# WORKING PAPER

## Capital Development under Collateral Constraints. Do Investment Subsidies Work?

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**Abstract**

*This paper studies the impact of productive investment subsidies on firms' production decisions under credit market frictions. Through the practice of secured borrowing, collateral constraints present a friction in external credit markets, which substantially affects access to credit by smaller firms located in economically depressed areas. Productive investment subsidies are able to smooth out these frictions and stimulate marginal investment by firms which would have otherwise remained unfunded, thus supporting private capital development. Empirical evidence is obtained from a productive investment subsidies programme, to support recovery following two major earthquakes in Italy. The identification design facilitates recognition of the impact of subsidies across a random sample of firms, including firms that are generally not targets of traditional subsidy programmes for development. Furthermore, the absence of conditionality clauses for employment allows an unbiased estimate of the impact on labour input decisions. The results suggest the effectiveness of investment subsidies in supporting capital development and employment generation in the case of SMEs, with firm location playing a significant role in determining the relative impact strength.*

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# 1 Introduction

This paper contributes to the literature studying the impact of productive investment subsidies on firms' factor allocation and production output decisions.

Public industrial subsidies have been used extensively in multiple countries and situations, attracting large amounts of public financial resources. State and local business tax incentives are the main location-based policy in the United States and amount to about $46bn per year, roughly 77% of the total resources devoted to local economic development spending (Bartik, 2019b).

The widespread use of subsidies, as a tool of public industrial policy, has fostered the development of a rich policy-evaluation literature (Bernini and Pellegrini, 2011; Bernini et al. 2017; Hart et al, 2008; Criscuolo et al, 2019; Busso et al., 2013; Kilen and Moretti, 2014 a-b). Overall, public subsidy programmes for investment have been shown to generate an increase in firms' capital, employment, and output (Bernini and Pellegrini, 2011; Criscuolo et al, 2019). There are, however, limitations to the findings derivable from policy evaluations, namely their inability to test the average treatment effect and a bias in their estimates of the impact on employment introduced by conditionality clauses, which is often present in those programmes.

This paper aims to contribute to this literature by exploiting an identification design that is not being subject to the same limitations applicable to most ex-post evaluations of public subsidy programmes.

Empirical evidence is obtained in the context of Italy, exploiting the allocation of investment subsidies as a post-emergency response following two major earthquakes. The purely location-based nature of the policy intervention object of study in this paper, facilitates the testing of the policy impact over a sample of firms, ranging across different sizes and sectors and on a broader set of dimensions than has been previously explored.

The identification design adopted allows a deeper delve into the optimal targeting of public investment subsidies, studying the policy effect in the context of credit market frictions, particularly those arising from secured access to credit.

Investment subsidies affect the cost of capital incurred by the firm, which, as Bond and Van Reenen (2007) discuss in their pecking order theory, is higher when the investment project cannot be financed internally and the firm has to resort to external financing. Criscuolo et al. (2019) show how firms which are "pecking order constrained" and have to resort to external funding to finance their investment projects, experience a larger increase in capital than firms internally financing, following a similar investment subsidy. Smaller firms, they argue, have a higher probability of falling into this particular- constrained category.

As Small and Medium Enterprises (SMEs) play a central role in the Italian economy, accounting for 76% of total employment and 64% of total value added (OECD, 2021), a credible assessment of optimal targeting of investment subsidies in that context, cannot be divorced from the specific challenges faced by SMEs' access to credit.

The constraint that SMEs face in credit markets is not just represented by a higher cost of financing, but also by the need, in most cases, to pledge assets as collateral to their borrowing, a practice referred to as secured borrowing. In the US, arguably one of the most developed capital markets in the world, an analysis of supervisory level data suggests that secured borrowing accounts for more than 95% of credit lines to SMEs, whilst up to 70% of credit lines to large and very large companies are unsecured (Chodorow-Reich et al., 2021). Similar differences are also detected across firms' size for term loans and have remained stable over time (Avery et al. 1998). The importance of collateral is even higher in the European Union, where around 80% of businesses finance their investments through secured borrowing (i.e., pledging collateral), with the percentage being higher for small and medium firms.

Thus, this leads to another characterisation of constraint in credit markets - collateral constraints. These are not a substitute for the pecking order constraints investigated by Criscuolo et al. (2019) but act alongside them in the context of investment subsidies' impact.

This paper aims to investigate the impact that such collateral constraints have on the effectiveness of investment subsidies, both from a theoretical and empirical standpoint. This has as an objective, the development of a theoretically grounded argument for the usage of investment subsidies, in response to credit market frictions associated with secured financing, with the aim of understanding the drivers behind the mixed effects often detected empirically, together with the ability to provide a framework for a welfare-maximising selection of the target group.

Finally, this paper provides insight into the effectiveness of an emergency response, aimed at supporting the local economy's recovery following a natural disaster. An increase in precipitations and extreme weather events, such as floods, hurricanes and tsunamis as a result of climate change, is going to make the physical destruction of private capital more frequent. Thus, the results from this paper can help to shape the policy response in such contexts.

The paper is organised as follows: Section II provides a short summary of the main literature findings; Section III sketches out the theoretical model acting as a framework for the impact of investment subsidies under imperfect credit markets and non-homothetic preferences; Section IV presents the empirical identification set up, before Section V discusses the econometric modelling strategy and Section VI details the data sources. Empirical results are presented in Section VII, with conclusions contained in Section VIII. The Appendix contains additional detail on the theoretical model derivation, dataset generation and robustness analysis.

## 2 Literature Review

The long-standing use of public investment subsidies has led to the development of a rich policy-evaluation literature, discussing their impact on firms' output, employment and capital. Notable examples of subsidy programmes used as an object of policy evaluation studies are the L. 488 investment subsidies' programme in Italy running from 1997 to 2007 (Bernini and Pellegrini, 2011; Bernini et al. 2017), the Regional Selective Assistance (RSA) programme in the UK (Hart et al, 2008; Criscuolo et al, 2019) - later rebranded as Selective Finance for Investment for England - running from 1972 to 2008 and later followed by the Grant for Business Investment and the Regional Growth Fund programmes, as well as the US Empowerment Zones (Busso et al. 2013) and Tennesse Valley Authority Policy in the US (Kilen and Moretti 2014 a-b).

Overall, public subsidies for investment have been shown to generate an increase in firms' capital, employment and output (Bernini and Pellegrini, 2011; Criscuolo et al, 2019). Evidence on the extent of the subsidies' stimulus on marginal investments is, however, contrasting; Bronzini and De Blasio (2006) find that L.488 investment subsidies do not seem to have stimulated marginal but rather inframarginal investments to some extent, as firms appear to have brought forward investments originally planned for a later period, in order to take advantage of the incentives. They also find suggestive evidence of subsidised firms crowding out investment opportunities to unsubsidised firms in some instances. In the same context, however, Cerqua and Pellegrini (2014) find evidence against the intemporal substitution of investment through a more robust identification design.

The impact on productivity is also mixed, with evidence of a short-term negative effect but medium-long term positive effect (Bernini et al. 2017). Literature also finds limited spatial spillovers in the short run, although it concedes that those could be more easily coming from start-ups which in some cases are excluded, whilst already established large firms might crowd out employment from other non-subsidized players (Bernini and Pellegrini, 2011). Criscuolo et al. (2019) however do not find spatial crowding out or employment mobility to be associated to subsidies but rather to unemployment reduction.

Whilst a positive effect of subsidies on output and capital is consistent with theory and across empirical evidence, the effect on employment, although mostly positive empirically, is unclear theoretically. The net effect on employment is, in fact, determined by the balance between scale effects (the increase in output as a consequence of higher capital leading to more labour inputs) and the substitution effects (determined by the decrease of the user cost of capital vs the cost of labour). But the positive impact on employment could also be a result of the design of the programmes analysed (e.g., L.488, RSA etc) which favour the allocation of subsidies to projects generating employment, thus creating an incentive to commit to hiring more employees than optimal, in order to increase the chances of receiving the subsidies. This could also explain the negative impact detected on productivity.

The empirical assessment of the investment subsidy programmes part of development policies has inevitably limited the ability to test the average treatment effect, given the non-randomness of subsidies allocation. "Local champions" tend, in fact, to be the main receivers of subsidies as a result of the allocation system design, generally rewarding firms proposing higher shares of co-financing and higher increases in employment associated with the subsidies. This limits the external validity of estimates, even when obtained through exogenous shocks to allocation, such as score thresholds exploited in discontinuity designs (Bronzini and Iachini, 2014; Bernini and Pellegrini, 2011; Bernini et al. 2017). Estimating the impact of subsidies on the treated local champion relative to the second-best untreated local champion is, in fact, hardly representative of the average treatment effect on the population of firms.

The existing literature on investment subsidies has, in general, treated the effectiveness of incentives largely as a purely empirical question, with limited progress in defining a theoretical model/framework capable of supporting programme tailoring and rationalising/providing a benchmark for empirical results, with the exception of Criscuolo et al. (2019).

In this direction, additional work is needed, particularly towards understanding the heterogeneity of the policy impact. Most of the literature provides empirical evidence of heterogeneity at size level and sometimes sector, with generally larger estimated policy impacts when firms are small (Criscuolo et al., 2019), in the situations in which such identification is possible. Although consistent across case studies and empirical setups, such heterogeneity in the results – often inconsistent with the theoretical model of reference adopted - is hardly discussed in detail and is generally rationalised through potential sources of bias, often sourced from the field of political economy, along the lines of "larger firms are better at gaming the system, hence why smaller employment gains".

No previous contribution provides a theoretical grounding of the heterogeneity of the policy impact attributable to credit market frictions beyond the pecking order hypothesis, as done by Criscuolo et al. (2019). This, despite the acknowledgement by notable literature contributions of the importance of credit constraints in capital development (Banerjee and Duflo, 2013), which investment subsidies cite to foster. The possibility that the higher impact observed for smaller firms could be associated with capital market frictions more strongly affecting them is, however, raised in a number of literature contributions, amongst which is a programme evaluation for R&D investment subsidies implemented in Northern Italy (Bronzini and Iachini, 2014). Often lacking sufficient collateral, they argue, together with stronger information asymmetries, likely leads to greater difficulty in externally financing investment projects. Empirical validation of this hypothesis has been left unanswered so far and this paper aims to fill this gap.

This paper delves into the heterogeneity of the policy impact by size and credit characteristics of firms, arguing that firms are not subject to just a standard pecking order friction in credit markets related to higher costs of capital when financing investments externally, but also to a friction associated with secured borrowing. Strong stylised facts support the argument that the importance of this last friction, in particular, differs across firm size, amongst other characteristics.

In the US, arguably one of the most developed capital markets in the world, an analysis of supervisory level data suggests that secured borrowing accounts for more than 95% of credit lines to SMEs, whilst up to 70% of credit lines to large and very large companies are unsecured (Chodorow-Reich et al., 2021). Similar differences are also detected across firms' size for term loans and have remained stable over time (Avery et al. 1998). The importance of collateral is even higher in the EU, where around 80% of businesses finance their investments through secured borrowing (i.e., pledging collateral), with the percentage being higher for small and medium firms. Thus, SME access to external liquidity appears to be more constrained and more sensitive to collateral values.

The type of collateral pledged for secured credit access depends on the credit facility. SME credit lines are mostly backed by account receivables and inventory (AR&I). Half of term loans to SMEs have real estate backing instead, whilst fixed assets backing is more prevalent for larger firms (Chodorow-Reich et al., 2021). This suggests that the extent of collateral constraints also depends more heavily on the firm's location in the case of small businesses. If, upon default, fixed asset resell value is quite independent from the firm location (assuming transport costs to be marginal relative to the asset value), the real estate value instead largely depends on the attractiveness of the location for the business sectors that the real estate asset can accommodate. In fact, a hotel estate can hardly be turned into a manufacturing factory. The theoretical model presented in this paper accounts for these stylised facts and provides theoretical results on the effectiveness of investment incentives by firm size, sector and credit risk.

## 3 Theoretical Model

This research paper intends to innovate the theoretical models underlying previous literature contributions on the topic - with particular emphasis on Criscuolo et al. (2019) being the most relevant from a theoretical standpoint – on two fronts: a) the origin of credit constraints and the consequent characterisation of the type of "constrained" firms, and b) the production function suitable to model the effect of a reduction in the cost of capital on employment across firm size.

***Impact of interest rate subsidies on Capital K***

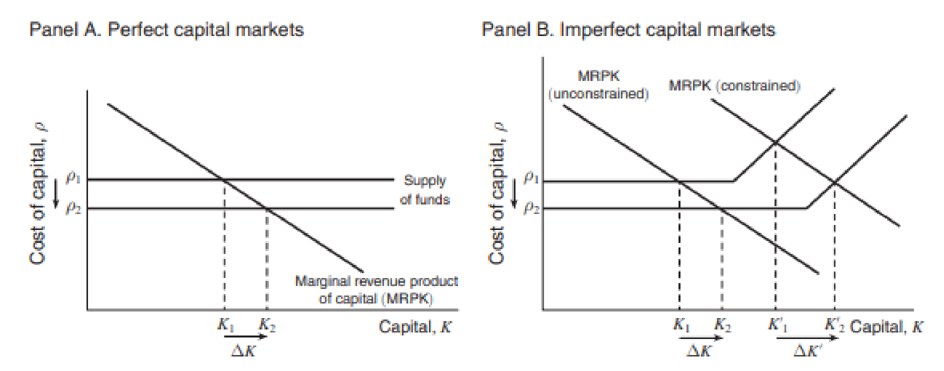
As in Criscuolo et al. (2019), investment subsidies can be considered as reductions in the cost of capital faced by the firm, using the Hall-Jorgenson cost of capital framework (King 1947), so that

$$\rho = \delta + \frac{r(1 - \varphi - \theta\tau)}{1 - \tau}$$

Where $\varphi$ is the investment grant, $\delta$ is the depreciation rate, $\tau$ is the statutory corporate tax rate, r is the interest rate and $\theta$ is the depreciation tax allowance. The cost of capital is falling in the generosity of the investment grant.

In the absence of credit market frictions, an investment subsidy corresponds to a decrease in the tax-adjusted user cost of capital ($\rho$) which leads to a downward shift of the supply of funds curve, generating an increase in the equilibrium level of capital, assuming a downward sloping marginal revenue productivity of capital curve, as illustrated in Criscuolo et al. (2019) (**Panel A in Figure 1**).

**Figure 1: Criscuolo et al. (2019) credit model**




But Criscuolo et al. (2019) concede that capital markets are not perfect and there exists a hierarchy of finance, based on pecking order financing hypothesis (Bond and Van Reenen, 2007). According to that model, a firm is “unconstrained” if it can finance the capital investment internally. Instead, it is “constrained” if it needs to resort to external debt or capital markets to finance the investment. This latter financing option implies a higher cost of capital, increasing with the amount of capital the firm needs to raise in external capital markets (hence the upward sloping curve in **Panel B of Figure 1**). In this framework, the “unconstrained” firm MRPK curve crosses the cost of capital curve in the flat part, whilst the “constrained” one crosses it in the upward sloping part. It follows that these “constrained” firms are subject to amplification effects and the same reduction in the cost of capital is associated with a higher increase in capital for the “constrained” firms than the “unconstrained” firms, thus specified. In the Criscuolo et al. (2019) framework, the credit access constraint arises from accumulation of capital beyond what can be financed internally. This framework implies that the firm always finances the project if the project’s Net Present Value (NPV) >0, or if MRPK>r but, within sector, small firms are more likely to hit internal financing constraints than larger firms and, consequently, are more likely to experience a higher cost of financing due to “pecking order” frictions.

Whilst this is a sufficient approximation for large firms located in markets with ease of direct access to financial markets, like the US, it does not consider frictions in accessing external financing due to secured borrowing requirements which, as already discussed in the previous section, are extremely relevant for small and medium firms and, more generally, firms located in markets where access to external financing still mostly occurs through financial intermediation and not directly through bond or equity markets.

In this paper, the Criscuolo et al. (2019) credit friction model is extended to account for constraints in the firm's investment demand, posed by the banking sector's secured lending rule. This aims to model the firm's inability to externally finance positive NPV projects when it lacks sufficient collateral to pledge against the investment loan.

In this model, the banking sector lends (secured) if two conditions pertaining to the investment project are satisfied: 1) the project presents a positive NPV, 2) the secured borrowing condition is satisfied, meaning that repossession sales – a function of assets pledged as collateral - are larger than or equal to expected losses, where $Expected\ Losses\ (EL) = financing\ exposure \times Probability\ of\ Default$

The Secured Borrowing Condition is obtained through the following model's building blocks:

A. *Repossession Sales*

(1) $$RPS = \nu C$$

(2) $$C = \text{cK}$$

(3) $$\nu = \alpha\bar{\nu} + (1-\alpha)\nu_l$$

Where ν is the recovery rate (i.e., the percentage of the collateral value obtainable upon liquidation net of the costs of liquidation), $C$ is the collateral asset which is a positive ($c > 0$) share of the total capital of the firm, $K$. The recovery rate ν can be decomposed into a recovery rate for "tradeable"/ "movable capital" $\bar{\nu}$ applicable to the share of capital assets which are movable ($\alpha$) and a location-dependent recovery rate $\nu_l$ applicable to unmovable assets (e.g., industrial real estate, heavy industrial machinery, access to location specific natural resources etc.).

B. *Expected Losses*

(4) $$EL = \Delta K(1+r) \times \pi$$

(5) $$\Delta K = \theta K$$

(6) $$\pi = \max[\pi_{sovereign}\,, (1-b)\pi_l + b\pi_f]$$

Where $\Delta K$ is the capital investment which can be thought of as a positive and unbounded share (θ, with θ >$c$) of the existing firm capital, r is the interest rate, π is the probability of default. The probability of default is lower bounded by the probability of default of the sovereign in which a given firm operates. It is otherwise a function of the location specific probability of default ($\pi_l$) adjusted for the firm-specific default probability ($\pi_f$). The extent of such adjustment depends on the factor $b$, $b \in$[0,1), with $b$=0 generally for distant transaction lenders and b>0 for local lenders for established firms, as they have better access to firm specific information (Inderst and Mueller, 2006). It assumes a competitive banking market b>0 only if $\pi_l > \pi_f$, otherwise firms would rather be financed by transaction lender than by local lenders, if they can get a better rate there (Inderst and Mueller, 2006). In the empirical testing of this model, I will later assume that i) the market is large enough $\pi_l \neq f(\pi_f)$, i.e., the average location specific default probability is exogenous to the firm specific probability of default, ii) the screening is difficult enough, which implies that $b \ll 1$ ; hence π is largely exogenous to the single firm characteristics.

Therefore, the Secured Borrowing Condition can be expressed, as follows:

$$vcK \geq \theta K(1+r)\pi$$

$$K - \frac{\theta}{c} K(1+r)\frac{\pi}{v} \geq 0$$

which becomes,

$$K\left(1 - \frac{\theta\pi}{cv}(1+r)\right) \geq 0 \qquad (7)$$

It is then possible to derive the marginal effects, later constituting the proposed testing hypotheses for the model:

[C.1] $$\frac{\partial SBC}{\partial K} = \left(1 - \frac{\theta\pi}{v}(1+r)\right) = \frac{v - \theta\pi(1+r)}{v}$$

$$v > 0$$

$$v > \theta\pi(1+r) \text{ by construction in SBC}$$

Hence $\frac{\partial SBC}{\partial K} > 0$. The higher the initial capital, the lower the probability of constraint to secured credit access.

Assuming K=1 for simplification:

[C.2] $$\frac{\partial SBC}{\partial \theta} = -\frac{\pi}{cv}(1+r) < 0$$

Hence, the larger the investment, the higher the probability of constraint in secured credit access.

[C.3] $$\frac{\partial SBC}{\partial \pi} = -\frac{\theta(1+r)}{cv} < 0$$

Hence, the higher the probability of default, the higher the probability of constraint in secured credit access.

[C.4] $$\frac{\partial SBC}{\partial r} = -\frac{\theta\pi}{cv} < 0$$

Hence, the higher the interest rate, the higher the probability of constraint in secured credit access.

