EUROPEAN CENTRAL BANK
EUROSYSTEM

Exploring non-linearities using the micro-aggregated CompNet database:

The investment-leverage relationship

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Motivation

- Starting from the empirical evidence of the existence of non-linearities in investment regressions

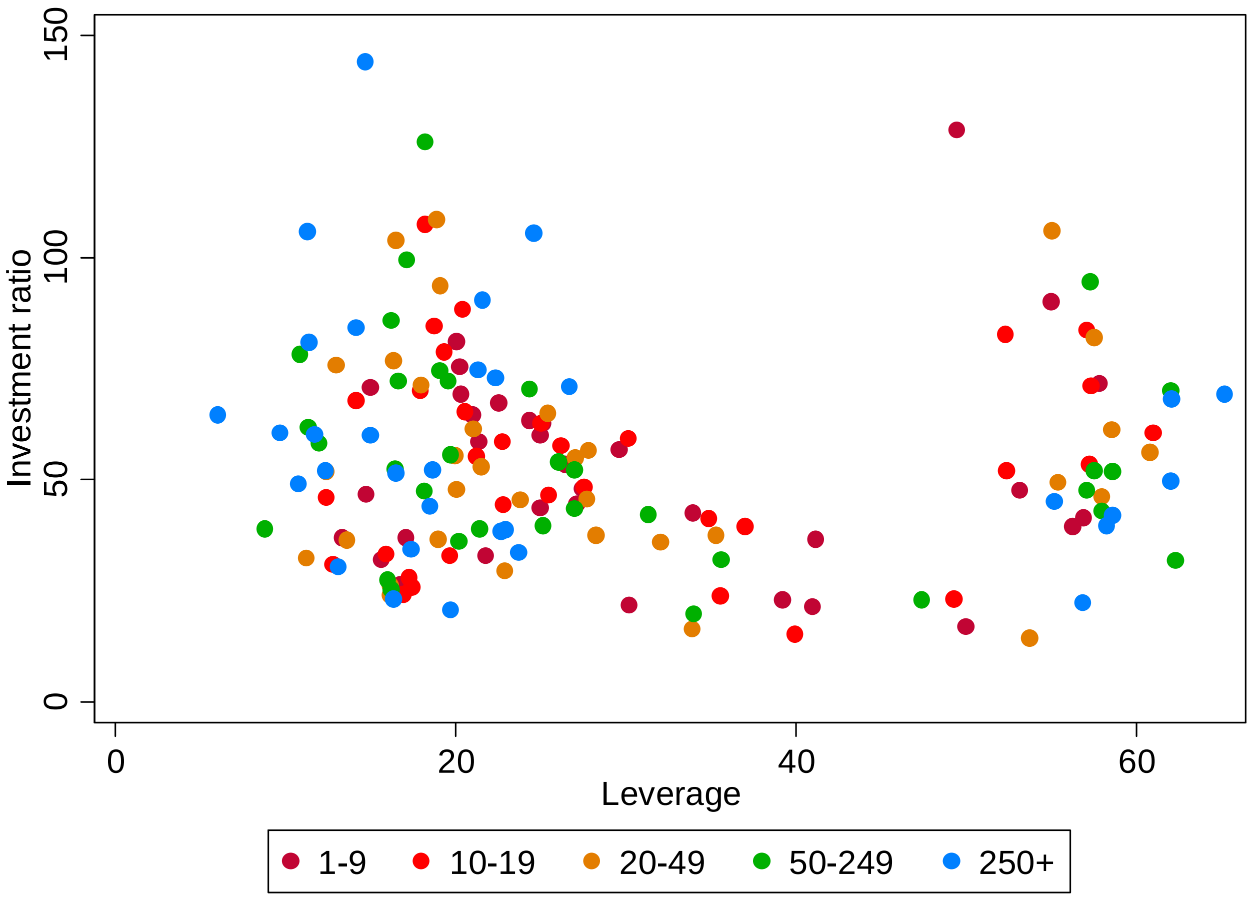
  ✓ Financial module's analysis

- How can we use the CompNet database to correctly estimate non-linearities?

- Two aims of the project :
  - Methodological (novelty!)
  - Empirical (we reached step 1 out of 3 steps)

STILL WORK IN PROGRESS!!!

Evidence of nonlinear impacts of indebtedness on investment:



Characteristics of the CompNet database

Starting from balance-sheet/profit and loss data:

Aggregates of individual firm accounting statements by country, sector of economic activity and firm size.

Regression analysis on micro-aggregated data:

Cell-based regressions using mean values: do we explain individual behavior?

