions and bankruptcy risk only when young.

### 4.2 Financing frictions and productivity dynamics

Consistently with prediction 1, Figure 6 shows that the percentage of firms doing R&D is higher in the unconstrained than in the constrained group of firms. Table 4 shows that both total Total R&D and fixed investment directed to innovate, two independent measures of innovation available for the sample, are both higher for the unconstrained group. Furthermore it also shows that firms in less constrained sectors are more likely to innovate by introducing new products, while are not more likely to innovate by improving current products.

It is certainly not possible to establish a clear mapping between product and process
innovation in the data and radical and incremental innovation in the model. Among other things, some new products may simply provide small incremental improvements on the old ones. However to the extent that product innovation is on average riskier than process innovation, as confirmed for this sample by Caggese (2012), this finding supports the theoretical predictions of the model.

In order to verify prediction 2, the following tables analyse the age profile of pro-

<table>
<thead>
<tr>
<th>Table 4: Percentage of innovating firms</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) R&amp;D</td>
</tr>
<tr>
<td>---------</td>
</tr>
<tr>
<td>All firms</td>
</tr>
<tr>
<td>Only constrained sectors</td>
</tr>
<tr>
<td>Only unconstrained sectors</td>
</tr>
</tbody>
</table>
ductivity. They report the results of several regressions where the dependent variable is \( \hat{v}_{s,t}^{j} \), an estimate of the average productivity of firm \( i \) in period \( s \).\(^7\) The index \( j = 1, 2 \) refers to two different measures of productivity.\(^8\) The first measure is \( \hat{v}_{s,t}^{1} \), revenue total factor productivity. I estimate a production function using the Levinshon and Petrin (2003) methodology, at the 2 digit level (see the details in appendix 1):

\[
\pi_{i,t}y_{i,t} = e^{\hat{\nu}_{i,t}} (p_{i,t}^{k} k_{i,t})^{\alpha} (w_{i,t} l_{i,t})^{\beta}
\]

Where \( p_{i,t} y_{i,t} \) is added value, \( p_{i,t}^{k} k_{i,t} \) is the value if capital, and \( w_{i,t} l_{i,t} \) is cost of labour for firm \( i \) in period \( t \). Using the estimated parameters \( \hat{\alpha} \) and \( \hat{\beta} \), I then obtain an empirical counterpart \( \hat{v}_{s,t}^{1} \) of the residual \( v_{s,t}^{1} \). The well known limitation of this measure is that it does not capture improvements in productivity that are passed to consumers in the form of price reductions.\(^9\)

Therefore I also compute a second measure based on the profitability of the firms. I first compute the ratio between profits and labour cost for each firm and period, \( \frac{\pi_{i,t}}{w_{i,t} l_{i,t}} \). This ratio is monotonously increasing in the productivity of the firm as long as the firm has some competitive power (or is a price taker but has a decreasing returns to scale production function), also when improvements in productivity are passed to consumers in the form of price reductions.\(^10\) I regress this measure over industry and

---

\(^7\)Given that each survey covers a 3-years period, for these regressions I consolidate all the balance sheet variables at the same time interval.


\(^9\)For example, in the model considered in the previous section an increase in marginal productivity of labour \( v \) does not affect revenue total factor productivity because the fall in prices completely offsets the productivity gain.

\(^10\)For the case of the model analyzed in the previous section, it is possible to show that

\[
\frac{\pi_{i,t}}{w_{i,t} l_{i,t}} = a - b \frac{F}{v_{i,t}^{\alpha-1}}
\]

Where \( a \) and \( b \) are positive constants which only depend on sector level variables, while \( F \) is the fixed overhead costs.
time dummies:
\[
\frac{\pi_{i,t}}{w_{i,t}^l_{i,t}} = \beta_0 + \sum_{s=1}^{N_s} \beta_s D_s + \sum_{y=1}^{N_y} \beta_y D_{y,t} + \nu_{i,t}^2
\]

Where \( D_s \) is 3 digit sector dummies and \( D_y \) is year dummies. \( \nu_{i,t}^2 \) is the estimated residual of this regression, while \( \nu_{s,t}^2 \) is the firm level average of \( \nu_{i,t}^2 \) over the three years of each survey. Changes over time in \( \nu_{s,t}^2 \) are orthogonal to aggregate demand and industry factors, and thus are likely to reflect changes in productivity of the firm.