[C.5] $$\frac{\partial SBC}{\partial v} = \frac{\theta\pi(1+r)}{cv^2} > 0$$

Hence, the higher the recovery rate, the lower the probability of constraint in secured credit access.

[C.6] $$\frac{\partial SBC}{\partial c} = \frac{\theta\pi(1+r)}{c^2 v} > 0; \qquad \frac{\partial^2 SBC}{\partial c^2} < 0$$

Hence, the higher the size of collateral pledged, the lower the probability of constraint in secured credit access. Furthermore, there is a decreasing marginal gain in the reduction of constraint probability, with an increase in collateral size.

In the more detailed SBC specification, additional marginal conditions can be derived:

$$[\alpha\bar{v} + (1-\alpha)v_l]cK \geq \theta K(1+r)[(1-b)\pi_l + b\pi_f]$$

$$K\left(1 - \frac{\theta[(1-b)\pi_l + b\pi_f]}{c[\alpha\bar{v} + (1-\alpha)v_l]}(1+r)\right) \geq 0$$

[C.7] $$\frac{\partial SBC}{\partial \alpha} = +\frac{\theta}{c}(1+r)[(1-b)\pi_l + b\pi_f]\frac{1}{[\alpha\bar{v}+(1-\alpha)v_l]^2}(\bar{v} - v_l)$$

[C.7a] $$\frac{\partial SBC}{\partial \alpha} > 0 \; if \; \bar{v} > v_l$$

[C.7b] $$\frac{\partial SBC}{\partial \alpha} < 0 \; if \; \bar{v} < v_l$$

If the movable capital recovery rate is higher than the local recovery rate for unmovable assets, then the higher the share of unmovable capital, the higher the probability of constraint in secured credit access.

[C.8] $$\frac{\partial SBC}{\partial b} = -\frac{\theta}{c}(1+r)\frac{1}{[\alpha\bar{v}+(1-\alpha)v_l]}(\pi_f - \pi_l)$$

[C.8a] $$\frac{\partial SBC}{\partial b} < 0 \; if \; \pi_f > \pi_l$$

[C.8b] $$\frac{\partial SBC}{\partial b} > 0 \; if \; \pi_f < \pi_l$$

If the firm specific probability of default is higher than the local probability of default, the higher the local banking dependence, the higher the probability of constraint in secured credit access.

In the Secured Borrowing Condition, defined as in eq.(7), upon a loan request $\theta K$ from a firm endowed with $K$, there are two choice parameters for the financial lending institution: the interest rate and the size of collateral, respectively $r$ and $c$.

As the SBC marginal conditions C.4 and C.6 suggest, an increase in the size of collateral (c) is associated with an increase in the likelihood of satisfying the borrowing condition, as it increases the revenues from repossession sales if the borrower were to default. An increase in interest rate (r) is instead associated with a reduced likelihood of satisfying the borrowing condition, given the higher debt servicing costs deriving from it and, therefore, the higher expected loss. This is consistent with the common stylised facts associated with monetary policy on access to credit, according to which a lower interest rate increases access to credit and stimulates investment. This does not refute the concept of risk-adjusted returns and risk premiums in lending rates, but it highlights the trade-off between risk reward and borrower's solvency, which financial institutions need to balance, given the endogeneity of default probabilities and banks' balance sheet management. This suggests, therefore, that the size of collateral is the parameter around which banks have the highest discretion when trying to satisfy the SBC.

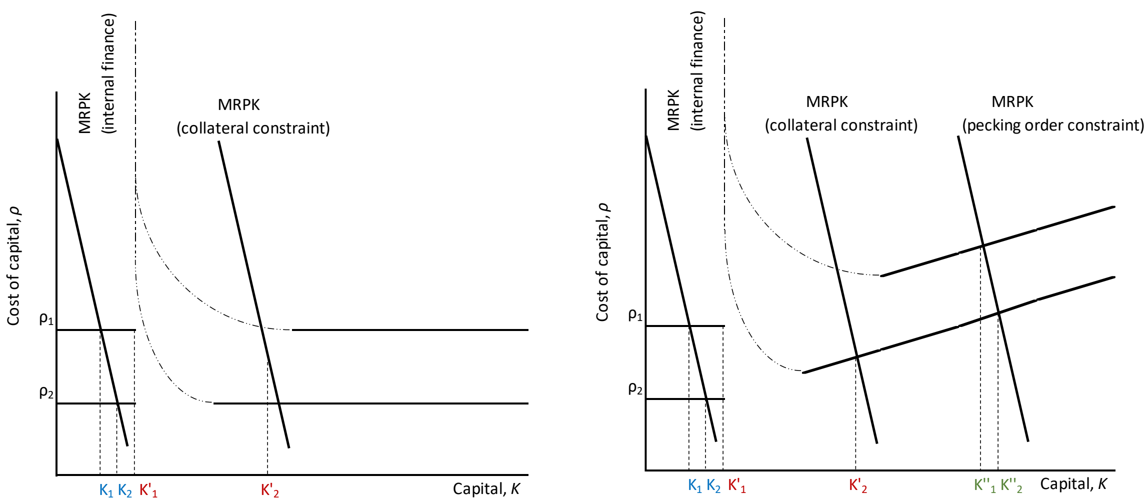
Holding the other parameters as exogeneous, upon a loan request $\theta K$ from a firm endowed with $K$, any bank can satisfy its SBC demanding a certain collateral size $c^D \in (0, +\infty]$. Firms are considered as price-takers in this model and, whilst $c^D$ can be above 1, firms can pledge at most their full capital as collateral, thus $c^S \in (0,1]$. This suggests, therefore, a non-continuous function in capital (K) for firms' access to investment, as shown in **Panel A of Figure 2.**

**Figure 2: Effect of investment subsidies in imperfect capital markets with secured borrowing**

***Panel A****: Collateral requirement as only friction between internal and external financing*

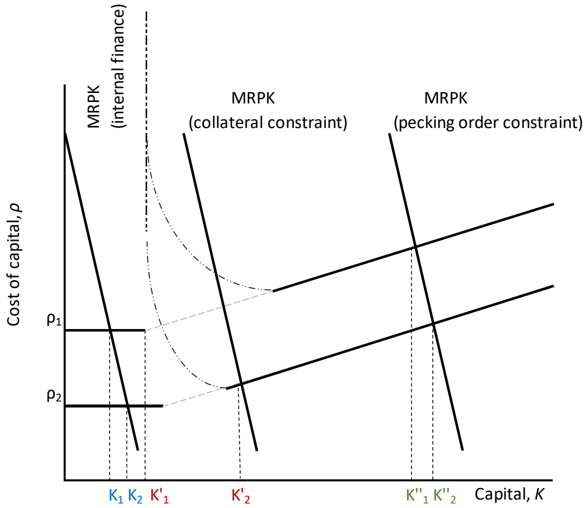
***Panel*** *B: i) Collateral requirement and*

*ii) increasing cost of capital as frictions between internal and external financing*



***Panel C**: i) Collateral requirements and ii) increasing cost of capital as frictions between internal and external financing, iii) endogenous internal financing limit*




### *Impact of Interest Rate subsidies on Capital*

In the most comprehensive model represented in *Panel C,* ΔK'> ΔK, meaning that for collateral constrained firms, a decrease in the cost of capital results in a larger capital increase than for unconstrained firms who internally finance their investments and for firms "pecking order" constrained (i.e., financing their capital investments via capital markets). The relative impact of a decrease in the cost of capital between unconstrained firms internally financing their investments (ΔK) and firms "pecking order" constrained (ΔK") is uncertain and depends on a number of factors: holding the "capital inflection point" (i.e., the level of capital corresponding to the internal financing limit – K'1 in *Panel B*) unaltered from a change in the cost of capital, the steeper the external cost of capital function the smaller ΔK" relative to ΔK. That is offset, however, by a responsiveness in the internal financing capability limits, to changes in the cost of capital (*Panel C*). The balance between these two effects determines the relative impact of Δρ on capital changes for these two groups of firms.

$$MRPK \quad \rho^D = q - mK$$

For unconstrained firms internally financing,

$$\rho^S = \rho$$

Hence,

$$\Delta K = -\frac{\Delta\rho}{m}$$

For constrained firms, the impact of a reduction in the cost of capital instead changes, depending on the frictions considered in the model. We will show here how the impact differs between the model presented in Panel B and the one in Panel C, with the latter being the most comprehensive model, providing the theoretical grounding for the rest of the paper.

In the model of *Panel B* firms face internal financing limits, independent from the cost of capital.

For Pecking Order constrained firms with internal financing limits η,

$$\rho^S = \rho - \eta m + \gamma K$$

$$\rho^{S'} = \rho + \Delta\rho - \eta m + \gamma K$$

$$\Delta K = -\frac{\Delta\rho}{\gamma + m} = \Delta K'$$

Hence, it is possible to see how the larger $\gamma$ is, the smaller ΔK' is relative to ΔK.

In model of *Panel C* with firms' internal financing limit η depending endogenously on the cost of capital and a Δρ reduction in the cost of capital is associated to a $\Delta\eta(\rho)$ change in the internal financing limit,

$$\rho^S = \rho - \eta m + \gamma K$$

$$\rho^{S'} = \rho + \Delta\rho - (\eta + \Delta\eta)m + \gamma K$$

$$\Delta K = -\frac{\Delta\rho - m\Delta\eta}{\gamma + m} = \Delta K''$$

Hence, it is possible to see how the larger $\Delta\eta(\rho)$ and $m$, the greater would be the elasticity of capital to a change in cost of financing, relative to *Panel B* model. Furthermore, in *Panel C* the relative size of ΔK" (the change in capital for pecking order constrained firms) relative to ΔK (the change in capital for firms internally financing) depends on the balance between $\Delta\rho \times \frac{\gamma}{m}$ and $m \times \Delta\eta$. With

$$\Delta K'' > \Delta K \ if \ \Delta\rho \frac{\gamma}{m} > -m\Delta\eta$$

$$\Delta K'' < \Delta K \ if \ \Delta\rho \frac{\gamma}{m} < -m\Delta\eta$$

The derivation of the supply of funds curves and the associated proofs are detailed in **Section A of the Appendix**.

### *Impact of Interest rate subsidies on Employment and Output: a non-homothetic preferences approach*

A standard production function Y=F(K,L) with Constant Elasticity of Substitution (CES) between Labour and Capital, homothetic preferences and perfect competition in all markets, is generally assumed in the existing body of literature empirically investigating the impact of investment subsidies on private allocation of production factors and output (Criscuolo et al. , 2019; Bernini and Pellegrini, 2011; Bernini et al., 2017). Whilst a reduction in the cost of capital is unequivocally associated with an increase in capital, as previously discussed, from the Marshallian conditions of derived demand, the impact on employment of a change in the cost of capital ($\partial L/\partial\rho$) depends on the elasticity of substitution between labour and capital ($\sigma$), the share of capital in total costs ($s_K$) and the absolute price elasticity of product demand (Hamermesh, 1990). Thus, the sign of the net effect on employment depends on the relative size of the scale effect (ϕ) and the substitution effect (σ), with the effect being amplified when capital accounts for a larger share of production factors ($s_K$).

$$\frac{\partial L}{\partial\rho} = s_K(\sigma - \varphi)$$

Under the assumption of homogeneous preferences across firm size, this framework suggests a linear expansion path in output and, therefore, a directionally homogeneous impact of a reduction in the cost of capital on employment and an optimal mix of capital and labour factors, largely dependent on their relative prices.

Criscuolo et al. (2019), Bernini and Pellegrini (2011) and Bernini et al. (2017) find that, in general, investment subsidies increase employment, thus suggesting that the scale effect is dominating the substitution effect. Leaving aside considerations related to the practical difficulties faced in obtaining an unbiased estimate of impact on employment given the employment conditionality clauses generally associated with the subsidy programmes[2], based on the reasoning illustrated above, this finding should be homogeneous across firm size, to be consistent with the theoretical model generally chosen to back the empirical analysis. However, larger firms are found to increase their employment, as a result of the subsidies, by less than the smaller firms, if at all. This finding is mostly attributed to large firms being better at gaming the system and less subject to scrutiny (Criscuolo et al. 2019).

Although possible, this proposed explanation is, however, not backed by additional evidence; the fact that the same empirical finding also occurs across different countries, programmes and different levels of institutional quality generates additional explanations, grounded in empirical evidence and/or theory.

This paper investigates the relaxation of the homotheticity assumption for production factor preferences, as a more appropriate theoretical framework for investigating changes in factor prices on factor allocations and output across firms of different sizes, including also small firms.

Under homogeneity, competitive markets and Hicksian neutral technological progress, a CES production function's marginal rate of substitution between labour and capital ($\omega$) is related to factor allocation as follows:

$$\log(k) = \log(a) + \sigma\log(\omega)$$

Where $k$ is the capital-to-labour ratio (K/L) and σ is the CES between labour and capital.

Empirically, however, the capital-to-labour ratio has been shown to vary - even at constant price ratio (del Rio and Lores, 2018) and across firm size and sector (Leonardi, 2007). But the difficulty in the reconciliation of the result of the theoretical model with the empirical evidence is matched by an equal mismatch between the assumptions underlying homothetic preferences between labour and capital allocation and the empirically observed firm structure.

Simply put, there cannot be a firm without workers. In the most extreme case, a sole-tradership still counts one worker, the self-employed. In some sectors, regulatory and scale-barriers mean that the minimum number of workers operating the business is actually more than one. This implies that flexibility around factor

[2] The UK RSA programme analysed by Criscuolo et al. (2019) conditions the fund to the creation or safeguard of jobs; in the L.488 subsidies programme in Italy analysed by Bernini and Pellegrini (2011) and Bernini et al. (2017) instead the number of jobs created increases the chances of obtaining the investment subsidies through the auction mechanism.

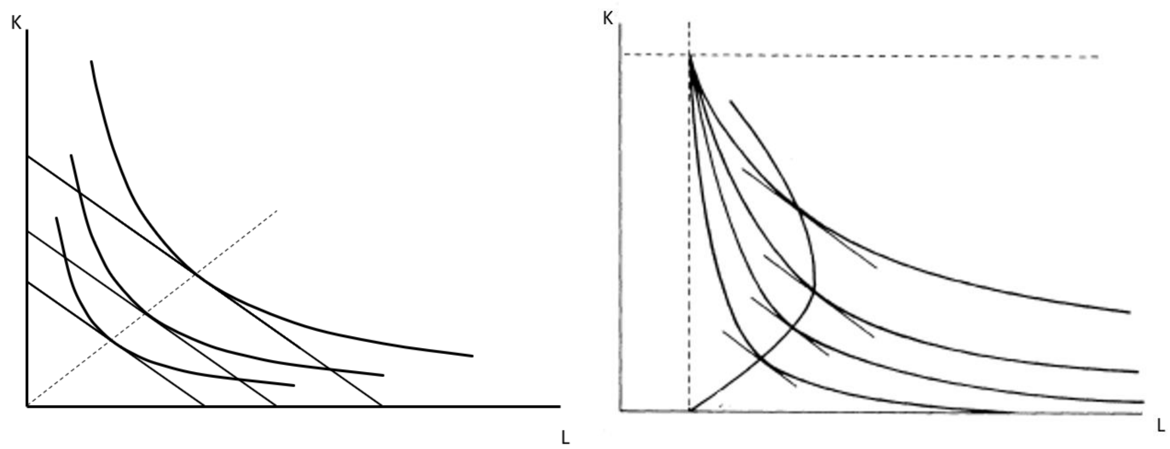
composition reduces as the firm size shrinks, given the greater likelihood of hitting operational workforce constraints.

Homothetic preferences do not allow accounting for such constraints when assessing changes in factor allocation, in response to changes in factor prices. Sato (1977) shows that a relaxation of homotheticity allows for this and there exists a class of non-homothetic production functions still characterised by CES, of which standard homothetic CES functions are a special case.

NH-CES production functions are characterised by a variable marginal rate of substitution even at constant factor prices, translating into a non-linear expansion path of preferences (Panel B, Figure 3), as opposed to the linear expansion path of H-CES traditional production functions (Panel A, Figure 3).

**Figure 3: Expansion paths for Production Functions with Constant Elasticity of Substitution**

***Panel A**: CES Homothetic Preferences* ***Panel B**: CES Non-Homothetic Preferences*




Sato (1977) provides an in-depth discussion of the properties and different classifications of the class of NH-CES production functions. For the purposes of this paper, it is assumed that firms operate according to a production function characterised by a constant non-homotheticity parameter, CES between factors of production and asymptotical behaviour in L (as in **Panel B of Figure 3**). This corresponds to the following functional form[3]:

$$Y^{\zeta} = \frac{b - L^{-\psi}}{s_K K^{-\psi} - a}$$

$$\psi = \frac{(1-\sigma)}{\sigma}$$

Such functional specification retains positive but decreasing marginal products of capital and labour, like in the case of a standard H-CES/Cobb-Douglas function commonly adopted in literature. It differs however, as discussed, in the marginal rate of substitution (ω) between capital and labour, which is equal to,

$$\omega = \frac{\partial Y/\partial L}{\partial Y/\partial K} = \frac{Y^{-\zeta}}{s_K}\left(\frac{K}{L}\right)^{1/\sigma}$$

and is log-linearisable as follows,

$$\log(k) = \sigma \log(s_K) + \sigma \log(\omega) + \sigma\zeta \log(Y)$$

Where $k$ is K/L as before, $Y$ is the output level, $s_K$ is the share of capital in total costs, σ is the CES between labour and capital, and $a$ and $b$ are constants. $Y^{\zeta}$ provides a constant homotheticity parameter with MRS variation with output.

This model suggests that the balance between scale and substitution effect changes with the firm's output level. Given a decrease in the cost of capital relative to the cost of labour, the model suggests that the substitution effect is going to be stronger in large firms than small firms. This implies that scale effects in response to that are more likely to dominate substitution effects in the context of small firms than large firms, where factor reallocation is more sensitive to changes in relative prices.

### *Summary of Theoretical Model Results*

Overall, these theoretical models provide several predictions, later tested in the empirical analysis.

[3] To be valid (ie. $Y \geq 0$) over the domain $K, L \in [0, +\infty)$, the following condition of existence applies: either $b \leq 0 \lor a \geq 0$, or $b \geq 0 \lor a \leq 0$.

First, the investment subsidy is expected to have a positive effect on investment and, therefore, capital accumulation. Such impact, at local level (in which $r$ and $b$ are constant), is expected to be negatively related to the initial capital stock (i.e., size of the firm), and positively related to the firm's probability of default (firm specific $\pi_f$, and location-sector specific $\pi_{s,l}$) and the relative size of the investment subsidised (θ). The impact of investment subsidies is also expected to be related to the share of unmovable assets $(1-\alpha)$, with the sign of their relationship depending on the location of the business from ranks in terms of demand for industrial real estate at national level $(\nu_l)$. The effect is expected to be greater, the larger the share of unmovable assets in areas with lower industrial density (associated to a less liquid market and, hence, lower recovery rate from bank repossession sales).

Second, the investment subsidy will have a positive effect on employment, if the scale effect outweighs the substitution effect. In the non-homothetic preferences model adopted, this is more likely to occur in the case of smaller firms, given the smaller substitution effect they are likely to experience from a reduction in the cost of capital relative to larger firms. Furthermore, given the higher capital increase small firms are expected to experience relative to larger firms (due to size and probability of default as just discussed), scale effects are also going to be stronger for smaller firms. This suggests that, whilst uncertainty remains over the sign of the net effect on employment, the theoretical models adopted in this paper suggest that investment subsidies should result in a larger increase/lower decrease in employment for small firms relative to larger firms. Likewise, the impact on output should be positive and larger for smaller firms.

## 4 Empirical Identification Strategy

Unlike most other literature contributions studying the impact of investment subsidies on private business outcomes, this paper does not aim to deliver an *ex-post* impact evaluation of a specific investment subsidy programme part of a development policy. Instead, it exploits the exogenous receipt of capital subsidies, as part of a post-disaster emergency policy intervention, to derive causal estimates of the impact of investment subsidies on firms' capital, labour and output. This is the first contribution adopting a similar identification strategy to my knowledge, at least within the context of Italy, for which studies on the impact of investment subsidies largely focus on L.488 policy impact evaluation.