- Implied assumption of micro homogeneity or representative/ typical agent
- Aggregation bias if *heterogeneity* (Theil, 1954) or *nonlinearity.*
- Aggregation gain (Grunfeld and Griliches, 1960).

Presence of non-linearities

- Numerous studies indicate **non-linear** impact of some determinants of firms' investment

$$Y_{it} = \beta_0 + \beta_1 X_{it} + \beta_2 X_{it}^2 + \alpha_i + u_{it}$$

- Non-linearities at the firm level imply that the **aggregate relationship** differ from the **individual relationship evaluated at the average**:

$$\sum_i Y_{it} = n\beta_0 + \beta_1 \sum_i X_{it} + \beta_2 \sum_i X_{it}^2 + \sum_i \alpha_i + e_{it}$$

$$\bar{Y}_t = \gamma_0 + \gamma_1 \bar{X}_t + \gamma_2 \bar{X}_t^2 + \bar{\alpha} + e_{it}$$

Non-linearities and firm-level data

$$Y_{it} = \beta_0 + \beta_1 X_{it} + \beta_2 X_{it}^2 + \alpha_i + u_{it}$$

$$Y_i^D = \beta_1 X_i^D + \beta_2 X_i^{2D} + \varepsilon_i \text{ , with } X_i^{2D} = X_{it_2}^2 - X_{it_1}^2$$

- β is point identified if access to the individual panel micro data.

- What with aggregated data?

What with aggregated data?

$$\text{Min } E\left(Y_i^D - \beta_1 X_i^D - \beta_2 X_i^{2D}\right)^2$$

- $\beta_1 = \frac{E\left(X_i^D Y_i^D\right)E\left(X_i^{2D} X_i^{2D}\right) - E\left(X_i^D X_i^{2D}\right)E\left(Y_i^D X_i^{2D}\right)}{E\left(X_i^D X_i^D\right)E\left(X_i^{2D} X_i^{2D}\right) - \left[E\left(X_i^D X_i^{2D}\right)\right]^2}$

- $\beta_2 = \frac{E\left(X_i^{2D} Y_i^D\right)E\left(X_i^D X_i^D\right) - E\left(X_i^{2D} X_i^D\right)E\left(Y_i^D X_i^D\right)}{E\left(X_i^{2D} X_i^{2D}\right)E\left(X_i^D X_i^D\right) - \left[E\left(X_i^{2D} X_i^D\right)\right]^2}$

→ Points identified if all moments are known.

What with CompNet micro-aggregated data?

Some information is missing!

$$E\left(X_i^D X_i^D\right) = E\left(X_{it_2}^2\right) - 2E\left(X_{it_2} X_{it_1}\right) + E\left(X_{it_1}^2\right)$$

$$E\left(X_i^{2D} X_i^{2D}\right) = E\left(X_{it_2}^4\right) - 2E\left(X_{it_2}^2 X_{it_1}^2\right) + E\left(X_{it_1}^4\right)$$

$$E\left(Y_i^D X_i^D\right) = E\left(Y_{it_2} X_{it_2}\right) + E\left(Y_{it_2} X_{it_1}\right) - \; \ldots$$

➔ **Partial identification** is the best we can do.

Identification methodology (I)

Cambanis-Simons-Stout Inequality (1976):

(Fan, Sherman and Shum 2014)

Let S and T random variables with known marginal distribution functions F_S and F_T and finite variances. Then

$$\int_0^1 F_S^{-1}(1-u)F_T^{-1}(u)\mathrm{d}u \leq E(ST) \leq \int_0^1 F_S^{-1}(u)F_T^{-1}(1-u)\mathrm{d}u$$

The bounds are finite and, without additional information, sharp.

➔ We can find bounds for $E\left(Y_{it_2}X_{it_2}\right)$ using information on $F_{Y_{t_2}}$ and $F_{X_{t_2}}$.