In order to measure the evolution of productivity over the firm’s life cycle, I estimate the following model:
\[
\hat{\nu}_{i,s}^j = \beta_0 + \beta_1 \text{age}_{i,s} + \beta_2 \text{age}_{i,s} \ast \text{constrained}_{k,t} + \sum_j^{m} \beta_j x_{j,s,t} + \varepsilon_{s,t}
\]

The productivity measure \( j \) of firm \( i \) in survey \( s \), \( \hat{\nu}_{i,s}^j \), is the dependent variable. Among the regressors, the age of the firm \( \text{age}_{i,s} \) is included individually and interacted with the financing constraints dummy \( \text{constrained} \), which is equal to one if the firm belongs to the 50% of 4-digit manufacturing sectors with the highest percentage of financially constrained firms, and zero otherwise. Thus \( \beta_1 \) measures the effect of age on productivity for the unconstrained group of firms, and \( \beta_2 \) measures the differential effect of age for the constrained group. \( x_j \) is the set of \( m \) control variables.

In Table 7 the estimated coefficients of age and age interacted with the constrained variable are reported. As control variables I include firm fixed effects and time effects. When comparing average productivity at different ages the sample of younger firms is different from the sample of older firms. Therefore without firm fixed effects a positive \( \beta \) coefficient could be driven by the fact that the most productive firms are more likely to survive, rather than by firms increasing their productivity by accumulating intangible capital as they become older. With firm fixed effects I control for this potential selection bias, because the \( \beta \) coefficient is only identified by changes in productivity for firms that are observed both when younger and when older.
Figure 7: Relation between age and productivity (Firms fixed effects and time effects are included. Standard Errors clustered at the firm level.)

<table>
<thead>
<tr>
<th></th>
<th>All observations</th>
<th>Currently constrained firms excluded</th>
<th>Time trend for constrained group included</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>v1</td>
<td>v2</td>
<td>v1</td>
</tr>
<tr>
<td>Age</td>
<td>0.00616***</td>
<td>0.000670</td>
<td>0.00686***</td>
</tr>
<tr>
<td></td>
<td>(5.83)</td>
<td>(1.35)</td>
<td>(6.17)</td>
</tr>
<tr>
<td>Age*Constrained</td>
<td>-0.00360**</td>
<td>-0.00207***</td>
<td>-0.00351**</td>
</tr>
<tr>
<td></td>
<td>(-2.59)</td>
<td>(-3.30)</td>
<td>(-2.37)</td>
</tr>
<tr>
<td>N</td>
<td>12390</td>
<td>12672</td>
<td>11065</td>
</tr>
<tr>
<td>adj. R-sq</td>
<td>0.011</td>
<td>0.006</td>
<td>0.013</td>
</tr>
</tbody>
</table>

t statistics in parentheses
* p<0.1  ** p<0.05  *** p<0.001

Columns 1 and 2 report the estimated age coefficients using $v^1$ and $v^2$ as dependent variables, respectively. In both cases productivity increases with age for firms in the least financially constrained sectors. Moreover, the relation between age and productivity is significantly less strong for the firms in the more financially constrained sectors, thus confirming prediction 2.

Column 3 and 4 replicate the analysis eliminating firms that declare financing frictions. This selection has two advantages: first, it eliminates the possibility that less dynamic and innovative firms are causing the higher frequency of financing constraints, rather than the opposite. Second, assuming that financing frictions are instead causing the lack of productivity growth rather than the opposite, it helps to distinguish between the direct effects of financing constraints (firms do not improve their productivity because they lack external finance to invest in innovation) from the indirect one (financing frictions distort entry and competition and reduce the incentives to invest in innovation). Columns 3 and 4 show very similar results to columns 1 and 2, indicating that the indirect effect of financing frictions must be the most important one in affecting life cycle growth of firm productivity, as predicted by the model.
One possible alternative explanation of this result is that more financially con-
strained sectors happen to be sectors in decline, with a progressive reduction in pro-
ductivity over time. This possibility can be controlled for by introducing a time trend
specific to the constrained group. This is done in columns 5 and 6. Here the results
are once again largely confirmed.