The choice of this specific identification strategy enables two main contributions to the existing empirical evidence on investment subsidies. First, it provides an improvement to the robustness of the causality nexus, particularly in the case of the estimates on employment, given the often-observed conditionality of investment subsidy programmes on increasing or, at least, not reducing employment upon receipt of the subsidy. Second, it allows assessment of the impact of investment subsidies on firms that generally do not receive them, in the case of subsidy programmes aimed at placed-based development (such as L.488 in Italy and RSA in the UK), not being the target population. The investment subsidy programmes part in place-based development policies tend, in fact, to allocate subsidies to "local champions" – often very locally competitive medium-sized firms - because of the allocation system design, generally rewarding firms proposing higher shares of co-financing and higher increases in employment associated with the subsidies (Criscuolo et al., 2019; Bernini and Pellegrini, 2011). By also providing quasi-experimental evaluation on the extension of investment subsidy programmes to non-target firms, the takeaways of this paper can be used to assess the potential of changes to current programmes and to inform future policy-design.

Since 2012, the post-disaster policy toolkit in Italy has been extended to offer investment subsidies, alongside long-standing state-sponsored reconstruction funding for the areas affected by natural disasters. By not being part of a specific development policy, but an emergency response to stimulate economic recovery in the areas affected by natural disasters, there is no centralised regulation defining the policy's eligibility requirements and implementation. Instead, investment subsidies are d legislated in each of the emergency decrees listing post-disaster interventions. Despite the lack of a permanent programme regulation, the subsidies programme has, however, remained largely consistent and unvaried since its introduction, allowing for a comparison of outcomes across different disaster events.

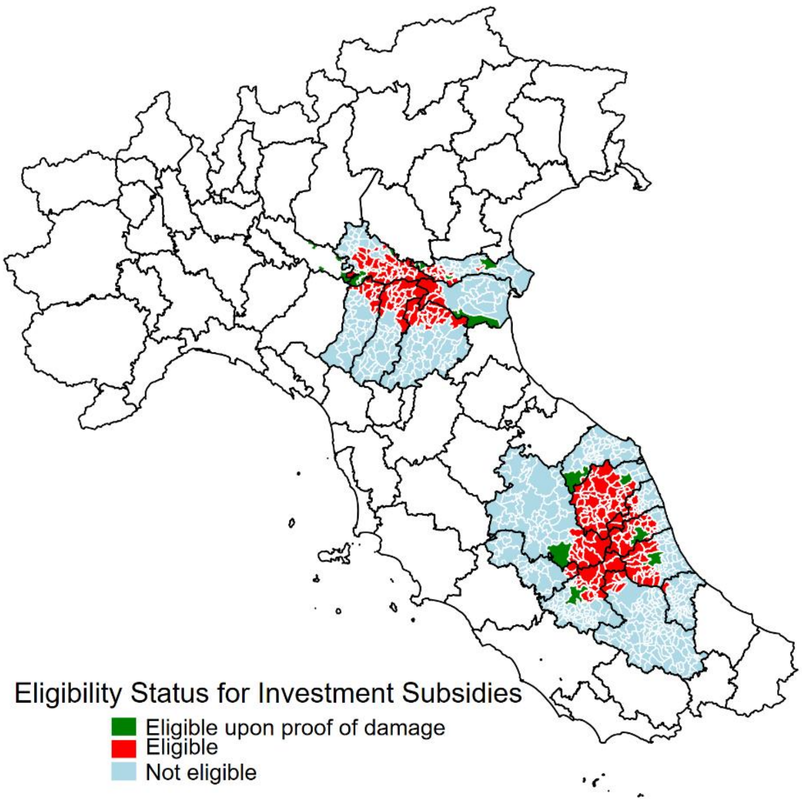
This paper focuses on the investment subsidies provided following major earthquake disasters since 2012. This includes the 2012 earthquake in Northern Italy, the 2016 event in Central Italy and the 2017 occurrence in Abruzzo, with the subsidy programmes regulated respectively by Art. 11 D.L. 74, Art. 20 D.L. 189 and Art. 18 D.L. 8. Although major floods and landslides have also benefited from such an emergency response, restricting the analysis to earthquakes ensures consistency in disaster dynamics across the events and leverages the destruction modelling already presented in Mari (2020) for the 2012 earthquake.

The programme provides a state-sponsored reduction in interest rate on loans undertaken to finance investments in the areas affected by the earthquake, with priority given to firms headquartered or operating in those territories, until exhaustion of the resources allocated to the local administrations. No conditionality is associated with the loans, which have a term limit of 15 years and are capped at €25 million per firm. Investment location constitutes the only formal eligibility requirement to access the programme (for most municipalities) but given that the interest rate reduction occurs on loans financed through the banking sector, by implication, eligibility for credit from the banking sector is also associated with the programme.

The eligibility for the investment subsidy programme extends well beyond the areas located in the near proximity of the epicentre and generally covers all municipalities that experienced a seismic intensity of at least 6 in one of the seismic shocks. The eligible municipalities are shaded in red in **Figure 4**. However, businesses located in large municipalities located at the "policy border", tend to be eligible for the subsidies but only upon proof of damage to their property attributable to the seismic shock – this is the case for the municipalities shaded in green in **Figure 4**. As the identification mechanism presented in this paper relies on the receipt of investment subsidies absent any damage to the firm from the earthquake, only firms located in the red areas – eligible without conditions – are considered as allocated for treatment. The control pool is generated from firms located in municipalities not eligible for treatment within the provinces with at least one municipality unconditionally eligible for treatment (light blue shaded areas in **Figure 4**).

**Figure 4: Eligibility for Investment Subsidies by NUTS 4**




The existence of a geographical policy border not coinciding with NUTS 2 or NUTS 3 borders allows one to match treated firms with suitable control firms located within the same regions, thus providing a better control for unobserved firms' characteristics than in the case of L.488 policy assessments (Bernini and Pellegrini, 2011; Bernini et al., 2017). The identification design associated with L.488 (the main other investment subsidies programme providing evidence on the topic in the context of Italy), in fact, only allows for comparisons of firms across regions and years to obtain a match, thus also introducing possible institutional differences amongst the local production environment and time effects.

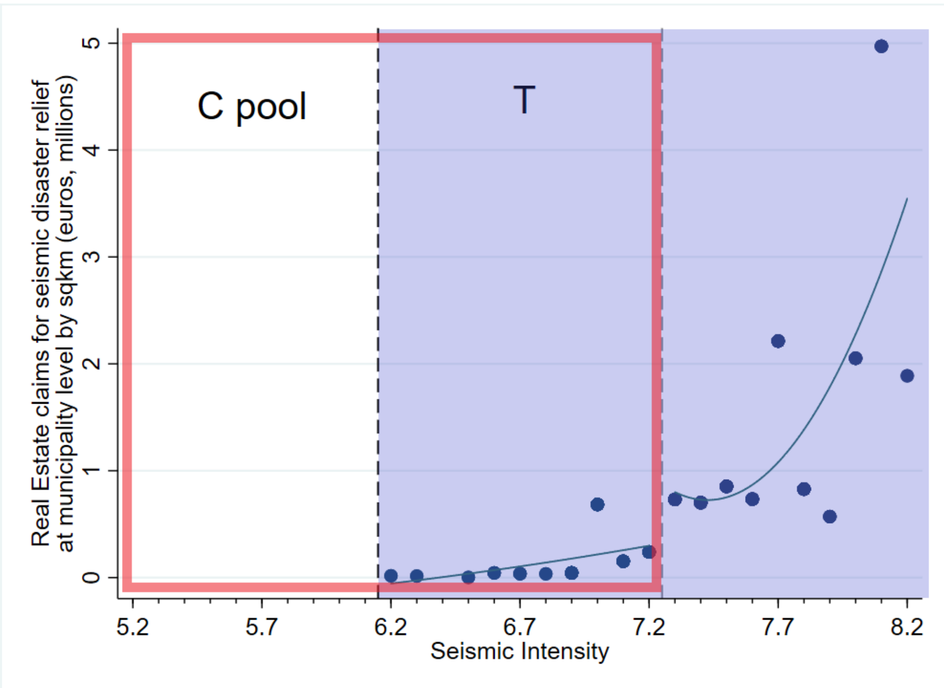
# 5 Econometric Modelling Strategy

The identification approach in this paper relies on a matching procedure within sector of economic activity and NUTS 3 region, between treated firms and non-eligible firms located in proximity of the spatial discontinuity for treatment eligibility.

The matching procedure allows one to estimate the policy effect at local level under the assumption of a constant risk-free rate ($r$) and relationship lending structure ($b$), and no confounding effect of significant relocation/destruction of physical and human capital (as would be the case for firms located near to the epicentre of the earthquake being considered). This, together with the limited size of the programme, ensures the absence of general equilibrium effects affecting the estimates.

Insights on the treatment effect are captured through two econometric models, estimated by restricting the matches to those with a treated firm located in a municipality having experienced a seismic intensity below 7.25, the threshold associated with a discontinuation in the size of structural damages (**Figure 5**).

**Figure 5: Identification set up for 2012 earthquake**




The first model is a simpler specification aimed at detecting aggregate results on the outcomes of interest by size of firm.

$$\Delta \boldsymbol{Y}_{\boldsymbol{f,t}} = \beta_0 + \beta_1 T_f + \beta_2 Small_f + \beta_3 Medium_f + \beta_4 (Small_f \times T_f) + \beta_5 (Medium_f \times T_f) + \boldsymbol{X}_{\boldsymbol{f,t}} + \varepsilon_{f,t}$$

In the regressions above, $\Delta \boldsymbol{Y}_{\boldsymbol{f,t}} \equiv \boldsymbol{Y}_{\boldsymbol{post-T}} - \boldsymbol{Y}_{\boldsymbol{pre-T}}$ is the logarithmic change in the outcome variables post-treatment, with capital, employment, output (proxied by operating revenue) and productivity (proxied by revenue per worker) being the outcomes of interest. $T_f$ is a dummy for having received the investment subsidies. $Small_f$ and $Medium_f$ are dummies controlling for the firm size, whilst $\boldsymbol{X}_{\boldsymbol{f,t}}$ is a vector of covariates including dummies controlling for the credit rating of the firm, the relative importance of the subsidised investment and the coverage ratio of the subsidy.

The second model, instead, aims to capture additional heterogeneity of the effect by the parameters identified in the theoretical results. To do so, the treatment dummy is interacted with a series of empirical variables representing or proxying the theoretical model drivers presented in Section III (Table 1). These variables are also included as individual controls, like in the case of the treatment dummy.

**Table 1: Econometric model interactions**

| Econometric model interaction with T | Theoretical model variable | FOC |
|---|---|---|
| Investment's size (as share of capital) | Investment's size | $\partial SBC/\partial \boldsymbol{\theta} < 0$ |
| Interaction between sector of the firm and business density for sector in NUTS 4 region where the firm conducts its business activities | Location-specific recovery rate | $\partial SBC/\partial \boldsymbol{v\_l} > 0$ |
| Firm's size dummies | Collateral's size | $\partial SBC/\partial \boldsymbol{c} < 0$ |
| Interaction dummies between the size and sector of the firm | Share of unmovable capital if the movable capital recovery rate is higher than the local recovery rate for unmovable assets | $\partial SBC/\partial \boldsymbol{\alpha} > 0$ if $\bar{v} > v\_l$ |
| | Share of unmovable capital if the movable capital recovery rate is lower than the local recovery rate for unmovable assets | $\partial SBC/\partial \boldsymbol{\alpha} < 0$ if $\bar{v} < v\_l$ |
| Average annual probability of default before the treatment year for sector and NUTS 3 region the firm operates from; | Location-specific probability of default | $\partial SBC/\partial \boldsymbol{\pi\_l} < 0$ |
| Dummies for the firm-specific estimated credit rating before the treatment year | Firm-specific probability of default | $\partial SBC/\partial \boldsymbol{\pi\_f} < 0$ |
| Coverage ratio of the investment incentive (ratio between the subsidised part of investment financing and the total financing cost) | Interest rate | $\partial SBC/\partial \boldsymbol{r} < 0$ |

Whilst in some cases the empirical variables perfectly mimic the ones contained in the theoretical mode, in other instances proxying or variable construction is needed, due to the lack of available data on the original model variables.

The interaction between the coverage ratio of the investment incentive and the treatment dummy aims to control for the relative intensity of treatment across the firms which received it. This is a proxy for the change in the interest rate.

The interaction between sector and size dummies aims to detect the heterogeneity of the policy impact by share of unmovable assets (1-α), which are assumed to be structurally determined by the sector and size of the firm (Chodorow-Reich et al., 2021). The interaction, instead, between sector dummies and business density aims to detect the heterogeneity of the policy impact by the location-specific recovery rate of unmovable assets ($v_l$). The rate of recovery of unmovable assets depends on the demand for industrial real estate with the same operational characteristics as the one that would go on sale upon default. It is assumed that the sectoral classification provides a sufficient representation of the operational characteristics of the industrial real estate a business operates from and of the associated segmentation of the industrial real estate market. The level of demand is proxied by the sectoral business density at NUTS 4 location, as it provides a good representation of agglomeration forces at local level and real estate market liquidity.

The firm-specific estimated credit rating before the treatment year is controlled through a series of dummy variables. This is obtained for the treated firms and their matched controls, by estimating a default probability from a survival model fit over the whole population of Italian firms on Historical Orbis (subject to data availability) from 1990 to 2019, and later converting it into a credit rating.

A Cox-Proportional hazard model stratified by firm size $h(t, \boldsymbol{X}(t), \boldsymbol{\beta}) = h_0(t)\, exp(\boldsymbol{\beta} \cdot \boldsymbol{X}(t))$, is adopted to model the firm-specific probability of default. This is consistent with other literature applications (Ferragina et al, 2009 in the context of Italy) and evidence pointing to the higher performance of Cox-Proportional hazard models over alternatives in credit scoring for retail credit (Dirick, 2017). Representing the hazard at time $t$, $h_t$ corresponds in this application to the annual probability of default at time $t$ for firm $f\,(\pi_{f,t})$; $h_0$ represents the baseline hazard rate, thus corresponding to the baseline probability of default at time 0 ($\pi_0$), and $X_{f,t}$ is a vector containing splines functions of covariates affecting firm survival.

$$\pi_{f,t} = \pi_{0,t} exp(\boldsymbol{\beta}' \boldsymbol{X}_{f,t}) + \epsilon_{f,t}$$

Additional details on the estimation and credit grade slotting are contained in **Section B.1 of the Appendix.**

As discussed in the previous section, eligibility for treatment occurs as a result of a random natural disaster shock, so is in itself spatially exogenous. But eligibility for treatment does not necessarily correspond with treatment given, implying an independent decision from the firm asking for external financing for an investment project and obtaining it from the banking sector. Therefore, within eligible municipalities, treatment is not fully random. This implies that firms not getting treated within eligible municipalities are not a suitable control group for those who do get treated, but they are useful for gauging factors which affect the propensity of receiving treatment, in order to ensure that the match between treated firms with the control pool of ineligible firms is appropriate.

The propensity for treatment appears to be significantly related to the size of the firm and the economic sector in which it operates. Within the eligible firms, being small in size and operating in the agricultural sector are two factors that significantly decrease the probability of receiving treatment (additional details contained in **Section B.2 of the Appendix**). This suggests the need for matching treated firms with untreated ineligible firms characterised by the same size and operating in the same sector of economic activity and NUTS3 region. Subject to these three hard constraints, the match with the control pool is achieved by minimising the Mahalanobis distance for a series of firm's financial characteristics observed before the seismic shock[4]. Mahalanobis distance matching with replacement is favoured over the option without replacement, in order to reduce bias; particularly given the large control pool, concerns of an associated trade-off with estimate precision are minimal. Robustness checks of the regression results between the matching option, with and without replacement, are nonetheless provided in the paper.

Finally, the analysis is restricted to firms falling within the eligible area but away from the epicentre and having experienced a seismic intensity below 7.25 (but above 6 - the threshold for treatment eligibility) – the level associated with a discontinuation in the extent of damages to physical capital (Mari, 2020). This further strengthens the exogeneity of the eligibility for treatment, as it weakens the link between eligibility and post-earthquake business side effects (e.g., caused by a loss of productive assets, loss of customers etc...).

[4] The constrained match is obtained by minimising the Mahalanobis distance for the pre-shock 3 year average of capital level, operating revenue, estimated firm specific probability of default, number of employees, debt-to-asset ratio, debt-to-equity ratio, share of employment for the firm's sector in the firm's municipality, total assets, business density of the firm's sector in the firm's municipality, cost of employees (when available) and yearly capital growth rate (when available).

# 6 Data

This subsection provides details on the datasets used in the analysis.

Data on the investment subsidies, handed out by the Italian Government as part of the post-disaster policy package for seismic events, are obtained from the OpenCup database, the official open data platform of the Italian government for public investments. A detailed discussion of the OpenCup database is provided in Mari (2020)[5]. Given the reduced coverage of the database for projects carried out in the early 2000s, we focus on investment subsidies legislated following the 2012, 2016 and 2017 earthquakes. The identification of records referring to the investment subsidies object of this paper has been carried out through a text search, within the database records of projects carried out in the provinces identified as eligible for the investment subsidies (**Table B1.A in Section B1 of the Appendix** contains the list of all the municipalities deemed eligible). A total of 2,416 records matched the search parameters, distributed across the regions of Abruzzo, Emilia-Romagna, Lazio, Lombardia, Marche, Toscana, Umbria and Veneto (**Table B1.B in Section B1 of the Appendix**), with details on the date of financing approval, the subsidy amount, the description and categorisation of the intervention and information on the receiving business (business name, address, sector of economic activity and tax code).

Financial data on the firms identified as receivers of the investment subsidies (2,367 unique firms) is obtained by matching OpenCup records with Orbis Historical records by tax code when available, and business name and municipality in the absence of that. Data is updated to end of 2020 balance sheets, when available. A match rate of 72% is achieved, slightly lower but comparable to the one of Pellegrini (2011) for firms obtaining L.488 incentives. The lower match can be attributed to the fact that, whilst firms obtaining L.488 incentives are generally "local champions" given the competitive process, in this case funds were assigned exclusively on the location eligibility requirement, thus resulting in a higher share of "micro" firms obtaining them, which notably have a lower representation in Orbis Historical records.

Overall, in terms of business size[6], small firms account for 53% of the treated sample, followed by medium firms accounting for 37% (**Table 1**). Sector-wise,

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[5] R. M. Mari, "When Capital Falls to Pieces: Public Investment and the Role of Private Capital Stock", 2020, Appendix Section A.2.

[6] The size classification adopted here closely follows Orbis size classification. A firm is considered "very large" if it presents operating revenues above or equal to $130mio, or total assets above or equal to $260mio, or over 999 employees; "large" if operating revenues are above or equal to $13m, or total assets above or equal to $26m, or over 149 employees;

manufacturing is the most prevalent sector, with 47% of the sample firms engaged in that activity. Wholesale, retail trade and repair of motor vehicles and motorcycles is the second largest sector represented in the sample (19%), followed by construction activities (9%) – both sectors being characterised by prevalently small firms.