Identification methodology (II)

- $$\beta_2 = \frac{E(X_i^{2D} Y_i^D) E(X_i^D X_i^D) - E(X_i^{2D} X_i^D) E(Y_i^D X_i^D)}{E(X_i^{2D} X_i^{2D}) E(X_i^D X_i^D) - [E(X_i^{2D} X_i^D)]^2}$$

$$= \frac{M_1 M_2 - M_3 M_4}{M_5 M_2 - [M_3]^2} = \mathcal{H}(M_1, M_2, M_3, M_4, M_5)$$

- $M_k^L \leq M_k \leq M_k^U$ for $k = 1, \ldots, 5$

Technical challenges

Hence $\beta_2^L \leq \beta_2 \leq \beta_2^U$ where the upper bound β_2^U is defined as:

$$\beta_2^U = \sup_{M_1,M_2,M_3,M_4,M_5} \mathcal{H}(M_1, M_2, M_3, M_4, M_5)$$

$$\text{s.t.}\, M_k^L \leq M_k \leq M_k^U \text{ for } k = 1, \ldots, 5$$

M_k^L and M_k^U are not exactly known but **estimated**

1. F_X, F_Y must be estimated using percentiles of the distribution available in CompNet

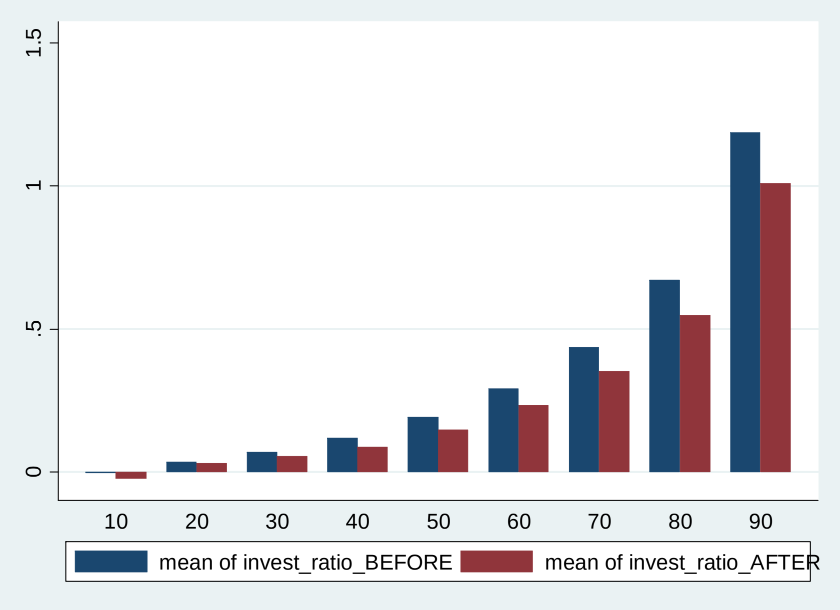
→ **interpolation** to get the complete distribution

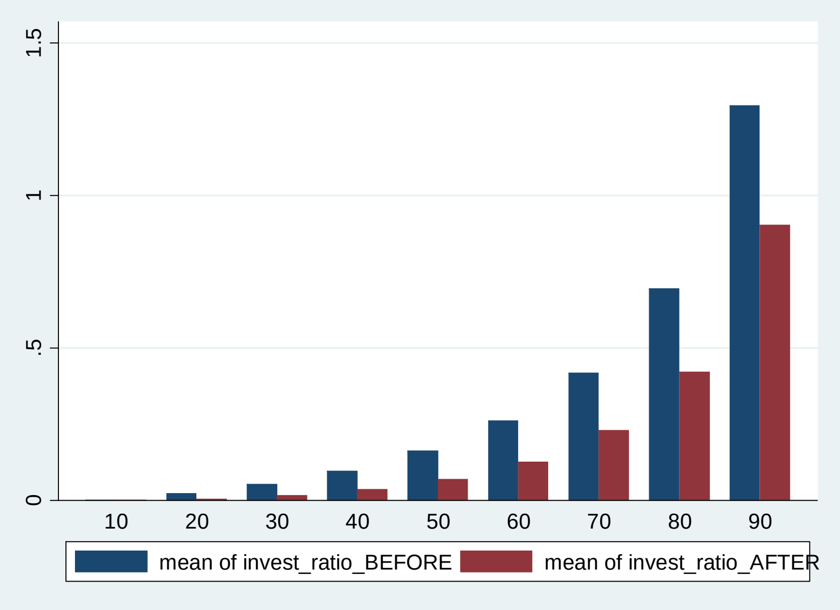
2. β_2^U might be imprecisely estimated near the estimated $\widehat{M}_k^L$ and $\widehat{M}_k^U$ bounds