Figure 8 replicates the analysis of figure 7 with a different selection of constrained
groups. The estimated equation is as follows:

$$v_{i,s,t} = \beta_0 + \beta_1 \text{age}_{i,t} + \beta_2 \text{age}_{s,t} \ast \text{midconstrained}_{k,t} + \beta_3 \text{age}_{s,t} \ast \text{highconstrained}_{k,t} + \sum_j \beta_j x_{j,s,t} + \varepsilon_{s,t}$$

Where midconstrained is equal to 1 if a firm is in the 33% of sectors with inter-
mediate constraints, and 0 otherwise, and highconstrained is equal to 1 if a firm is in
the 33% of most constrained sectors and zero otherwise.

The results show that the effect of age on productivity monotonously decreases
with the intensity of financing frictions, in all the different regressions. In figure 9
I represent graphically the relation between age and productivity for the constrained
and unconstrained group. The curves are computed from the estimated coefficient of
a piecewise linear regression in which the $\beta$ coefficient is allowed to vary for different
age groups:

$$v_{i,s,t} = \beta_0 + \sum_{l=1}^n \beta_l^r (\text{unconstrained} \ast \text{age}^l_{s,t}) + \sum_{l=1}^n \beta_l^c (\text{constrained} \ast \text{age}^l_{s,t}) + \sum_j \beta_j x_{j,s,t} + \varepsilon_{s,t}$$

I consider firms aged between 5 and 44, which is similar to the interval considered
by Hsieh and Klenow (2012), and also the interval for which most observations are
available in the empirical sample. The index $l = 1, 2, \ldots, 8$ indicates the 5-years intervals,
with $l = 1$ indicating firms with age from 5 to 10, up to $l = 8$ indicating ages from
39 to 44. I then construct a set of variables $\text{age}^l$ which is equal to the age of the firm
Figure 8: Relation between age and productivity, more categories (Firms fixed effects and time effects are included. Standard Errors clustered at the firm level).

<table>
<thead>
<tr>
<th></th>
<th>All observations</th>
<th>Currently constrained firms excluded</th>
<th>Time trend for constrained group included</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>v1</td>
<td>v2</td>
<td>v1</td>
</tr>
<tr>
<td>Age</td>
<td>0.00755***</td>
<td>0.000722</td>
<td>0.00818***</td>
</tr>
<tr>
<td></td>
<td>(5.79)</td>
<td>(1.18)</td>
<td>(6.02)</td>
</tr>
<tr>
<td>Age*Mid Constrained</td>
<td>-0.00387**</td>
<td>-0.000528</td>
<td>-0.00359*</td>
</tr>
<tr>
<td></td>
<td>(-2.19)</td>
<td>(-0.66)</td>
<td>(-1.94)</td>
</tr>
<tr>
<td>Age*Most Constrained</td>
<td>-0.00529**</td>
<td>-0.00260***</td>
<td>-0.00529**</td>
</tr>
<tr>
<td></td>
<td>(-3.16)</td>
<td>(-3.42)</td>
<td>(-2.96)</td>
</tr>
<tr>
<td>N</td>
<td>12390</td>
<td>12672</td>
<td>11065</td>
</tr>
<tr>
<td>adj. R-sq</td>
<td>0.011</td>
<td>0.006</td>
<td>0.013</td>
</tr>
</tbody>
</table>

T statistics in parentheses
* p<0.1  ** p<0.05  *** p<0.001

if the firm is in group \( l \), and zero otherwise. Moreover the dummy "unconstrained" is the complementary of "constrained". So the coefficients \( \beta_1^u \ldots \beta_8^u \) measure the effect of age on productivity for the constrained firms, and the coefficients \( \beta_1^c \ldots \beta_8^c \) for the constrained ones. Finally, I use these estimated coefficients to construct the age profile of productivity. The set of control variables includes fixed effects, time dummies, and time dummies interacted with the constrained group, to allow for different trends in the two groups.

Figure 9 shows the age profile of \( \hat{\nu}_{i,s,t}^1 \) for the constrained and unconstrained group. The starting point is the average level of \( \hat{\nu}_{i,s,t}^1 \) for firms younger than 5 years old. The upward sloping profile is almost linear for unconstrained sectors, while it is declining over time for the constrained group.

Figure 10 shows the age profile of the profits-based measure of productivity \( \hat{\nu}_{i,s,t}^2 \).
Figure 9: Life cycle of the productivity of firms, RTFP measure

The starting point is normalized to 1 because the estimated measure $\hat{\nu}_{i,s,t}$ is a nonlinear transformation of the true productivity. It is only useful to identify changes over time in productivity, not its level. Also this figure shows that the gap in productivity between the unconstrained and the constrained group increases along the firms life cycle.