**Table 1: Economic Activity and Size distribution of Treated firms**

| | | Size | | | | |
|---|---|---|---|---|---|---|
| **Economic activity** | **NACE2 code** | *Very Large* | *Large* | *Medium* | *Small* | *Total* |
| Agriculture, Forestry and Fishing | A | 0 | 1 | 6 | 52 | 59 |
| Mining and Quarrying | B | 0 | 2 | 3 | 1 | 6 |
| Manufacturing | C | 2 | 147 | 521 | 339 | 1,009 |
| Electricity, Gas, Steam and Air Conditioning Supply | D | 1 | 1 | 4 | 3 | 9 |
| Water Supply; Sewerage, Waste Management and Remediation Activities | E | 0 | 2 | 8 | 6 | 16 |
| Construction | F | 0 | 9 | 43 | 148 | 200 |
| Wholesale and Retail Trade; Repair of Motor Vehicles and Motorcycles | G | 0 | 43 | 137 | 221 | 401 |
| Transportation and Storage | H | 0 | 4 | 14 | 16 | 34 |
| Accommodation and Food Service Activities | I | 0 | 0 | 24 | 116 | 140 |
| Information and Communication | J | 0 | 3 | 21 | 22 | 46 |
| Financial and Insurance Activities | K | 0 | 0 | 1 | 0 | 1 |
| Real Estate Activities | L | 1 | 5 | 21 | 33 | 60 |
| Professional, Scientific and Technical Activities | M | 0 | 5 | 26 | 50 | 81 |
| Administrative and Support Service Activities | N | 0 | 3 | 8 | 18 | 29 |
| Education | P | 0 | 0 | 1 | 7 | 8 |
| Human Health and Social Work Activities | Q | 0 | 3 | 11 | 11 | 25 |
| Arts, Entertainment and Recreation | R | 0 | 0 | 3 | 11 | 14 |
| Other Service Activities | S | 0 | 1 | 3 | 24 | 28 |
| Total | | 4 | 229 | 855 | 1078 | 2,166 |

Financial data for the control pool of firms is also obtained from Orbis Historical. The control pool encompasses all the firms satisfying the following requirements: a) located within the provinces including the eligible municipalities but excluding those, b) active for at least 2 years, starting the business before 2016 and closing after 2012 (if inactive today), c) with detail on the sector of economic activity they operate in. A result control pool of around 120,000 firms is obtained. In the control pool small firms account for 70%, a larger percentage than in the treated sample, with lower representation overall of both medium and large firms, suggesting somehow that, amongst the eligible firms, the probability of getting treated depends on size – consistent with the theoretical model on constraints to credit access. Additional details on the control pool characteristics are presented in **Tables D.1 - D.2 in the Appendix**.

Geographical coordinates data is obtained from the Italian Statistical Office (ISTAT). Data on seismic intensity at municipality level for the 2012, 2016 and 2017 earthquakes is obtained through the application of Pasolini et al. (2008) seismic

"medium" if operating revenues are above or equal to $1.3m, or total assets above or equal to $2.6m, or over 14 employees; "small" otherwise.

attenuation law, over data from the Parametric Catalogue of Italian Earthquakes (CPTI15 v2.0) as detailed in Mari (2020).

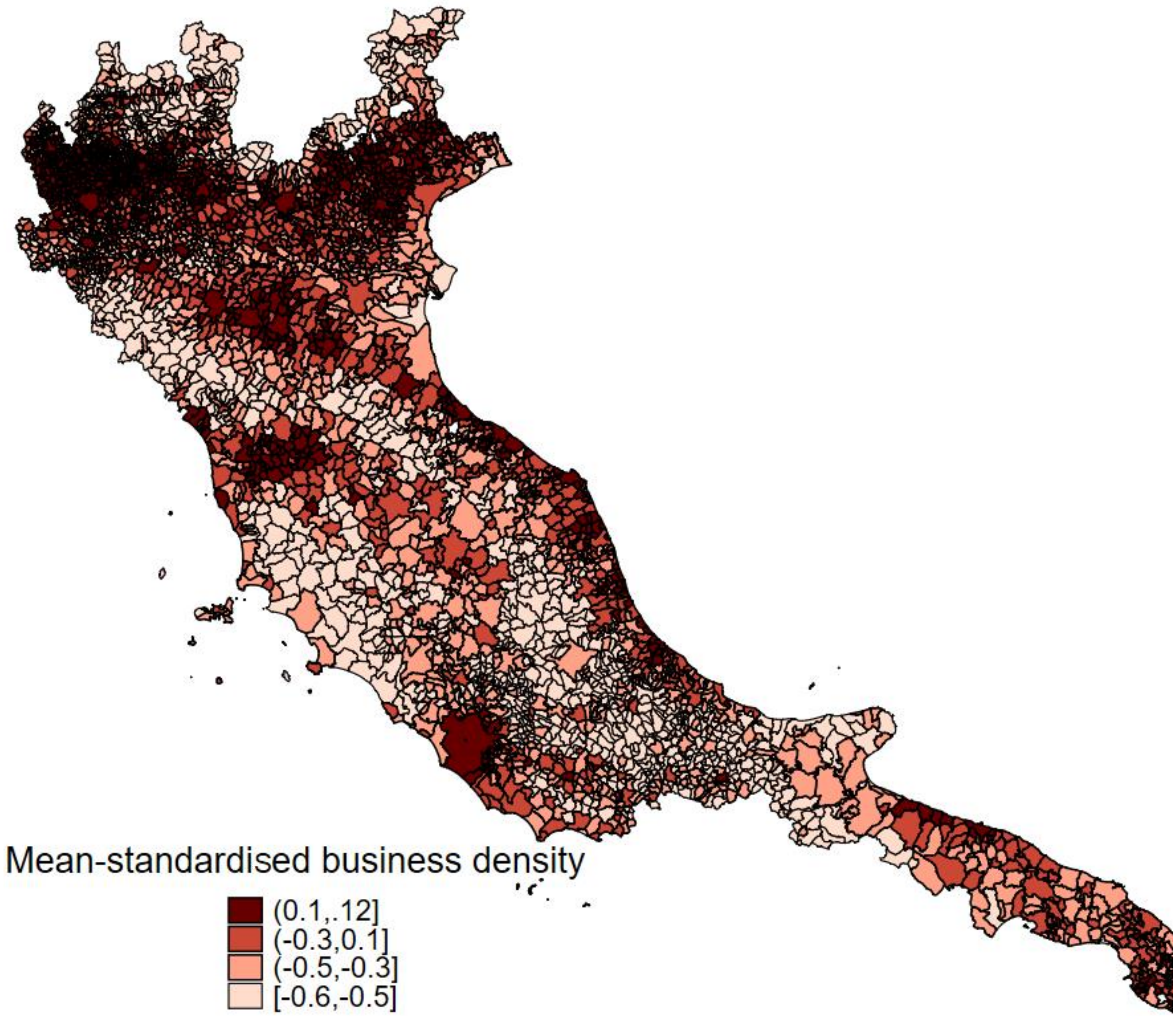
The measure for business density by sector at NUTS4 level and year is obtained from data from the Business Register of Local Units (ASIA LU), by dividing the number of local business units of a given sector $j$ in municipality $i$ at time $t$ by the area of municipality $i$. This is then standardised at national level by subtracting the mean national business density of sector $j$ at time $t$ and dividing by the standard deviation observed at national level of such statistics.

$$bdens_{jit} = \frac{n.local\ units_{jit}}{area\ sqkm_{it}}$$

$$std.bdens_{jit} = \left(bdens_{jit} - mean\ bdens_{jt}\right)/st.dev.bdens_{jt}$$

The choice of the municipality surface area, as denominator of the business density measure instead of the municipality's population, aims to provide a measure of business density adequately proxying demand for commercial real estate in both rural sparsely populated municipalities and densely populated cities. This data is not available for the agricultural sector – hence, we exclude agricultural firms from the analysis. **Figure 5** provides a representation of the business density distribution for manufacturing sector in the regions of interest. It is possible to notice how the measure accurately detects the manufacturing industrial hubs, not just in the Northern regions of Lombardy and Veneto, but also those more localised, of Prato in Tuscany and the Adriatic coast.

**Figure 5: Spatial distribution of 2017 business density for Manufacturing at NUTS 4 level**




Annual estimates on firm-specific probabilities of default are the fitted values from a Cox-Proportional hazard model, stratified by firm size calibrated over almost 30 years of historical balance sheet data on all the Italian firms with data available from Historical Orbis. These are then converted into credit ratings, as detailed in **Section B1 of the Appendix**.

Annual estimates on loan baseline probabilities of default by sector of economic activity, loan size and province (NUTS3 region) from 2006 to 2019, are obtained using official data on default rates from Bank of Italy, territorial accounts data from the Italian Statistical Office (ISTAT) and data from the Business Register of Local Units (ASIA LU).

Data on the historical rate of annual conversions of performing loans into bad loans is commonly used as an indicator of historical probability of default (Grippa and Viviani, 2001). Bank of Italy publishes quarterly data on annual default rates by NUTS 1 region, loan size and borrower's economic activity and quarterly data on annual default rates by NUTS 3 region and loan size. Data on value added by branch of economic activity at NUTS 3 level is used to obtain a sectoral decomposition of probabilities of default at NUTS 3 level, under the assumption that province-specific risk factors, summarised by the average probability of default by loan size, are homogeneous across sector. Additional detail on the creation of probabilities of default estimates is discussed in **Section C2 of the Appendix**.

As **Figure 6** shows, the annual conversion rates to default are higher in more economically depressed areas, with an evident difference between the North and South of Italy. At sectoral level, construction activities appear to be characterised by the highest risk of default, followed by accommodation and food service activities and mining and quarrying (**Table 3**). This is in line with stylised facts of corporate risk.

**Figure 6: Distribution of average loan's annual conversion rate to default by NUTS 3 region**

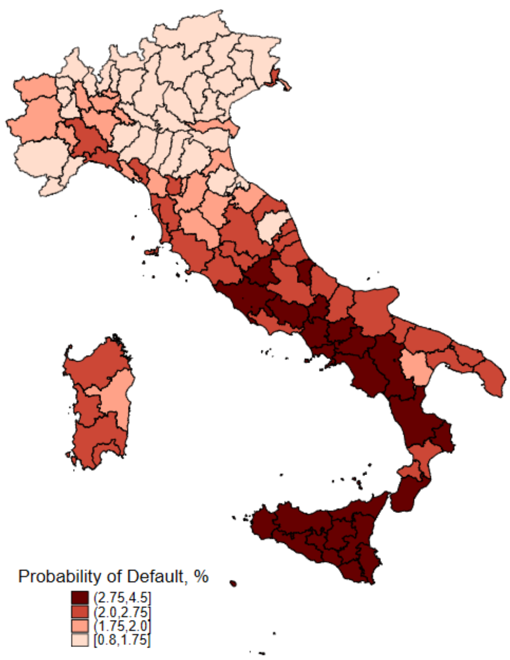


**Table 3: Annual Historical Loan's Conversion to Default by Borrower's Legal Seat and and Economic Activity, %**

| Economic activity | NACE 2 code | Italy | North-Western Italy | North-Eastern Italy | Central Italy | Southern Italy | Insular Italy |
|---|---|---|---|---|---|---|---|
| Agriculture, Forestry and Fishing | A | 2.7 | 1.9 | 1.9 | 3.4 | 4.1 | 5.4 |
| Mining and Quarrying | B | 3.8 | 2.9 | 3.1 | 4.7 | 3.8 | 6.0 |
| Manufacturing | C | 3.2 | 2.6 | 2.6 | 3.7 | 4.7 | 5.4 |
| Electricity, Gas, Steam and Air Conditioning Supply | D | 1.9 | 1.7 | 1.4 | 2.4 | 2.6 | 2.1 |
| Water Supply; Sewerage, Waste Management and Remediation Activities | E | 2.9 | 2.3 | 2.0 | 3.2 | 4.3 | 4.4 |
| Construction | F | 5.0 | 4.4 | 4.4 | 5.5 | 6.1 | 6.4 |
| Wholesale and Retail Trade; Repair of Motor Vehicles and Motorcycles | G | 3.4 | 2.8 | 2.6 | 3.8 | 4.4 | 4.6 |
| Transportation and Storage | H | 3.6 | 3.3 | 2.7 | 4.2 | 4.9 | 4.8 |
| Accommodation and Food Service Activities | I | 4.1 | 4.0 | 3.1 | 4.6 | 5.2 | 5.9 |
| Information and Communication | J | 3.1 | 2.6 | 2.3 | 3.8 | 4.4 | 4.7 |
| Financial and Insurance Activities | K | 2.9 | 2.4 | 2.6 | 3.3 | 3.6 | 4.2 |
| Real Estate Activities | L | 3.1 | 2.8 | 2.9 | 3.4 | 3.7 | 4.3 |
| Professional, Scientific and Technical Activities | M | 2.7 | 2.4 | 2.4 | 3.0 | 3.3 | 3.4 |
| Administrative and Support Service Activities | N | 3.8 | 3.3 | 3.0 | 4.4 | 4.9 | 5.1 |
| Other Service Activities (NACE2 O,P,Q,R,S) | O P Q R S T | 2.6 | 2.3 | 2.1 | 2.9 | 3.2 | 3.1 |
| Total Activities (excl. NACE2 U) | | 3.5 | 3.0 | 2.8 | 3.9 | 4.5 | 4.9 |

# 7 Empirical Results

**Table 4** presents the mean differences for a series of firms and their location's characteristics, between the treated firms and the control firms (selected from the control pool) before the seismic shock. The Mahalanobis distance matching technique employed, appears to be successful at eliminating most of the statistically significant differences observed from the unmatched sample (**Table D.2 in the Appendix**). No significant difference is detected between the matched treatment and control group for small sized firms. Instead, a few statistically significant differences remain between the groups in the medium and large sized categories. Those are, however, generally small and mostly associated with pre-treatment levels of outcome variables or covariates controlled for in the econometric model specification, thus they are of limited concern given the focus on changes in outcomes.

**Table 4: Table of Means Matched Sample**

| | *Small* | | | *Medium* | | | *Large* | | |
|---|---|---|---|---|---|---|---|---|---|
| | Treated | Control | Difference | Treated | Control | Difference | Treated | Control | Difference |
| Age | 6.33 | 6.52 | -0.19 | 10.73 | 10.57 | 0.16 | 13.69 | 14.98 | -1.29 ** |
| | [3.6912] | [3.837] | (0.48) | [5.0416] | [4.892] | (0.35) | [4.8533] | [4.023] | (0.60) |
| Capital (US dollar, thousand) | 26.92 | 29.90 | -2.98 | 179 | 119.00 | 59.68 * | 1157 | 1216 | -58.56 |
| | [25.99] | [55.17] | (5.54) | [677] | [262] | (36.24) | [2305] | [1546] | (264) |
| Operating Revenue (US dollar, thousand) | 514 | 507 | 7.29 | 4333 | 3653 | 680 *** | 23900 | 23300 | 600 |
| | [348] | [289] | (41.19) | [3005] | [2650] | (199) | [13200] | [14700] | (1882) |
| Firm-specific predicted probability of default | 0.31 | 0.31 | 0.00 | 0.29 | 0.29 | 0.00 | 0.30 | 0.32 | -0.02 ** |
| | [.1635] | [.1566] | (0.02) | [.1073] | [.1053] | (0.007) | [.0918] | [.0741] | (0.01) |
| N. Employees | 4.69 | 4.04 | 0.65 | 19.91 | 15.83 | 4.08 *** | 61.14 | 54.69 | 6.46 |
| | [3.2689] | [3.0111] | (0.40) | [16.1852] | [13.3621] | (1.05) | [41.6035] | [36.608] | (5.28) |
| Debt-to-Assets | 0.79 | 0.80 | -0.01 | 0.74 | 0.75 | -0.01 | 0.68 | 0.69 | -0.01 |
| | [.2084] | [.2025] | (0.03) | [.2019] | [.1973] | (0.01) | [.1879] | [.1922] | (0.02) |
| Debt-to-Equity | 10.39 | 10.46 | -0.08 | 7.93 | 11.35 | -3.41 | 1.72 | 6.26 | -4.54 |
| | [37.8261] | [19.5404] | (3.87) | [46.7586] | [21.4764] | (2.57) | [46.074] | [15.8189] | (4.64) |
| Share of employment for the firm's sector in the firm's municipality | 0.13 | 0.13 | 0.00 | 0.21 | 0.21 | 0.00 | 0.20 | 0.20 | 0.00 |
| | [.0998] | [.0998] | (0.01) | [.0953] | [.0953] | (0.01) | [.0876] | [.0875] | (0.01) |
| Total Assets (US dollar, thousand) | 504 | 504 | -0.10 | 4411 | 3572 | 839 *** | 22300 | 21700 | 600 |
| | [453] | [368] | (53.11) | [3750] | [3161] | (245) | [15700] | [14700] | (2054) |
| Standardised business density for the firm's sector in the firm's municipality | -0.08 | 0.01 | -0.09 | 0.04 | 0.10 | -0.05 * | -0.01 | 0.16 | -0.17 *** |
| | [.406] | [.5028] | (0.06) | [.39] | [.4543] | (0.03) | [.3513] | [.5262] | (0.06) |
| Cost of Employees (US dollar, thousand) | 132 | 118 | 14.17 | 901 | 748 | 153 *** | 3285 | 3140 | 146 |
| | [110] | [87.13] | (13.56) | [785] | [684] | (52.55) | [2217] | [2056] | (288) |
| Number of firms | 121 | 121 | | 402 | 402 | | 110 | 110 | |

*Standard deviations in square brackets, standard errors in parentheses*
**** p<0.01, ** p<0.05, * p<0.1*

**Table 5** presents the results of Model 1 (Section IV), estimating the impact of investment incentives by firm size on the outcomes of interest. The matched sample of treated and control firms is further restricted to exclusively include the pairs for which the treated firm is located in a municipality, which experienced a seismic intensity below 7.25, associated with no serious structural damage from the seismic event.

The results show the effectiveness of investment incentives in stimulating investment across all firm sizes. The impact is estimated to be largest for medium sized firms, followed by small and then large sized firms. Receiving the investment subsidies is associated with a 10.5% increase in capital for medium firms relative to the unsubsidised counterfactual, 7.2% for small firms and 6.3% for large firms.

Incentives are only associated with a significantly positive impact on employment, operating revenue and productivity for small and medium sized companies, whilst large companies register a significant negative impact from investment incentives in all of these outcomes. In this instance, small firms register the highest impact, recording an increase in employment by 6.5%, operating revenue by 19.9% and productivity per worker by 9.9%. The positive effect is, instead, substantially reduced in the case of medium firms, which register a 1.4% increase in employment, a 9.3% increase in revenues and 7.9% increase in productivity. At the same time, the effect for large firms is insignificant on employment and large treated firms experience revenues that, on average, are 14% lower than their untreated counterparts and show a 13.7% reduction in productivity per worker.

The inclusion of a control for the coverage ratio of the investment subsidy provides certainty that the heterogeneity of these results is not the consequence of a differential treatment across firm size. The inclusion of the coverage ratio control leads to an increase in the estimated impact of investment subsidies for small and large firms, somewhat suggesting a more generous investment subsidy to medium sized companies relative to small and large companies. The ranking of the effects by size remains unchanged across the outcomes of interest but, in the case of the impact of employment, only small firms register a statistically significant positive impact (regression 6). The negative impact of treatment on revenues and productivity per worker for large companies, instead becomes insignificant (regression 9).

Finally, a control is included to factor in the relative “importance” of the firm investment (i.e., as share of pre-investment capital). A strongly significant positive coefficient is estimated for the impact on capital, consistent with the theoretical model. Furthermore, the results suggest that the subsidised investment was largest in terms of capital increase for medium firms, followed by small and then large firms.

**Table 5: Investment Incentives Effect by Firm Size.**
**Regression Results from Mahalanobis Distance Matching with Replacement and Seismic Intensity ≤ 7.25**

| VARIABLES | Δlog (Capital) | | | Δlog (Employment) | | | Δlog (Revenue) | | | Δlog (Productivity) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) |
| Treated | 0.0625*** | 0.0454*** | 0.298* | -0.00371 | -0.00421 | 0.0654 | -0.141*** | -0.141*** | -0.0734 | -0.137*** | -0.137*** | -0.143 |
| | (0.000381) | (0.00118) | (0.0715) | (0.00157) | (0.00246) | (0.0677) | (0.00115) | (0.00147) | (0.137) | (0.000666) | (0.00139) | (0.0736) |
| Small | -0.0466*** | -0.0466*** | -0.0466*** | 0.117*** | 0.117*** | 0.117*** | 0.0806*** | 0.0806*** | 0.0806*** | -0.0288** | -0.0288** | -0.0288** |
| | (0.000625) | (0.000626) | (0.000626) | (0.00267) | (0.00267) | (0.00267) | (0.00307) | (0.00308) | (0.00308) | (0.00568) | (0.00568) | (0.00568) |
| Small X Treated | 0.00999** | -0.0140** | 0.0377** | 0.0686*** | 0.0679*** | 0.0767** | 0.340*** | 0.339*** | 0.348*** | 0.236*** | 0.236*** | 0.236*** |
| | (0.00105) | (0.00206) | (0.00803) | (0.00421) | (0.00548) | (0.0118) | (0.00242) | (0.00232) | (0.0144) | (0.00647) | (0.00751) | (0.00635) |
| Medium | -0.0552*** | -0.0552*** | -0.0552*** | 0.0555*** | 0.0555*** | 0.0555*** | -0.128*** | -0.128*** | -0.128*** | -0.184*** | -0.184*** | -0.184*** |
| | (0.000703) | (0.000703) | (0.000703) | (0.00300) | (0.00300) | (0.00300) | (0.00345) | (0.00346) | (0.00346) | (0.00612) | (0.00613) | (0.00613) |
| Medium X Treated | 0.0417*** | -0.0116* | 0.0451*** | 0.0177* | 0.0161 | 0.0187 | 0.234*** | 0.233*** | 0.235*** | 0.216*** | 0.216*** | 0.216*** |
| | (0.00141) | (0.00344) | (0.00110) | (0.00564) | (0.00850) | (0.00650) | (0.00261) | (0.00273) | (0.00232) | (0.00736) | (0.00964) | (0.00662) |
| Subsidised Investment Size X Treated | | 0.00476*** | | | 0.000138 | | | 0.000119 | | | -1.95e-05 | |
| | | (0.000183) | | | (0.000259) | | | (9.04e-05) | | | (0.000204) | |
| Coverage Ratio Investment Subsidy X Treated | | | -0.634* | | | -0.186 | | | -0.181 | | | 0.0147 |
| | | | (0.193) | | | (0.178) | | | (0.366) | | | (0.199) |
| BB credit rating | -0.0461** | -0.0461** | -0.0461** | -0.137** | -0.137** | -0.137** | -0.126** | -0.126** | -0.126** | 0.00953 | 0.00953 | 0.00953 |
| | (0.00521) | (0.00522) | (0.00522) | (0.0222) | (0.0222) | (0.0222) | (0.0256) | (0.0256) | (0.0256) | (0.0454) | (0.0455) | (0.0455) |
| BB credit rating X Treated | -2.70e-05 | 0.0358 | 0.0135 | 0.0738 | 0.0749 | 0.0778 | 0.114** | 0.115** | 0.118** | 0.0440 | 0.0438 | 0.0437 |
| | (0.0119) | (0.0225) | (0.0126) | (0.0473) | (0.0489) | (0.0429) | (0.0198) | (0.0201) | (0.0232) | (0.0570) | (0.0585) | (0.0600) |
| Observations | 514 | 514 | 514 | 514 | 514 | 514 | 514 | 514 | 514 | 512 | 512 | 512 |
| R-squared | 0.008 | 0.066 | 0.018 | 0.027 | 0.027 | 0.029 | 0.034 | 0.034 | 0.035 | 0.060 | 0.060 | 0.060 |

Robust standard errors in parentheses.
*** p<0.01, ** p<0.05, * p<0.1

Small is a dummy equal to 1 for small sized companies, 0 otherwise; Medium is a dummy equal to 1 for medium sized companies, 0 otherwise; Treated is a dummy equal to 1 for companies receiving treatment and 0 otherwise; BB credit rating is a dummy equal to 1 if the company is rated as equivalent to BB on S&P rating scale on average in the 3 years before the earthquake shock, 0 otherwise (Appendix Section B.1 provides additional detail on the company rating procedure); Subsidised Investment Size is a continuous variable defined as the financed amount expressed as share of the pre-investment firm's capital; Coverage Ratio Investment Subsidy is a continuous variable defined as the ratio between the subsidised part of investment financing and the total investment financing cost.

The regression results are robust to the sampling specification of the matching technique, with the coefficients estimated by matching with the control pool without replacement being broadly unchanged (**Table D.3 in Appendix**). Unconstraining the regression to treated firms, on the basis of experienced seismic intensity, leads to significantly different coefficients, consistent with the structural damage and related capital destruction associated with the earthquake (**Table D.4 in Appendix**).

The estimated marginal rates of substitution for treated firms, between capital and labour by firm size, are presented in **Table 6**. The marginal rate of substitution is significantly higher amongst small firms relative to medium and large firms, even after controlling for the coverage ratio. Furthermore, small firms are estimated to increase their employment by more than the increase in capital, different from medium and large firms presenting a marginal rate of substitution below 1, although still positive. These results are particularly relevant given the absence of an employment conditionality associated with the investment subsidy programme analysed, in contrast to those previously considered in the literature. These results, therefore, provide support to the non-homotheticity hypothesis, proposed in Section II.

**Table 6: Marginal Rates of Substitution between Capital and Labour by Firm Size**

| $\partial L/\partial K$ | Small | Medium | Large |
|---|---|---|---|
| *without control for coverage ratio* | 6.87 | 0.42 | -0.06 |
| *with control for coverage ratio* | 2.03 | 0.41 | 0.22 |

Finally, **Table 7** presents the empirical results associated with the theoretical model on credit market frictions tested empirically through Model 2 (Section IV). The results suggest that, holding everything else constant, the impact of treatment on capital growth is significantly associated with demand for unmovable assets, proxied by the business density of the sector within which the firm operates and in the municipality it is located. The relationship is estimated to be negative in the case of manufacturing and retail and hospitality. The impact of treatment is, instead, positively associated with demand for unmovable assets in the case of the construction sector and other services. The heterogeneity of impact across sector can be traced back to the relatively higher importance of unmovable assets, as share of total assets in the manufacturing and hospitality sectors relative to other sectors.

In fact, according to the theoretical model presented in Section II, upon a local recovery rate for unmovable assets lower than the movable capital recovery rate, the higher the share of unmovable capital, the higher the probability of constraint to secured credit access. A higher impact from a relaxation of credit constraints, such as the one occurring from investment subsidies should, therefore, be expected in the areas characterised by a lower expected recovery rate for sectors with a high share of unmovable capital. This is consistent with the findings hereby presented.

The regressions in Table 7 also provide an insight into the heterogeneity by sector of the impact of treatment on small and medium enterprises. Noticeable is the higher impact of treatment, in terms of employment, output and productivity for the construction sector, relative to the other sectors. Stronger productivity gains are also experienced by the manufacturing sector and retail and hospitality services. For the latter, however, these are mostly driven by a lower impact of treatment on employment and capital accumulation, whilst output has remained unchanged.

The regression results do not detect a significant impact on treatment effect associated with differences in credit rating and baseline probability of default of the sector and NUTS 3 region the firm operates in. Overall, a BB credit rating is associated with lower revenue growth relative to a firm rated as A. Lower productivity growth relative to A-rated firms is associated with both BBB and BB-rated firms. The lack of significance of credit rating on treatment effect could be attributed, in this setup, to the strong relationship between credit grade and firm size and the limited variation, observed as a consequence in the sample of 257 treated-control pairs hereby analysed. The baseline sector-province default probability presents a positive coefficient but is insignificant in Table 7. The coefficient remains positive across the board, except for retail and hospitality services (negative but insignificant) in single sector regressions, acquiring significance for the utilities and construction sector (**Table D.5 in the Appendix**). Single sector regressions allow for the disentanglement of cross-sector effects from the coefficient, although these are subject to the trade-off of a smaller estimation sample.

**Table 7: Empirical Testing of Theoretical Model for Credit Market Frictions on Investment Incentives Effect. Regression Results from Mahalanobis Distance Matching with Replacement and Seismic Intensity ≤ 7.25**

| VARIABLES | Δlog (Capital) | | Δlog (Employment) | | Δlog (Revenue) | | Δlog (Productivity) | |
|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| PD of economic sector and province | 0.00595 | 0.00595 | -0.0341 | -0.0341 | 0.00249 | 0.00249 | 0.0364* | 0.0364* |
| | (0.0657) | (0.0657) | (0.0371) | (0.0371) | (0.0256) | (0.0256) | (0.0144) | (0.0144) |
| PD of economic sector and province X Treated | 0.436 | 0.271 | 0.112 | 0.600 | 0.288 | 0.485 | 0.0939 | -0.106 |
| | (0.278) | (0.425) | (0.377) | (0.776) | (0.421) | (1.052) | (0.206) | (0.373) |
| PD of economic sector and province X Treated X SME | | 0.215 | | -0.637 | | -0.258 | | 0.282 |
| | | (0.401) | | (0.792) | | (1.011) | | (0.363) |
| BBB credit rating | 0.0630 | 0.0630 | 0.0779 | 0.0779 | -0.136 | -0.136 | -0.214*** | -0.214*** |
| | (0.128) | (0.128) | (0.0889) | (0.0890) | (0.0750) | (0.0751) | (0.0420) | (0.0421) |
| BB credit rating | 0.0395 | 0.0395 | -0.0905 | -0.0905 | -0.277** | -0.277** | -0.186*** | -0.186*** |
| | (0.108) | (0.108) | (0.121) | (0.121) | (0.0867) | (0.0868) | (0.0381) | (0.0382) |
| BBB credit rating X Treated | -0.131 | -0.126 | -0.00324 | -0.0186 | -0.105 | -0.111 | -0.105 | -0.0975 |
| | (0.119) | (0.118) | (0.205) | (0.173) | (0.173) | (0.146) | (0.0925) | (0.0893) |
| BB credit rating X Treated | -0.120 | -0.114 | 0.0740 | 0.0558 | -0.00794 | -0.0153 | -0.0804 | -0.0727 |
| | (0.123) | (0.124) | (0.112) | (0.0972) | (0.123) | (0.112) | (0.0810) | (0.0806) |
| Coverage Ratio Investment Subsidy X Treated | -0.501** | -0.498** | -0.124 | -0.136 | -0.00534 | -0.00995 | 0.0782 | 0.0912 |
| | (0.123) | (0.120) | (0.234) | (0.203) | (0.357) | (0.340) | (0.186) | (0.187) |
| Treated | -1.059 | -0.548 | -0.242 | -1.750 | -0.755 | -1.366 | -0.238 | 0.375 |
| | (0.657) | (1.196) | (1.315) | (2.671) | (1.578) | (3.549) | (0.693) | (1.148) |
| SME | 0.155 | 0.155 | -0.0567** | -0.0567** | 0.147** | 0.147** | 0.204*** | 0.204*** |
| | (0.173) | (0.173) | (0.0190) | (0.0190) | (0.0389) | (0.0390) | (0.0232) | (0.0232) |
| SME X Treated | 0.370*** | -0.277 | 0.341 | 2.252 | 0.119 | 0.892 | -0.260** | -1.098 |
| | (0.0649) | (1.248) | (0.254) | (2.437) | (0.249) | (3.135) | (0.0758) | (1.105) |
| SME X sector C | -0.324*** | -0.324*** | 0.181*** | 0.181*** | -0.108** | -0.108** | -0.289*** | -0.289*** |
| | (0.0435) | (0.0435) | (0.0309) | (0.0310) | (0.0243) | (0.0244) | (0.0135) | (0.0135) |
| SME X sector C X Treated | -0.300 | -0.330 | -0.403 | -0.317 | -0.0754 | -0.0404 | 0.368** | 0.322** |
| | (0.154) | (0.170) | (0.199) | (0.207) | (0.200) | (0.194) | (0.103) | (0.0850) |
| SME X sector E | -0.292*** | -0.292*** | -0.0477 | -0.0477 | -0.163*** | -0.163*** | -0.115*** | -0.115*** |
| | (0.0558) | (0.0559) | (0.0325) | (0.0325) | (0.0225) | (0.0225) | (0.0128) | (0.0128) |
| SME X sector E X Treated | 0.243 | 0.283 | -0.201 | -0.319 | 0.252 | 0.204 | 0.381 | 0.447** |
| | (0.245) | (0.273) | (0.338) | (0.314) | (0.377) | (0.327) | (0.183) | (0.153) |
| SME X sector F | -0.562* | -0.562* | -0.806*** | -0.806*** | -1.542*** | -1.542*** | -0.735*** | -0.735*** |
| | (0.233) | (0.233) | (0.122) | (0.122) | (0.0838) | (0.0839) | (0.0470) | (0.0470) |
| SME X sector F X Treated | 0.289 | -0.00906 | 1.751* | 2.631* | 3.252** | 3.608** | 1.640** | 1.223* |
| | (0.611) | (0.866) | (0.647) | (1.126) | (0.708) | (1.212) | (0.373) | (0.507) |
| SME X sector G,H,I | -0.156** | -0.156** | 0.138** | 0.138** | -0.249*** | -0.249*** | -0.387*** | -0.387*** |
| | (0.0513) | (0.0513) | (0.0341) | (0.0341) | (0.0242) | (0.0242) | (0.0132) | (0.0132) |
| SME X sector G,H,I X Treated | -0.397* | -0.424* | -0.453* | -0.372* | 0.00515 | 0.0379 | 0.475*** | 0.437*** |
| | (0.149) | (0.164) | (0.171) | (0.170) | (0.184) | (0.167) | (0.0916) | (0.0783) |
| Sectoral business density | -0.310*** | -0.310*** | 0.210*** | 0.210*** | 0.187*** | 0.187*** | -0.0228** | -0.0228** |
| | (0.0161) | (0.0161) | (0.0148) | (0.0148) | (0.0123) | (0.0123) | (0.00518) | (0.00518) |
| Sectoral business density X Treated | 0.750*** | 0.813*** | 0.486*** | 0.301 | 1.523*** | 1.448** | 1.045*** | 1.125*** |
| | (0.0609) | (0.111) | (0.0793) | (0.262) | (0.104) | (0.332) | (0.0420) | (0.122) |
| Sectoral business density X sector C | 0.361*** | 0.361*** | -0.147*** | -0.147*** | -0.0566** | -0.0566** | 0.0905*** | 0.0905*** |
| | (0.0152) | (0.0152) | (0.0195) | (0.0195) | (0.0195) | (0.0195) | (0.00328) | (0.00328) |
| Sectoral business density X sector C X Treated | -0.966*** | -1.033*** | -0.562*** | -0.365 | -1.697*** | -1.617*** | -1.140*** | -1.227*** |
| | (0.00990) | (0.132) | (0.0381) | (0.254) | (0.0596) | (0.326) | (0.0261) | (0.115) |
| Sectoral business density X sector E | 0.309*** | 0.309*** | -0.179*** | -0.179*** | -0.0462** | -0.0462** | 0.133*** | 0.133*** |
| | (0.00605) | (0.00606) | (0.0143) | (0.0143) | (0.0124) | (0.0124) | (0.00352) | (0.00352) |
| Sectoral business density X sector E X Treated | -0.307 | -0.325 | -0.767 | -0.715 | -2.113*** | -2.092** | -1.422*** | -1.430*** |
| | (0.244) | (0.254) | (0.419) | (0.429) | (0.457) | (0.498) | (0.164) | (0.150) |
| Sectoral business density X sector F | -0.674** | -0.674** | -3.155*** | -3.155*** | -3.187*** | -3.187*** | -0.0323 | -0.0323 |
| | (0.233) | (0.233) | (0.0573) | (0.0573) | (0.0629) | (0.0630) | (0.0279) | (0.0279) |
| Sectoral business density X sector F X Treated | 4.616*** | 3.714 | 7.370** | 10.03* | 13.73*** | 14.81** | 6.029*** | 4.915* |
| | (0.734) | (1.913) | (1.625) | (3.859) | (1.725) | (5.192) | (0.726) | (1.819) |
| Sectoral business density X sector G,H,I | 0.706*** | 0.706*** | -0.406*** | -0.406*** | -0.217*** | -0.217*** | 0.190*** | 0.190*** |
| | (0.0465) | (0.0466) | (0.0296) | (0.0296) | (0.0260) | (0.0260) | (0.00630) | (0.00630) |
| Sectoral business densityX sector G,H,I X Treated | -1.406*** | -1.480*** | -0.201* | 0.0159 | -1.374*** | -1.286** | -1.194*** | -1.286*** |
| | (0.0272) | (0.114) | (0.0889) | (0.309) | (0.0904) | (0.379) | (0.0134) | (0.124) |
| Observations | 514 | 514 | 514 | 514 | 514 | 514 | 512 | 512 |
| R-squared | 0.069 | 0.069 | 0.120 | 0.128 | 0.148 | 0.148 | 0.141 | 0.142 |

Robust standard errors in parentheses. Standard errors clustered at NACE 2 sector level.
*** p<0.01, ** p<0.05, * p<0.1

SME is a dummy equal to 1 for small and medium sized companies, 0 for large companies; Treated is a dummy equal to 1 for companies receiving treatment and 0 otherwise; BBB credit rating is a dummy equal to 1 if the company is rated as equivalent to BBB on S&P rating scale on average in the 3 years before the earthquake shock, 0 otherwise; BB credit rating is a dummy equal to 1 if the company is rated as equivalent to BB on S&P rating scale on average in the 3 years before the earthquake shock, 0 otherwise (Appendix Section B.1 provides additional detail on the company rating procedure); business density of the economic sector in firms' municipality is controlled through the 3 year average of the ratio between the number of business units and the municipality area in sqkm mean standardised at national level (details in Section V); the sector and province specific loan's baseline probability of default (PD) is controlled as continuous variable and corresponds to the baseline province and sector probability of default at the end of the year before the earthquake shock; t Coverage Ratio Investment Subsidy is a continuous variable defined as the ratio between the subsidised part of investment financing and the total investment financing cost. Sectoral dummies for the NACE 2 sectors part of the relevant sample are included (C, E, F, GHI, and remaining service sectors).

## 8 Section VII - Conclusions

This paper contributes to the literature studying the impact of productive investment subsidies on firms' factor allocation and production output decisions. It does so by extending the framework shaping the impact of investment subsidies, to account for credit frictions associated with secured borrowing and testing them empirically. Empirical evidence is obtained in the context of Italy, exploiting a productive investment subsidies programme rolled out in response to two major earthquakes.

Productive investment subsidies are found to be associated with a positive impact on capital growth for all the treated firms, with medium firms being the most strongly affected, followed by small and large firms. The impact of treatment on capital growth is estimated to be significantly positively associated with the relative importance of the subsidised investment, the firm specific probability of default and, with less strong evidence, with the baseline probability of default of the sector-macro area in which the firm operates (NUTS 3 region). The impact of productive investment subsidies is, instead, estimated to be significantly negatively related to the expected recovery rate for sectors with high share of unmovable capital, upon a local recovery rate for unmovable assets lower than the movable capital recovery rate. Productive investment subsidies, therefore, appear to effectively increase capital investment, with marginal gains being the largest for those firms with the higher probability of being collateral constrained, with curtailed access to secured credit. Therefore, the impact of such subsidies on investment appears to be particularly higher for firms that are generally not targeted by traditional investment subsidy programmes.

The results estimating the impact of investment subsidies on employment paint a similar picture. The incentives, to which no employment conditionality was associated, are only estimated to have a strongly significant positive impact on employment for small sized companies, with a positive impact on medium sized companies' employment becoming insignificant when controlling for differences in the coverage ratio of the subsidies. The estimated marginal rate of substitution between capital and labour of small firms is above 1 and significantly higher than those of medium and large firms, suggesting stronger impacts on employment from the intervention when targeting small firms.

Smaller firms, therefore, not only appear to be amongst those realising the largest marginal increases in investment following the receipt of investment subsidies, but they also seem to be the ones recording the largest marginal expansion of their work force. This appears to be a result of larger scale effects (driven by the larger gains in terms of capital) and lower substitution effects.