As an additional robustness check I further explore the relation between innovation and the life cycle of firms by selecting sectors based on the average frequency of innovating firms, in figure 11. Four digit sectors are selected in two groups according to the frequency of firms doing r&d. In the first three columns, the age profile of productivity is computed for sectors selected according to intensity of r&d, intensity of r&d to introduce new products, and intensity of other type of r&d. From the results it is clear that in sectors with more r&d, productivity grows faster over the life cycle, and that such difference is driven by r&d to introduce new products. Columns 4-6 repeat analysis using the profits based measure of productivity. The results go in the same
Figure 10: Life cycle of the productivity of firms, profits based measure.
Figure 11: Relation between age and productivity, R&D based groups (Firms fixed effects and time effects are included. Standard Errors clustered at the firm level.)

<table>
<thead>
<tr>
<th></th>
<th>Revenue TFP measure of productivity</th>
<th>Profits based measure of productivity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RTFP</td>
<td>RTFP</td>
</tr>
<tr>
<td>Age</td>
<td>0.00115</td>
<td>0.00176</td>
</tr>
<tr>
<td></td>
<td>(0.85)</td>
<td>(1.26)</td>
</tr>
<tr>
<td>Age*(high R&amp;D sectors)</td>
<td>0.00444**</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(2.15)</td>
<td></td>
</tr>
<tr>
<td>Age*(Sectors high in R&amp;D to introduce new prod.)</td>
<td>0.00281</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(1.38)</td>
<td></td>
</tr>
<tr>
<td>Age*(Sectors high in other types of R&amp;D)</td>
<td>-0.00118</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(-0.58)</td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>12390</td>
<td>8378</td>
</tr>
<tr>
<td>adj. R-sq</td>
<td>0.011</td>
<td>0.007</td>
</tr>
</tbody>
</table>

T statistics in parentheses
* p<0.1, ** p<0.05, *** p<0.001

direction as before even though the differences are not statistically significant.

Finally, figure 12 repeats the analysis using the innovation measures based on fixed investment rather than r&d, finding broadly similar results, with stronger statistical significance.

5 Concluding remarks

The literature on firm dynamics and productivity emphasizes that both financing frictions and innovation dynamics are key factors to understand differences in aggregate productivity across industries and countries. This paper analyses the effects of financing frictions, on entry, exit, industry equilibrium and the incentive to perform radical versus incremental innovation.

By calibrating, solving, and simulating the model of an industry I show that the indirect effects of financing frictions, those that reduce competition because of reduced entry and early exit of firms with financial difficulties, are much more important for innovation decisions than the direct effects, which are the inability to innovate because
Figure 12: Relation between age and productivity, groups based on innovative investment (Firms fixed effects and time effects are included. Standard Errors clustered at the firm level.)

<table>
<thead>
<tr>
<th></th>
<th>Revenue TFP measure of productivity</th>
<th>Profits based measure of productivity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RTFP</td>
<td>RTFP</td>
</tr>
<tr>
<td>Age</td>
<td>0.00198</td>
<td>0.00271**</td>
</tr>
<tr>
<td></td>
<td>(1.43)</td>
<td>(2.22)</td>
</tr>
<tr>
<td>Age*(high fixed investment sectors)</td>
<td>0.00362**</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(2.58)</td>
<td></td>
</tr>
<tr>
<td>Age*(Sectors high in inv. to introduce new prod.)</td>
<td>0.00337**</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(2.42)</td>
<td></td>
</tr>
<tr>
<td>Age*(Sectors high in other types of fixed inv.)</td>
<td>-0.00157</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(-1.11)</td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>12390</td>
<td>8378</td>
</tr>
<tr>
<td>adj. R-sq</td>
<td>0.011</td>
<td>0.007</td>
</tr>
</tbody>
</table>

t statistics in parentheses
* p<0.1, ** p<0.05, *** p<0.001

of insufficient financial wealth and inability to borrow. However, these indirect effects have opposite effects on different innovation types. I show that the negative effects on radical innovation decisions are key in determining a significant negative effect of financing constraints on life cycle productivity dynamics and on aggregate productivity. The empirical analysis conducted on a sample of Italian manufacturing firms is able to confirm these dynamics.

References


6 Computational appendix

To be added

7 Empirical Appendix

To be added