The investment subsidies' treatment effects presented in this paper, although robust to potential biases in employment decisions, should be considered a lower boundary. The identification strategy hereby adopted could, in fact, bring in slightly underestimated impacts on output and employment, if treated firms (located in the outmost border of the "disaster area") are more integrated with heavily damaged firms located near the epicentre than control firms are (located just outside the "disaster area"). There is, however, no empirical indication to support this.

These results contribute to existing literature contributions studying the impact of productive investment subsidies, providing an identification design suitable for studying the treatment effect on a range of different firms - not generally targeted by subsidy programmes – unbiased by employment conditionality clauses. This derives findings on the impact of the subsidies on small and micro enterprises, making a case for the potential of a similar policy intervention to stimulate local economic development driven by small businesses. However, this should be caveated by the fact that the identification design adopted, somewhat limits the external validity of the results hereby presented.

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# 10 Appendix

**Section A - Mathematical proofs**

Given, a standard demand for capital,

$$MRPK \quad \rho^D = q - mK$$

A) For unconstrained firms internally financing,

$$\rho^S = \rho$$

In equilibrium, $\rho^S = \rho^D$

$$\rho = q - mK$$

$$mK = q - \rho$$

$$K = \frac{q - \rho}{m}$$

Given a change $\Delta\rho$,

$$\rho^S = \rho \rightarrow \rho + \Delta\rho$$

$$\rho + \Delta\rho = q - mK$$

$$mK = q - \rho - \Delta\rho$$

$$K = \frac{q - \rho - \Delta\rho}{m}$$

Hence,

$$\Delta K = \frac{q - (\rho + \Delta\rho)}{m} - \frac{q - \rho}{m} = -\frac{\Delta\rho}{m}$$

B) For Pecking Order constrained firms (see Box A for proof to obtain the supply of funds curve for constrained firms),

$$\rho^S = \rho - \eta m + \gamma K$$

$$\rho - \eta m + \gamma K = q - mK$$

$$(m + \gamma)K = q - \rho + \eta m$$

$$K = \frac{q - \rho + \eta m}{\gamma + m}$$

Given a change $\Delta\rho$,

$$\rho^S = \rho - \eta m + \gamma K \rightarrow \rho + \Delta\rho - \eta m + \gamma K$$

$$\rho + \Delta\rho + \gamma K = q - mK$$

$$(m + \gamma)K = q - \rho - \Delta\rho + \eta m$$

$$K = \frac{q - \rho - \Delta\rho + \eta m}{\gamma + m}$$

Hence,

$$\Delta K = \frac{q - (\rho + \Delta\rho) + \eta m}{\gamma + m} - \frac{q - \rho + \eta m}{\gamma + m} = -\frac{\Delta\rho}{\gamma + m}$$

C) For Pecking Order constrained firms and Endogenous Internal Financing Limits (see Box A for proof to obtain the supply of funds curve for constrained firms),

Given a change $\Delta\rho$,

$$\rho^S = \rho - \eta m + \gamma K \rightarrow \rho + \Delta\rho - \eta m - m\Delta\eta + \gamma K$$

$$\rho + \Delta\rho - (\eta + \Delta\eta)m + \gamma K = q - mK$$

$$(m + \gamma)K = q - \rho - \Delta\rho + (\eta + \Delta\eta)m$$

$$K = \frac{q - \rho - \Delta\rho + (\eta + \Delta\eta)m}{\gamma + m}$$

Hence,

$$\Delta K = \frac{q - (\rho + \Delta\rho) + (\eta + \Delta\eta)m}{\gamma + m} - \frac{q - \rho + \eta m}{\gamma + m} = -\frac{\Delta\rho - m\Delta\eta}{\gamma + m}$$

Comparing the relative size of ΔK(C) and ΔK(A),

$$\Delta K(C) - \Delta K(A) = -\frac{\Delta\rho - m\Delta\eta}{\gamma + m} - \left(-\frac{\Delta\rho}{m}\right) = \frac{-m\Delta\rho + m^2\Delta\eta + \Delta\rho(\gamma + m)}{(\gamma + m)m}$$

$$= \frac{\gamma\Delta\rho + m^2\Delta\eta}{(\gamma + m)m}$$

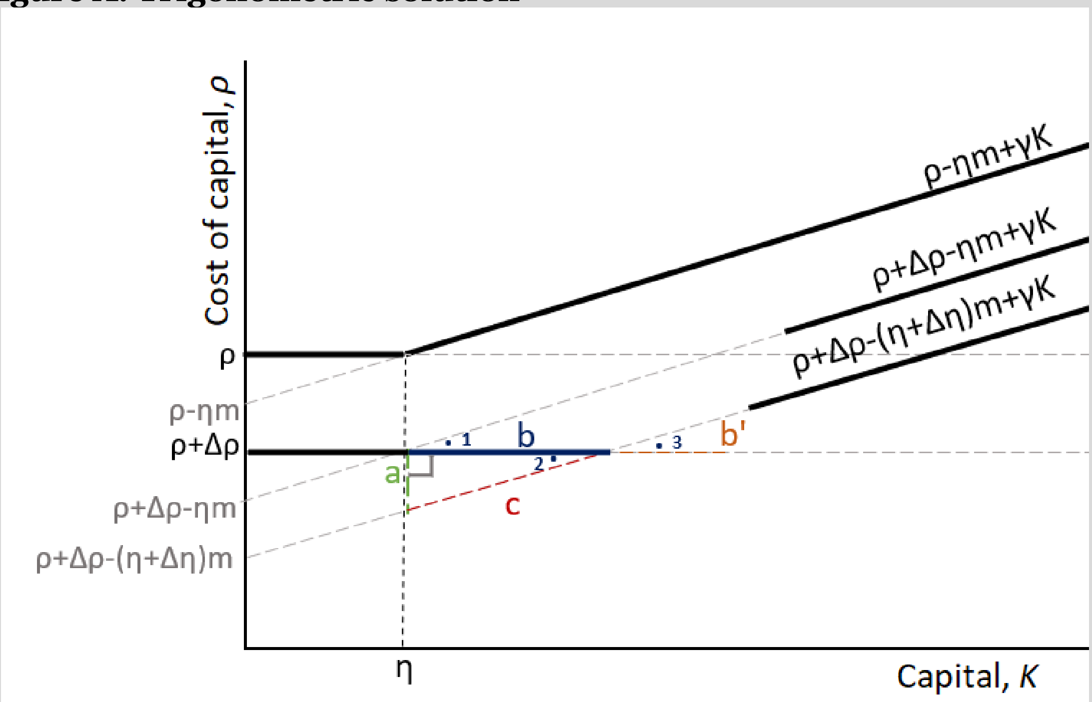
$$As\ \gamma + m > 0\ and\ m > 0,$$

$$\Delta K(C) - \Delta K(A) > 0 \quad if \quad \Delta\rho\frac{\gamma}{m} > -m\Delta\eta$$

$$\Delta K(C) - \Delta K(A) < 0 \quad if \quad \Delta\rho\frac{\gamma}{m} < -m\Delta\eta$$

**Box A: Derivation of supply of funds curve for Pecking order constrained firms with endogenous internal financing limits**

**Figure A: Trigonometric solution**




- The endogenous financing limit does not affect the extent of pecking order constraint → the slope of the external financing segments remains at γ
- Given b = Δη(ρ) = Δη and angle $\hat{1} = \gamma$, $\hat{1} = \hat{3}$ as adjacent and $\hat{2} = \hat{3}$ as opposite, hence $\hat{1} = \hat{2} = \hat{3} = \gamma$
- It follows that a = −b × tan(γ) = −Δη × m as we set tan(γ) = m

Same logic applies to the derivation of the supply of funds for pecking order constrained firms without endogenous internal financing limits.

## Section B – Econometric Modelling Strategy

### B1. Survival Model

A Cox-Proportional hazard model, stratified by size of the firm, $h(t, \boldsymbol{X}(t), \boldsymbol{\beta}) = h_0(t)\, exp(\boldsymbol{\beta} \cdot \boldsymbol{X}(t))$, is used to estimate firm-specific probabilities of default for the firms in the treated and control group. In order to do so, the hazard model is calibrated on the whole sample of firms in Italy, with records on Orbis from 1990 to 2019. This is consistent with other literature applications (Ferragina et al, 2014 in the context of Italy) and there is evidence pointing to the higher performance of Cox-Proportional hazard models over alternative techniques in credit scoring for retail credit (Dirick, 2017).

In this application, the hazard is represented by default. For ease, the model is estimated in terms of survival probabilities (**Table B1.C**) and then converted into default probabilities. The annual survival probability at time $t$ for firm $f$ ($s_{f,t}$), corresponding to the complement of the probability of default, is a function of $s_0$ representing the baseline probability of survival, and $X_{f,t}$ is a vector of covariates affecting firm survival.

$$s_{f,t}|age_{f,t} = s_{0,t}|age_{f,t} \cdot exp\left(\boldsymbol{\beta}'\boldsymbol{X}_{f,t}\right) + \epsilon_{f,t}$$

$$s_{f,t} = 1 - \pi_{f,t}$$

$age_{f,t}$ is defined as the difference between the year of observation and the year of entry, with the latter obtained in practice from the first year for which balance sheet records are available.

Stratification occurs at size level, with four size categories, “Very Large”, “Large”, “Medium” and “Small”. The classification of firms in each of these age categories is based on Orbis classification detailed in footnote 5. **Table B1.A** and **table B1.B** show how larger firms tend to be around for longer on average and are characterised by lower credit risk indicators.

The vector $\boldsymbol{X}_{f,t}$ contains splines of indicators of leverage and liquidity of the firm (**Table B1.D**) plus time effects, constructed as follows.

- Leverage: proxied by a 3 nodes spline for the ratio of debt to total assets based on percentiles
- Liquidity: proxied by a 3 nodes spline for the ratio of debt to equity based on percentiles
- Time effects: controlled through year dummies

A spline function applied to variable $x$ with 3 nodes at $x_1$, $x_2$, $x_3$, generates four segmentations of variable $x$ as follows:

$$splineX1 = \begin{cases} x_1 \; if \; x \geq x_1 \\ x \; if \; x < x_1 \end{cases}$$

$$splineX2 = \begin{cases} x_2 - x_1 \; if \; x \geq x_2 \\ x - x_1 \; if \; x_1 < x < x_2 \\ 0 \; if \; x \leq x_1 \end{cases}$$

$$splineX3 = \begin{cases} x_3 - x_2 \; if \; x \geq x_3 \\ x - x_2 \; if \; x_2 < x < x_3 \\ 0 \; if \; x \leq x_2 \end{cases}$$

$$splineX4 = \begin{cases} x - x_3 \; if \; x > x_3 \\ 0 \; if \; x \leq x_3 \end{cases}$$

A default event is recorded at the year of exit.

The continuous measure of probability for default obtained from the fitted model is then "slotted" into a credit rating (**Table B1.E**) in order to appropriately account for non-linearities and threshold effects in the credit risk associated with the firm by the banking sector.

**Table B1.A: Average number of years of survival by size, conditional on default**

| *Size* | *Survival* |
|---|---|
| Very Large | 13 |
| Large | 13 |
| Medium | 11 |
| Small | 7 |

**Figure B1: Survival functions by size**

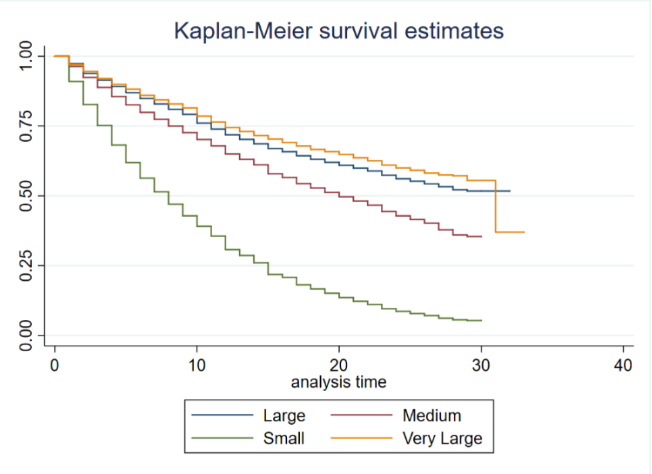



**Table B1.B: Credit risk factors by size**

| *Size* | *Debt-to-Assets* | *Debt-to-Equity* |
|---|---|---|
| Very Large | 0.69 | 6.23 |
| Large | 0.72 | 8.94 |
| Medium | 0.77 | 13.44 |
| Small | 0.77 | 8.31 |

**Table B1.C: Results from Cox-H model predicting firm's survival probability conditional on firm age**

| Variables | Coefficient | Standard Error |
|---|---|---|
| debt-to-assets spline1 | -1.1149 | 0.01059 *** |
| debt-to-assets spline2 | 1.4830 | 0.03951 *** |
| debt-to-assets spline3 | 6.2765 | 0.09061 *** |
| debt-to-assets spline4 | 0.0942 | 0.00184 *** |
| debt-to-equity spline1 | 0.0132 | 0.00016 *** |
| debt-to-equity spline2 | -0.0964 | 0.00527 *** |
| debt-to-equity spline3 | -0.1115 | 0.00162 *** |
| debt-to-equity spline4 | 0.0004 | 0.00005 *** |
| Observations | 14799583 | |
| LR Chi-squared | 637719.61 | |

*Cox Proportional Hazard model stratified by firm size.*
*Time effects controlled through dummy variables.*

**Table B1.D: Spline nodes**

| | *knot 1* | *knot 2* | *knot 3* |
|---|---|---|---|
| debt-to-assets | 0.5630 | 0.8152 | 0.9434 |
| debt-to-equity | 0.6772 | 2.8976 | 9.5069 |

**Table B1.E: Credit grade slotting**

| S&P credit grade | Probability of default (bps) | |
|---|---|---|
| | min | max |
| AAA | 0.00 | 0.85 |
| AA | 0.85 | 2.80 |
| A | 2.80 | 12.19 |
| BBB | 12.19 | 38.85 |
| BB | 38.85 | 173.96 |

## B2. Propensity Score for Treatment

As in most cases, in this empirical set-up, eligibility for treatment does not correspond necessarily to treatment, given that it implies an independent decision from the firm to ask for external financing for an investment project and to obtain it from the banking sector.

As a result, within eligible municipalities, treatment is not perfectly random.

It is necessary, therefore, to identify the factors affecting propensity of treatment, in order to match treated observations to the control pool characterised by the same propensity – had they been eligible for treatment.

This is done by estimating a probit model predicting the probability of receiving treatment conditional on eligibility ( $P(T_{it}|E=1)$ ) over a dummy for being a small sized firm in the year prior to the shock, as well as a series of sector dummies controlling for operating in agriculture (NACE 2 code A), industrials (NACE 2 codes B, C, D, E), construction (NACE2 code F) and consumer services (NACE 2 codes G, H, I), omitting other services to avoid multicollinearity.

$$P(T_{it}|E=1) = \beta_1 small_{i,t-1} + \beta_2 agri_i + \beta_2 industrial_i + \beta_2 construction_i + \beta_2 consumer\_services_i + \varepsilon_i$$

The results suggest that being a small firm significantly negatively affects the probability of getting treated, despite being eligible. Given the structure of the incentives programme, this is not surprising. Given the higher riskiness, small firms are more likely to be denied credit from the banking sector, which remains an entry barrier to the treatment (although lowered, given the interest rate subsidy, than in the case of a standard loan). Furthermore, small firms might also have a lower propensity to invest.

At sectoral level, operating in the agriculture sector is associated with a significantly lower probability of receiving treatment.

These results suggest the need to ensure size and sector pairing when matching treated firms to the control pool. They cannot, however, be applied directly in a propensity score matching set-up, given the limitation of the control group underlying this probit specification. The eligible but untreated firms' sample is, in fact, obtained from Orbis database, as the firms located in the eligible municipalities do not correspond to a match with those receiving the subsidies registered on the public procurement database. This approach inevitably underestimates the size of the control group, particularly for small firms, given the non-mandatory filing of information on Orbis relating to the city the firm operates from. Furthermore, the lack of a sufficiently sized control sample, paired with the scarcity of financial information for small firms, make it impossible to account for a broad range of financial characteristics in the calibration of the propensity to get treated, which are likely to be relevant.

**Table B2: Propensity score model for Treatment among eligible**

| Treated | Coeff. | Robust Std. Error | |
|---|---|---|---|
| Small | -0.7883 | 0.2446 | *** |
| A | -0.9581 | 0.2664 | *** |
| BCDE | 0.3456 | 0.2811 | |
| F | 0.0710 | 0.3146 | |
| GHI | -0.0619 | 0.2215 | |
| Constant | 2.4829 | 0.2716 | *** |
| Observations | 1305 | | |
| Chi-squared | 62.11 | | |

# Section C – Data

## C1. Investment incentives data

**Table C1.A: List of eligible municipalities for productive investment subsidies by earthquake and NUTS 2 region**

| | | May 2012 | Aug 2016 | Oct 2016 | Jan 2017 |
|---|---|---|---|---|---|
| | *Abruzzo* | | | | |
| 1 | Barete (AQ) | | | | X |
| 2 | Cagnano Amiterno (AQ) | | | | X |
| 3 | Campli (TE) | | | X | |
| 4 | Campotosto (AQ) | | X | | |
| 5 | Capitignano (AQ) | | X | | |
| 6 | Castelcastagna (TE) | | | | X |
| 7 | Castelli (TE) | | | X | |
| 8 | Civitella del Tronto (TE) | | | X | |
| 9 | Colledara (TE) | | | | X |
| 10 | Cortino (TE) | | X | | |
| 11 | Crognaleto (TE) | | X | | |
| 12 | Fano Adriano (TE) | | | | X |
| 13 | Farindola (PE) | | | | X |
| 14 | Isola del Gran Sasso (TE) | | | | X |
| 15 | Montereale (AQ) | | X | | |
| 16 | Montorio al Vomano (TE) | | X | | |
| 17 | Pietracamela (TE) | | | | X |
| 18 | Pizzoli (AQ) | | | | X |
| 19 | Rocca Santa Maria (TE) | | X | | |
| 20 | Teramo * | | | X | |
| 21 | Torricella Sicura (TE) | | | X | |
| 22 | Tossicia (TE) | | | X | |
| 23 | Valle Castellana (TE) | | X | | |
| | *Emilia - Romagna* | | | | |
| 24 | Argelato (BO) | X | | | |
| 25 | Argenta (FE) * | X | | | |
| 26 | Baricella (BO) | X | | | |
| 27 | Bastiglia (MO) | X | | | |
| 28 | Bentivoglio (BO) | X | | | |
| 29 | Bologna | X | | | |
| 30 | Bomporto (MO) | X | | | |
| 31 | Bondeno (FE) | X | | | |
| 32 | Boretto (RE) | X | | | |
| 33 | Brescello (RE) | X | | | |
| 34 | Campagnola Emilia (RE) | X | | | |
| 35 | Campogalliano (MO) | X | | | |
| 36 | Camposanto (MO) | X | | | |
| 37 | Carpi (MO) | X | | | |
| 38 | Castel Maggiore (BO) | X | | | |
| 39 | Castelfranco Emilia (MO) | X | | | |
| 40 | Castello d'Argile (BO) | X | | | |
| 41 | Cavezzo (MO) | X | | | |
| 42 | Cento (FE) | X | | | |
| 43 | Concordia sulla Secchia (MO) | X | | | |
| 44 | Correggio(RE) | X | | | |
| 45 | Crevalcore (BO) | X | | | |
| 46 | Fabbrico (RE) | X | | | |
| 47 | Ferrara | X | | | |
| 48 | Finale Emilia (MO) | X | | | |
| 49 | Galliera (BO) | X | | | |
| | *Emilia - Romagna* | | | | |
| 50 | Gualtieri (RE) | X | | | |
| 51 | Guastalla (RE) | X | | | |
| 52 | Luzzara (RE) | X | | | |
| 53 | Malalbergo (BO) | X | | | |
| 54 | Medolla (MO) | X | | | |
| 55 | Minerbio (BO) | X | | | |
| 56 | Mirabello (FE) | X | | | |
| 57 | Mirandola (MO) | X | | | |
| 58 | Modena | X | | | |
| 59 | Molinella (BO) | X | | | |
| 60 | Nonantola (MO) | X | | | |
| 61 | Novellara (RE) | X | | | |
| 62 | Novi di Modena (MO) | X | | | |
| 63 | Pieve di Cento (BO) | X | | | |
| 64 | Poggio Renatico (FE) | X | | | |
| 65 | Ravarino (MO) | X | | | |
| 66 | Reggio Emilia | X | | | |
| 67 | Reggiolo (RE) | X | | | |
| 68 | Rio Saliceto (RE) | X | | | |
| 69 | Rolo (RE) | X | | | |
| 70 | Rovigo | X | | | |
| 71 | Sala Bolognese (BO) | X | | | |
| 72 | San Felice sul Panaro (MO) | X | | | |
| 73 | San Giorgio di Piano (BO) | X | | | |
| 74 | San Giovanni in Persiceto (BO) | X | | | |
| 75 | San Martino in Rio (RE) | X | | | |
| 76 | San Pietro in Casale (BO) | X | | | |
| 77 | San Possidonio (MO) | X | | | |
| 78 | San Prospero (MO) | X | | | |
| 79 | Sant'Agata Bolognese (BO) | X | | | |
| 80 | Sant'Agostino (FE) | X | | | |
| 81 | Soliera (MO) | X | | | |
| 82 | Vigarano Mainarda (FE) | X | | | |
| | *Lazio* | | | | |
| 83 | Accumoli (RI) | | X | | |
| 84 | Amatrice (RI) | | X | | |
| 85 | Antrodoco (RI) | | X | | |
| 86 | Borbona (RI) | | X | | |
| 87 | Borgo Velino (RI) | | X | | |
| 88 | Cantalice (RI) | | | X | |
| 89 | Castel Sant'Angelo (RI) | | X | | |
| 90 | Cittaducale (RI) | | | X | |
| 91 | Cittareale (RI) | | X | | |
| 92 | Leonessa (RI) | | X | | |
| 93 | Micigliano (RI) | | X | | |
| 94 | Poggio Bustone (RI) | | | X | |
| 95 | Posta (RI) | | X | | |
| 96 | Rieti * | | | X | |
| 97 | Rivodutri (RI) | | | X | |

* Municipalities eligible for investment subsidies only upon certified proof of earthquake related damage affecting the business applying for the subsidy. As a result subsidies assigned to businesses located in these municipalities are discarded.

**Table C1.A ct'd**

| | Marche | May 2012 | Aug 2016 | Oct 2016 | Jan 2017 |
|---|---|---|---|---|---|
| 98 | Acquacanina (MC) | | X | | |
| 99 | Acquasanta Terme (AP) | | X | | |
| 100 | Amandola (FM) | | X | | |
| 101 | Apiro (MC) | | | X | |
| 102 | Appignano del Tronto (AP) | | | X | |
| 103 | Arquata del Tronto (AP) | | X | | |
| 104 | Ascoli Piceno * | | | X | |
| 105 | Belforte del Chienti (MC) | | | X | |
| 106 | Belmonte Piceno (FM) | | | X | |
| 107 | Bolognola (MC) | | X | | |
| 108 | Caldarola (MC) | | | X | |
| 109 | Camerino (MC) | | | X | |
| 110 | Camporotondo di Fiastrone (MC) | | | X | |
| 111 | Castel di Lama (AP) | | | X | |
| 112 | Castelraimondo (MC) | | | X | |
| 113 | Castelsantangelo sul Nera (MC) | | X | | |
| 114 | Castignano (AP) | | | X | |
| 115 | Castorano (AP) | | | X | |
| 116 | Cerreto D'esi (AN) | | | X | |
| 117 | Cessapalombo (MC) | | X | | |
| 118 | Cingoli (MC) | | | X | |
| 119 | Colli del Tronto (AP) | | | X | |
| 120 | Colmurano (MC) | | | X | |
| 121 | Comunanza (AP) | | X | | |
| 122 | Corridonia (MC) | | | X | |
| 123 | Cossignano (AP) | | X | | |
| 124 | Esanatoglia (MC) | | | X | |
| 125 | Fabriano (AN) * | | | X | |
| 126 | Falerone (FM) | | | X | |
| 127 | Fiastra (MC) | | X | | |
| 128 | Fiordimonte (MC) | | X | | |
| 129 | Fiuminata (MC) | | | X | |
| 130 | Folignano (AP) | | | X | |
| 131 | Force (AP) | | X | | |
| 132 | Gagliole (MC) | | | X | |
| 133 | Gualdo (MC) | | X | | |
| 134 | Loro Piceno (MC) | | | X | |
| 135 | Macerata * | | | X | |
| 136 | Maltignano (AP) | | | X | |
| 137 | Massa Fermana (FM) | | | X | |
| 138 | Matelica (MC) | | | X | |
| 139 | Mogliano (MC) | | | X | |
| 140 | Monsapietro Morico (FM) | | | X | |
| 141 | Montalto delle Marche (AP) | | X | | |
| 142 | Montappone (FM) | | | X | |
| 143 | Monte Rinaldo (FM) | | | X | |
| 144 | Monte San Martino (MC) | | | X | |
| 145 | Monte Vidon Corrado (FM) | | | X | |
| 146 | Montecavallo (MC) | | | X | |
| 147 | Montedinove (AP) | | X | | |
| 148 | Montefalcone Appennino (FM) | | | X | |
| 149 | Montefortino (FM) | | X | | |

| | Marche | May 2012 | Aug 2016 | Oct 2016 | Jan 2017 |
|---|---|---|---|---|---|
| 150 | Montegallo (AP) | | X | | |
| 151 | Montegiorgio (FM) | | | X | |
| 152 | Monteleone (FM) | | | X | |
| 153 | Montelparo (FM) | | | X | |
| 154 | Montemonaco (AP) | | X | | |
| 155 | Muccia (MC) | | | X | |
| 156 | Offida (AP) | | | X | |
| 157 | Ortezzano (FM) | | | X | |
| 158 | Palmiano (AP) | | X | | |
| 159 | Penna San Giovanni (MC) | | X | | |
| 160 | Petriolo (MC) | | | X | |
| 161 | Pieve Torina (MC) | | X | | |
| 162 | Pievebovigliana (MC) | | X | | |
| 163 | Pioraco (MC) | | | X | |
| 164 | Poggio San Vicino (MC) | | | X | |
| 165 | Pollenza (MC) | | | X | |
| 166 | Ripe San Ginesio (MC) | | | X | |
| 167 | Roccafluvione (AP) | | X | | |
| 168 | Rotella (AP) | | X | | |
| 169 | San Ginesio (MC) | | X | | |
| 170 | San Severino Marche (MC) | | | X | |
| 171 | Sant'Angelo in Pontano (MC) | | X | | |
| 172 | Santa Vittoria in Matenano (FM) | | | X | |
| 173 | Sarnano (MC) | | X | | |
| 174 | Sefro (MC) | | | X | |
| 175 | Serrapetrona (MC) | | | X | |
| 176 | Serravalle del Chienti (MC) | | | X | |
| 177 | Servigliano (FM) | | | X | |
| 178 | Smerillo (FM) | | | X | |
| 179 | Tolentino (MC) | | | X | |
| 180 | Treia (MC) | | | X | |
| 181 | Urbisaglia (MC) | | | X | |
| 182 | Ussita (MC) | | X | | |
| 183 | Venarotta (AP) | | X | | |
| 184 | Visso (MC) | | X | | |
| | *Umbria* | | | | |
| 185 | Arrone (TR) | | X | | |
| 186 | Cascia (PG) | | X | | |
| 187 | Cerreto di Spoleto (PG) | | X | | |
| 188 | Ferentillo (TR) | | X | | |
| 189 | Montefranco (TR) | | X | | |
| 190 | Monteleone di Spoleto (PG) | | X | | |
| 191 | Norcia (PG) | | X | | |
| 192 | Poggiodomo (PG) | | X | | |
| 193 | Polino (TR) | | X | | |
| 194 | Preci (PG) | | X | | |
| 195 | Sant'Anatolia di Narco (PG) | | X | | |
| 196 | Scheggino (PG) | | X | | |
| 197 | Sellano (PG) | | X | | |
| 198 | Spoleto (PG) * | | | X | |
| 199 | Vallo di Nera (PG) | | X | | |

* Municipalities eligible for investment subsidies only upon certified proof of earthquake related damage affecting the business applying for the subsidy. As a result subsidies assigned to businesses located in these municipalities are discarded.

Table C1.A ct'd

| | *Lombardia* | May 2012 | Aug 2016 | Oct 2016 | Jan 2017 |
|---|---|---|---|---|---|
| 200 | Bagnolo San Vito (MN) | X | | | |
| 201 | Borgoforte (MN) | X | | | |
| 202 | Borgofranco sul Po (MN) | X | | | |
| 203 | Carbonara di Po (MN) | X | | | |
| 204 | Casalmaggiore (CR) * | X | | | |
| 205 | Castel d'Ario (MN) * | X | | | |
| 206 | Castelbelforte (MN) | X | | | |
| 207 | Casteldidone (CR) * | X | | | |
| 208 | Castellucchio (MN) | X | | | |
| 209 | Commessaggio (MN) * | X | | | |
| 210 | Corte de' Frati (CR) * | X | | | |
| 211 | Curtatone (MN) | X | | | |
| 212 | Dosolo (MN) * | X | | | |
| 213 | Felonica (MN) | X | | | |
| 214 | Gonzaga (MN) | X | | | |
| 215 | Magnacavallo (MN) | X | | | |
| 216 | Mantova | X | | | |
| 217 | Marcaria (MN) | X | | | |
| 218 | Moglia (MN) | X | | | |
| 219 | Motteggiana (MN) * | X | | | |
| 220 | Ostiglia (MN) | X | | | |
| 221 | Pegognaga (MN) | X | | | |
| 222 | Piadena (CR) * | X | | | |
| 223 | Pieve di Coriano (MN) | X | | | |
| 224 | Poggio Rusco (MN) | X | | | |
| 225 | Pomponesco (MN) * | X | | | |
| 226 | Porto Mantovano (MN) | X | | | |
| 227 | Quingentole (MN) | X | | | |
| 228 | Quistello (MN) | X | | | |
| 229 | Revere (MN) | X | | | |
| 230 | Robecco d'Oglio (CR) * | X | | | |
| 231 | Rodigo (MN) | X | | | |
| 232 | Roncoferraro (MN) | X | | | |
| 233 | Sabbioneta (MN) | X | | | |
| 234 | San Benedetto Po (MN) | X | | | |
| 235 | San Daniele Po (CR) * | X | | | |
| 236 | San Giacomo delle Segnate (MN) | X | | | |
| 237 | San Giovanni del Dosso (MN) | X | | | |
| 238 | Schivenoglia (MN) | X | | | |
| 239 | Sermide (MN) | X | | | |
| 240 | Serravalle a Po (MN) | X | | | |
| 241 | Sustinente (MN) | X | | | |
| 242 | Suzzara (MN) | X | | | |
| 243 | Viadana (MN) * | X | | | |
| 244 | Villa Poma (MN) | X | | | |
| 245 | Villimpenta (MN) | X | | | |
| 246 | Virgilio (MN) | X | | | |

| | *Veneto* | May 2012 | Aug 2016 | Oct 2016 | Jan 2017 |
|---|---|---|---|---|---|
| 247 | Adria (RO) * | X | | | |
| 248 | Bagnolo di Po (RO) | X | | | |
| 249 | Bergantino (RO) * | X | | | |
| 250 | Calto (RO) | X | | | |
| 251 | Canaro (RO) | X | | | |
| 252 | Canda (RO) | X | | | |
| 253 | Castelguglielmo (RO) | X | | | |
| 254 | Castelmassa (RO) | X | | | |
| 255 | Castelnovo Bariano (RO) * | X | | | |
| 256 | Ceneselli (RO) | X | | | |
| 257 | Ficarolo (RO) | X | | | |
| 258 | Flesso Umbertiano (RO) * | X | | | |
| 259 | Gaiba (RO) | X | | | |
| 260 | Gavello (RO) | X | | | |
| 261 | Giacciano con Barucchella (RO) | X | | | |
| 262 | Melara (RO) | X | | | |
| 263 | Occhiobello (RO) | X | | | |
| 264 | Pincara (RO) | X | | | |
| 265 | Rovigo | X | | | |
| 266 | Salara (RO) | X | | | |
| 267 | Stienta (RO) | X | | | |
| 268 | Trecenta (RO) | X | | | |

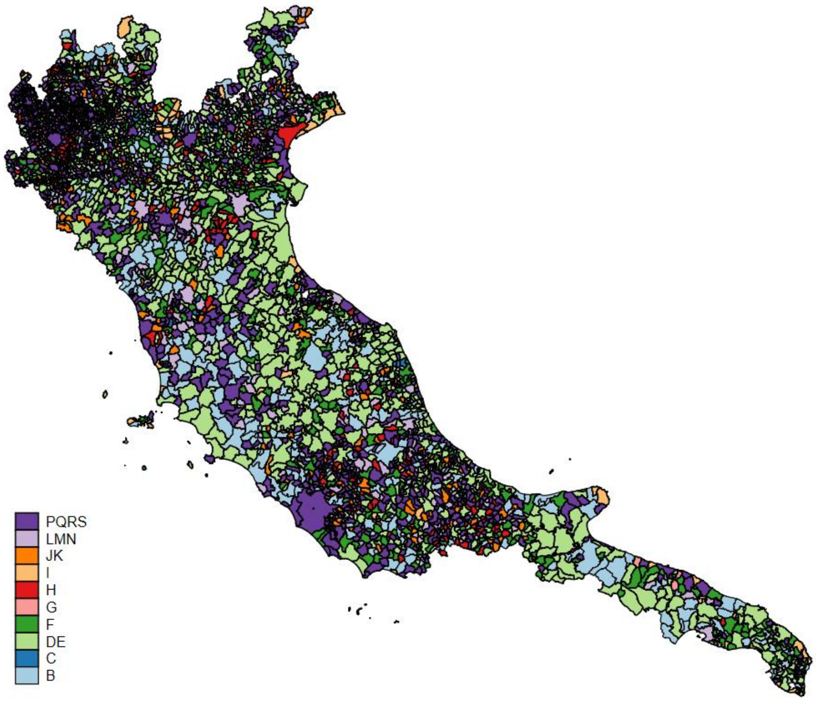
* Municipalities eligible for investment subsidies only upon certified proof of earthquake related damage affecting the business applying for the subsidy. As a result subsidies assigned to businesses located in these municipalities are discarded.

**Table C1.B: Distribution of investment subsidies matched records by region and year of approval**

| | *Financing approval year* | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| *NUTS 2 Region* | 2012 | 2013 | 2014 | 2015 | 2017 | 2018 | 2019 | Total |
| Abruzzo | 0 | 0 | 0 | 0 | 0 | 0 | 26 | 26 |
| Emilia-Romagna | 80 | 1,345 | 3 | 0 | 0 | 0 | 0 | 1,428 |
| Lazio | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 4 |
| Lombardia | 9 | 381 | 10 | 2 | 0 | 0 | 1 | 403 |
| Marche | 0 | 3 | 0 | 0 | 3 | 2 | 0 | 8 |
| Toscana | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 2 |
| Umbria | 0 | 1 | 0 | 0 | 2 | 536 | 0 | 539 |
| Veneto | 0 | 5 | 0 | 0 | 0 | 1 | 0 | 6 |

### C2. Business density data

**Figure C2: Top NACE 2 business density by percentile rank at NUTS 4**




### C3. Probabilities of default data

Annual estimates on loan probabilities of default by sector of economic activity, loan size and province (NUTS3 region) from 2006 to 2019 are obtained using official data on default rates from Bank of Italy, territorial accounts data from the Italian Statistical Office (ISTAT) and data from the Business Register of Local Units (ASIA LU).

Data on the historical rate of annual conversions of performing loans into bad loans is commonly used as an indicator of historical probability of default, π (Grippa and Viviani, 2001).

$$\pi_{it} = \left(\frac{n.\,of\ loans\ defaulted\ in\ year\ t, which\ were\ performing\ in\ year\ t-1}{n.\,of\ loans\ performing\ in\ year\ t-1}\right)_{it}$$

Bank of Italy publishes quarterly data on annual default rates by NUTS1 region, loan size and borrower's economic activity and quarterly data on annual default rates by

NUTS3 region and loan size. The NACE 2 sectoral decomposition of probabilities of default at NUTS 3 level, used in this paper, is obtained using data on value added by branch of economic activity at NUTS3 level[7] under the assumption that province-specific risk factors, summarised by the average probability of default by loan size, are homogeneous across sector.

For any given territorial unit $i$, the average probability of default in year $t$ can be considered as the weighted average of probabilities of default by NACE 2 sector of economic activity $s$ in year $t$, with the weights ($w_{sit}$) being the share of borrowing represented by sector $s$ in year $t$.

$$\bar{\pi}_{it} = \sum_{s=1}^{n} w_{sit}\pi_{sit}$$

Given the absence of granular data on the share of borrowing by sector and province (NUTS 3 region) over time, we approximate $w_{sit}$ by the contribution to total value added at regional level $i$ by sector $s$.

$$w_{sit} \cong s_{sit}$$

$$s_{sit} = \frac{VA_{sit}}{VA_{it}}$$

Therefore,

$$\forall\ NUTS\ 1\ region, i = m \qquad \bar{\pi}_{mt} \cong \sum_{s=1}^{n} s_{smt}\pi_{smt}$$

A difference between the average observed PD and the sectoral PD for every sector and year at macroregion would deliver macroregion-consistent sectoral spreads (calibrated on the average) but would ignore the differences in sectoral composition between each individual province and the macroregion they belong to. This can lead to substantial estimation error for provinces with a heavier prevalence of high risk or low risk activities within the macroregion. To solve this problem, a decomposition

[7] An additional complication is created by the imperfect match between the NACE 2 sectoral decomposition of probabilities of default by microregion (NUTS 1) and the decomposition of value added by branch of economic activity and province (NUTS 3). Whilst the former has details for every NACE 2 individual primary code except U (i.e., A, B, C, D, E, F, G, H, I, J, K, L, M, N, O, P, Q, R, S, T), the contributions of value added are aggregated for some codes at NUTS 3 level (BDE, GHI, MN, OPQ, RS). In those cases, except for sector O (public employment), the relative shares of each sector contributing to the aggregated sectoral detail for value added data, is proxied by the relative share of employment (employees and employed) in that sector at province level, obtained from municipality level data from the Business Register of Local Units (ASIA LU). In the case of sector O (public employment), the share of O within OPQ at NUTS3 is assumed to be the same as that observed at NUTS1 level.

approach, akin to Oaxaca, is applied which aims to control for sectoral composition differences when generating sectoral spreads calibrated on the average PD.

Through data on the probability of default by sector $s$ and macroregion (NUTS 1) $m$ for every year $t$ and the shares of value added by sector s at provincial level (NUTS 3) $p$, it is possible to obtain an indicator by province of the average probability of default calibrated on macroregion sectoral PDs, adjusted to reflect the province's sectoral decomposition ($\widehat{\bar{\pi}_{m(p)t}}$). This indicator is used to obtain provincial sectoral composition-adjusted default spreads by sector ($ds_{pst}$), which are then used to decompose the average probability of default by province p and year t obtained from Bank of Italy data.

$$i = p \; for \; NUTS \; 3 \; regions, m \; for \; NUTS 1 \; regions$$

$$\bar{\pi}_{mt} \cong \sum_{s=1}^{n} s_{smt} \pi_{smt}$$

$$\widehat{\bar{\pi}_{m(p)t}} = \sum_{s=1}^{n} s_{spt} \pi_{smt}$$

This indicator is then used to obtain provincial sectoral composition-adjusted default spreads by sector ($ds_{pst}$), which are then used to decompose the average probability of default by province $p$ and year $t$ ($\bar{\pi}_{pt}$) obtained from Bank of Italy data.

$$\forall s, t \quad ds_{pst} = \frac{\left(\pi_{mst} - \widehat{\bar{\pi}_{m(p)t}}\right)}{\widehat{\bar{\pi}_{m(p)t}}}$$

$$\pi_{pst} = \bar{\pi}_{pt}(1 + ds_{mst})$$

The estimates of probability of default sector and time at provincial level thus obtained, encompass information on the relative sector riskiness observed at macroregion controlling for differences in relative sector composition. Through this approach, positive (/negative) differences in the average provincial PD relative to the macroregion they belong to, which are not explainable by differences in sectoral composition, are attributed to a higher (/lower) probability of default across every sector, holding spreads to the average constant.

## Section D – Additional Tables

**Table D.1: Economic Activity and Size distribution of Control pool firms**

| | | Size | | | | |
|---|---|---|---|---|---|---|
| **Economic activity** | **NACE2 code** | *Very Large* | *Large* | *Medium* | *Small* | *Total* |
| Agriculture, Forestry and Fishing | A | 7 | 87 | 654 | 10244 | 10992 |
| Mining and Quarrying | B | 2 | 14 | 68 | 104 | 188 |
| Manufacturing | C | 209 | 1619 | 7500 | 10148 | 19,476 |
| Electricity, Gas, Steam and Air Conditioning Supply | D | 10 | 41 | 254 | 656 | 961 |
| Water Supply; Sewerage, Waste Management and Remediation Activities | E | 8 | 56 | 228 | 260 | 552 |
| Construction | F | 25 | 439 | 4804 | 11520 | 16788 |
| Wholesale and Retail Trade; Repair of Motor Vehicles and Motorcycles | G | 99 | 1050 | 6337 | 14412 | 21898 |
| Transportation and Storage | H | 16 | 180 | 1090 | 1773 | 3059 |
| Accommodation and Food Service Activities | I | 6 | 31 | 1046 | 4512 | 5595 |
| Information and Communication | J | 11 | 84 | 726 | 3250 | 4071 |
| Financial and Insurance Activities | K | 128 | 248 | 522 | 1104 | 2002 |
| Real Estate Activities | L | 35 | 438 | 3998 | 10974 | 15445 |
| Professional, Scientific and Technical Activities | M | 74 | 296 | 1515 | 6208 | 8093 |
| Administrative and Support Service Activities | N | 20 | 125 | 951 | 3178 | 4274 |
| Public Administration activities | O | 1 | 3 | 8 | 6 | 18 |
| Education | P | 1 | 6 | 141 | 600 | 748 |
| Human Health and Social Work Activities | Q | 10 | 81 | 469 | 1098 | 1658 |
| Arts, Entertainment and Recreation | R | 2 | 20 | 388 | 1481 | 1891 |
| Other Service Activities | S | 3 | 16 | 166 | 1425 | 1610 |
| | U | 0 | 0 | 0 | 3 | 3 |
| Total | | 667 | 4834 | 30865 | 82956 | 119,322 |

**Table D.2: Table of Means Unmatched Sample**

| | *Small* | | | *Medium* | | | *Large* | | |
|---|---|---|---|---|---|---|---|---|---|
| | Treated | Control pool | Difference | Treated | Control pool | Difference | Treated | Control pool | Difference |
| Age | 6.16 | 6.50 | -0.34 | 10.59 | 9.44 | 1.15 *** | 13.53 | 12.61 | 0.92 * |
| | [3.59] | [3.88] | (0.30) | [5.08] | [5.15] | (0.26) | [5.06] | [5.60] | (0.54) |
| Capital | 57 | 75 | -18 | 202 | 278 | -76 | 1124 | 4632 | -3508 *** |
| (US dollar, thousand) | [409] | [1604] | (114) | [723] | [1313] | (63.73) | [2262] | [14000] | (1309) |
| Operating Revenue | 545 | 408 | 138 | 4218 | 2615 | 1603 *** | 23200 | 25700 | -2483 |
| (US dollar, thousand) | [1889] | [6097] | (432) | [3012] | [3206] | (157) | [13500] | [25500] | (2405) |
| Firm-specific predicted probability of | 0.31 | 0.37 | -0.06 *** | 0.29 | 0.29 | 0.00 | 0.30 | 0.29 | 0.01 |
| default | [.161] | [.201] | (0.02) | [.109] | [.134] | (0.01) | [.094] | [.1095] | (0.01) |
| N. Employees | 4.62 | 4.61 | 0.01 | 19.85 | 14.92 | 4.93 *** | 61.01 | 81.86 | -20.84 ** |
| | [4.89] | [53.04] | (4.19) | [16.07] | [16.83] | (0.84) | [41.28] | [107.19] | (10.19) |
| Debt-to-Assets | 0.75 | 24.35 | -23.60 | 0.74 | 0.78 | -0.04 ** | 0.67 | 0.72 | -0.05 |
| | [.250] | [1832] | (139.68) | [0.21] | [0.41] | (0.02) | [0.20] | [0.30] | (0.03) |
| Debt-to-Equity | 8.78 | -14.70 | 23.47 | 7.60 | 50.26 | -42.66 | 1.55 | 349.98 | -348.44 |
| | [32.20] | [2109] | (160.82) | [45.62] | [3317] | (160.34) | [45.08] | [12943] | (1207) |
| Share of employment for the firm's | 0.12 | 0.09 | 0.03 *** | 0.21 | 0.12 | 0.09 *** | 0.20 | 0.14 | 0.06 *** |
| sector in the firm's municipality | [.089] | [.064] | (0.005) | [.097] | [.081] | (0.004) | [.089] | [.087] | (0.008) |
| Total Assets | 720 | 861 | -140 | 4481 | 4414 | 68 | 22300 | 40000 | -17700 *** |
| (US dollar, thousand) | [2597] | [11900] | (907) | [3827] | [4634] | (226) | [16100] | [41700] | (3913) |
| Standardised business density for the | -0.13 | 1.05 | -1.18 *** | 0.04 | 1.15 | -1.11 *** | -0.01 | 1.21 | -1.22 *** |
| firm's sector in the firm's municipality | [.3769] | [2.0254] | (0.144) | [.3914] | [2.0034] | (0.097) | [.3554] | [2.0549] | (0.192) |
| Cost of Employees | 149 | 161 | -12 | 888 | 581 | 307 *** | 3276 | 4209 | -933 * |
| (US dollar, thousand) | [301] | [2077] | (177) | [773] | [674] | (33.84) | [2205] | [5207] | (495) |
| Number of firms | 552 | 77530 | | 439 | 11692 | | 115 | 1676 | |

*Standard deviations in square brackets, standard errors in parentheses*
**** p<0.01, ** p<0.05, * p<0.1*

**Table D.3: Investment Incentives Effect by Firm Size.**
**Regression Results from Mahalanobis Distance Matching without Replacement and Seismic Intensity ≤ 7.25**

| VARIABLES | Δlog (Capital) | | | Δlog (Employment) | | | Δlog (Revenue) | | | Δlog (Productivity) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) |
| Treated | 0.0625*** | 0.0454*** | 0.298* | -0.00371 | -0.00421 | 0.0654 | -0.141*** | -0.141*** | -0.0734 | -0.137*** | -0.137*** | -0.143 |
| | (0.000381) | (0.00118) | (0.0715) | (0.00157) | (0.00246) | (0.0677) | (0.00115) | (0.00147) | (0.137) | (0.000666) | (0.00139) | (0.0736) |
| Small | -0.0467*** | -0.0467*** | -0.0467*** | 0.122*** | 0.122*** | 0.122*** | -0.0150 | -0.0150 | -0.0150 | -0.133*** | -0.133*** | -0.133*** |
| | (0.000581) | (0.000581) | (0.000581) | (0.00254) | (0.00254) | (0.00254) | (0.00590) | (0.00591) | (0.00591) | (0.00747) | (0.00747) | (0.00747) |
| Small X Treated | 0.0100** | -0.0140** | 0.0378** | 0.0640*** | 0.0633*** | 0.0722** | 0.436*** | 0.435*** | 0.443*** | 0.341*** | 0.341*** | 0.340*** |
| | (0.00102) | (0.00204) | (0.00819) | (0.00344) | (0.00460) | (0.0106) | (0.00500) | (0.00473) | (0.0116) | (0.00827) | (0.00930) | (0.00656) |
| Medium | -0.0549*** | -0.0549*** | -0.0549*** | 0.0387*** | 0.0387*** | 0.0387*** | -0.164*** | -0.164*** | -0.164*** | -0.203*** | -0.203*** | -0.203*** |
| | (0.000680) | (0.000680) | (0.000680) | (0.00297) | (0.00297) | (0.00297) | (0.00690) | (0.00691) | (0.00691) | (0.00839) | (0.00840) | (0.00840) |
| Medium X Treated | 0.0414*** | -0.0119* | 0.0448*** | 0.0344** | 0.0329** | 0.0354** | 0.270*** | 0.268*** | 0.271*** | 0.235*** | 0.235*** | 0.235*** |
| | (0.00141) | (0.00347) | (0.00119) | (0.00470) | (0.00743) | (0.00550) | (0.00547) | (0.00497) | (0.00395) | (0.00963) | (0.0119) | (0.00888) |
| Subsidised Investment Size X Treated | | 0.00476*** | | | 0.000138 | | | 0.000119 | | | -1.95e-05 | |
| | | (0.000183) | | | (0.000259) | | | (9.04e-05) | | | (0.000204) | |
| Coverage Ratio Investment Subsidy X Treated | | | -0.634* | | | -0.186 | | | -0.181 | | | 0.0147 |
| | | | (0.193) | | | (0.178) | | | (0.366) | | | (0.199) |
| BB credit rating | -0.0457** | -0.0457** | -0.0457** | -0.114** | -0.114** | -0.114** | -0.0667 | -0.0667 | -0.0667 | 0.0468 | 0.0468 | 0.0468 |
| | (0.00484) | (0.00484) | (0.00484) | (0.0212) | (0.0212) | (0.0212) | (0.0492) | (0.0492) | (0.0492) | (0.0597) | (0.0598) | (0.0598) |
| BB credit rating X Treated | -0.000456 | 0.0354 | 0.0130 | 0.0510 | 0.0520 | 0.0549 | 0.0545 | 0.0554 | 0.0583 | 0.00665 | 0.00651 | 0.00635 |
| | (0.0117) | (0.0218) | (0.0115) | (0.0389) | (0.0405) | (0.0353) | (0.0366) | (0.0367) | (0.0438) | (0.0713) | (0.0728) | (0.0744) |
| Observations | 514 | 514 | 514 | 514 | 514 | 514 | 514 | 514 | 514 | 512 | 512 | 512 |
| R-squared | 0.009 | 0.078 | 0.022 | 0.024 | 0.024 | 0.026 | 0.037 | 0.037 | 0.038 | 0.066 | 0.066 | 0.066 |

Robust standard errors in parentheses.
*** p<0.01, ** p<0.05, * p<0.1

Small is a dummy equal to 1 for small sized companies, 0 otherwise; Medium is a dummy equal to 1 for medium sized companies, 0 otherwise; Treated is a dummy equal to 1 for companies receiving treatment and 0 otherwise; BB credit rating is a dummy equal to 1 if the company is rated as equivalent to BB on S&P rating scale on average in the 3 years before the earthquake shock, 0 otherwise (Appendix Section B.1 provides additional detail on the company rating procedure); Subsidised Investment Size is a continuous variable defined as the financed amount expressed as share of the pre-investment firm's capital; Coverage Ratio Investment Subsidy is a continuous variable defined as the ratio between the subsidised part of investment financing and the total investment financing cost

**Table D.4: Investment Incentives Effect by Firm Size.**
**Regression Results from Mahalanobis Distance Matching with Replacement and no limit to Seismic Intensity**

| VARIABLES | Δlog (Capital) | | | Δlog (Employment) | | | Δlog (Revenue) | | | Δlog (Productivity) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) |
| Treated | 0.133*** | 0.127*** | 0.160 | 0.00406*** | 0.00494** | 0.0915* | -0.124*** | -0.125*** | 0.0890 | -0.125*** | -0.126*** | -0.129* |
| | (0.00215) | (0.00205) | (0.0813) | (0.000175) | (0.000821) | (0.0311) | (0.00196) | (0.00275) | (0.163) | (0.000163) | (0.000386) | (0.0409) |
| Small | -0.0141 | -0.0141 | -0.0141 | 0.0886*** | 0.0886*** | 0.0886*** | -0.149** | -0.149** | -0.149** | -0.308*** | -0.308*** | -0.308*** |
| | (0.0111) | (0.0111) | (0.0111) | (0.00869) | (0.00869) | (0.00869) | (0.0230) | (0.0231) | (0.0231) | (0.0123) | (0.0123) | (0.0123) |
| Small X Treated | -0.123*** | -0.132*** | -0.113** | 0.0635** | 0.0651** | 0.0938** | 0.264*** | 0.263*** | 0.335** | 0.400*** | 0.397*** | 0.400*** |
| | (0.0104) | (0.0115) | (0.0180) | (0.00863) | (0.00721) | (0.0145) | (0.0185) | (0.0171) | (0.0702) | (0.0120) | (0.0127) | (0.0119) |
| Medium | -0.00700 | -0.00700 | -0.00700 | 0.0125* | 0.0125* | 0.0125* | -0.151*** | -0.151*** | -0.151*** | -0.168*** | -0.168*** | -0.168*** |
| | (0.00453) | (0.00453) | (0.00453) | (0.00353) | (0.00353) | (0.00353) | (0.00955) | (0.00956) | (0.00956) | (0.00584) | (0.00584) | (0.00584) |
| Medium X Treated | -0.111*** | -0.126*** | -0.111*** | 0.0758*** | 0.0782*** | 0.0763*** | 0.256*** | 0.255*** | 0.258*** | 0.183*** | 0.179*** | 0.183*** |
| | (0.00426) | (0.00525) | (0.00372) | (0.00352) | (0.00147) | (0.00349) | (0.00865) | (0.00630) | (0.00913) | (0.00577) | (0.00661) | (0.00588) |
| Subsidised Investment Size X Treated | | 0.00148*** | | | -0.000251 | | | 0.000157 | | | 0.000337* | |
| | | (9.71e-05) | | | (0.000220) | | | (0.000246) | | | (0.000109) | |
| Coverage Ratio Investment Subsidy X Treated | | | -0.0726 | | | -0.235 | | | -0.574 | | | 0.0115 |
| | | | (0.219) | | | (0.0841) | | | (0.446) | | | (0.109) |
| BB credit rating | -0.0506 | -0.0506 | -0.0506 | -0.0446 | -0.0446 | -0.0446 | 0.000722 | 0.000722 | 0.000722 | 0.0269 | 0.0269 | 0.0269 |
| | (0.0364) | (0.0364) | (0.0364) | (0.0284) | (0.0284) | (0.0284) | (0.0768) | (0.0768) | (0.0768) | (0.0483) | (0.0483) | (0.0483) |
| BB credit rating X Treated | 0.00931 | 0.0175 | 0.0129 | -0.0457 | -0.0471 | -0.0340 | -0.0162 | -0.0153 | 0.0136 | 0.0109 | 0.0127 | 0.0108 |
| | (0.0352) | (0.0384) | (0.0453) | (0.0281) | (0.0265) | (0.0264) | (0.0561) | (0.0550) | (0.0309) | (0.0466) | (0.0475) | (0.0466) |
| Observations | 1,266 | 1,266 | 1,266 | 1,266 | 1,266 | 1,266 | 1,264 | 1,264 | 1,264 | 1,202 | 1,202 | 1,202 |
| R-squared | 0.006 | 0.014 | 0.007 | 0.026 | 0.026 | 0.030 | 0.019 | 0.019 | 0.027 | 0.050 | 0.051 | 0.050 |

Robust standard errors in parentheses.
*** p<0.01, ** p<0.05, * p<0.1

Small is a dummy equal to 1 for small sized companies, 0 otherwise; Medium is a dummy equal to 1 for medium sized companies, 0 otherwise; Treated is a dummy equal to 1 for companies receiving treatment and 0 otherwise; BB credit rating is a dummy equal to 1 if the company is rated as equivalent to BB on S&P rating scale on average in the 3 years before the earthquake shock, 0 otherwise (Appendix Section B.1 provides additional detail on the company rating procedure); Subsidised Investment Size is a continuous variable defined as the financed amount expressed as share of the pre-investment firm's capital; Coverage Ratio Investment Subsidy is a continuous variable defined as the ratio between the subsidised part of investment financing and the total investment financing cost.

**Table D.5: Empirical Testing of Theoretical Model for Credit Market Frictions on Investment Incentives Effect by Sector. Regression Results from Mahalanobis Distance Matching with Replacement and Seismic Intensity ≤ 7.25**

| | Δlog (Capital) | | | | |
|---|---|---|---|---|---|
| VARIABLES | *Manufacturing* | *Utilities* | *Construction* | *Retail and Hospitality Services* | *Other Services* |
| | (1) | (2) | (3) | (4) | (5) |
| PD of economic sector and province | -0.00681 | 6.40e-06 | -0.252*** | 0.242 | -0.317 |
| | (0.0112) | (1.32e-06) | (0.0163) | (0.167) | (0.226) |
| PD of economic sector and province X Treated | 0.650 | 0.0386*** | 2.160*** | -0.155 | 0.979 |
| | (0.734) | (1.32e-06) | (0.117) | (0.190) | (0.682) |
| BBB credit rating | -0.0397 | -0.0637*** | -0.0616 | -0.0220 | 0.741 |
| | (0.0355) | (2.45e-06) | (0.104) | (0.340) | (0.568) |
| BB credit rating | -0.0401 | - | - | -0.413 | 1.003 |
| | (0.0406) | | | (0.371) | (0.769) |
| BBB credit rating X Treated | -0.0731 | -0.103*** | -0.0529 | 0.212 | 0.580 |
| | (0.194) | (2.45e-06) | (0.155) | (0.369) | (0.829) |
| BB credit rating X Treated | -0.0638 | - | - | 0.671 | - |
| | (0.174) | | | (0.526) | |
| Coverage Ratio Investment Subsidy X Treated | -0.354 | 0.146*** | 2.671*** | -0.289 | -3.077 |
| | (0.374) | (0) | (0.337) | (0.265) | (2.743) |
| Treated | -1.775 | - | -8.869*** | -0.172 | -0.529 |
| | (2.539) | | (0.877) | (0.319) | (1.841) |
| SME | -0.0418 | - | 1.332*** | -0.686 | 0.313 |
| | (0.0319) | | (0.197) | (0.584) | (0.223) |
| SME X Treated | -0.000154 | - | -2.082*** | 0.548 | -1.251 |
| | (0.0999) | | (0.215) | (0.648) | (1.374) |
| Sectoral business density | 0.0662 | -1.42e-05* | 0.157 | 0.157 | -0.299 |
| | (0.0446) | (1.15e-06) | (0.231) | (0.462) | (0.222) |
| Sectoral business density X Treated | -0.251 | -0.0553*** | 4.041*** | -0.447 | 0.352 |
| | (0.205) | (1.15e-06) | (0.809) | (0.547) | (1.591) |

Robust standard errors in parentheses.
*** p<0.01, ** p<0.05, * p<0.1

SME is a dummy equal to 1 for small and medium sized companies, 0 for large companies; Treated is a dummy equal to 1 for companies receiving treatment and 0 otherwise; BBB credit rating is a dummy equal to 1 if the company is rated as equivalent to BBB on S&P rating scale on average in the 3 years before the earthquake shock, 0 otherwise; BB credit rating is a dummy equal to 1 if the company is rated as equivalent to BB on S&P rating scale on average in the 3 years before the earthquake shock, 0 otherwise (Appendix Section B.1 provides additional detail on the company rating procedure); business density of the economic sector in firms' municipality is controlled through the 3 year average of the ratio between the number of business units and the municipality area in sqkm mean standardised at national level (details in Section V); the sector and province specific loan's baseline probability of default (PD) is controlled as continuous variable and corresponds to the baseline province and sector probability of default at the end of the year before the earthquake shock; the Coverage Ratio Investment Subsidy is a continuous variable defined as the ratio between the subsidised part of investment financing and the total investment financing cost.

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