→ **precision-correction** to control for sampling errors

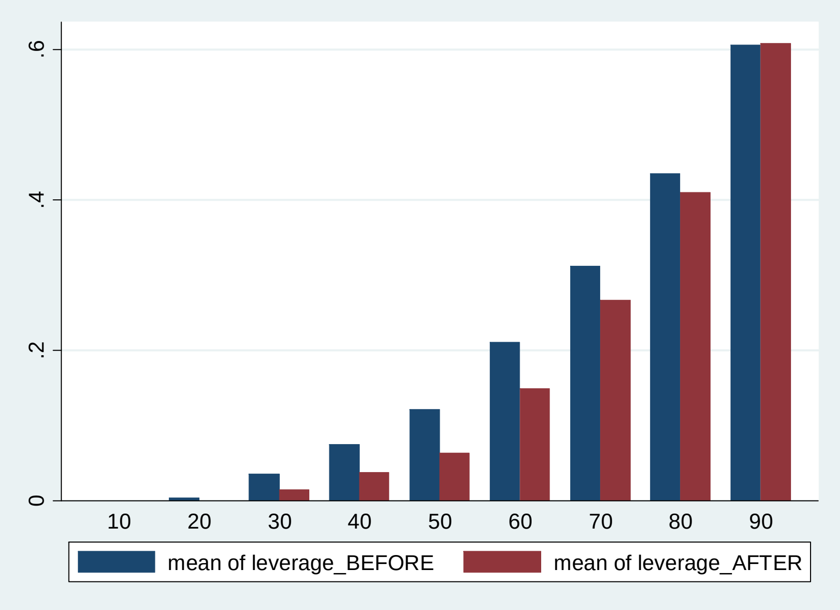
Investment ratio and leverage by percentiles

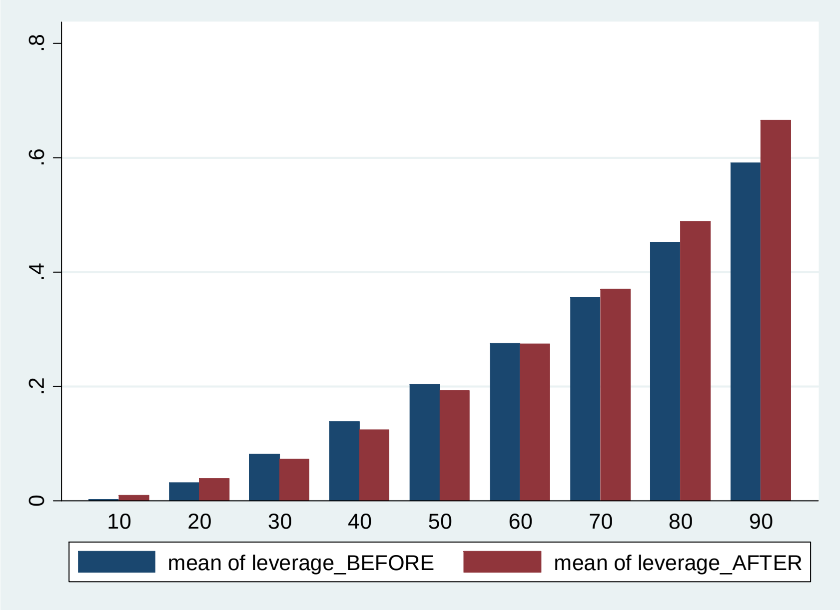
Non-stressed countries INVESTMENT Stressed countries





Non-stressed countries (excluding DE) LEVERAGE Stressed countries (excluding SI)





A new methodology: Multi-step implementation (I)

CompNet data provides aggregates at the country-sector-size cell level over several years (T>2).

Step 1: obtain bounds for each cell and each t=2,…,T

$$\beta_2^U = \sup_{M_1,M_2,M_3,M_4,M_5} \mathcal{H}(M_1, M_2, M_3, M_4, M_5)$$

$$\text{s.t.}\, M_k^L \leq M_k \leq M_k^U \text{ for } k = 1, \ldots, 5$$

Multi-step implementation (II)

Step 2: for each cell, intersect bounds obtained at each t

$$Y_{it_2}^{D} = \beta_1 X_{it_2}^{D} + \beta_2 X_{it_2}^{2D} + \varepsilon_{it_2} \rightarrow (\beta_2^L)^2 \leq \beta_2 \leq \left(\beta_2^U\right)^2$$
$$Y_{it_3}^{D} = \beta_1 X_{it_3}^{D} + \beta_2 X_{it_3}^{2D} + \varepsilon_{it_3} \rightarrow (\beta_2^L)^3 \leq \beta_2 \leq \left(\beta_2^U\right)^3$$
$$\ldots$$

$$\rightarrow \max_{\tau=2,\ldots,T} (\beta_2^L)^\tau \leq \beta_2 \leq \min_{\tau=2,\ldots,T} \left(\beta_2^U\right)^\tau$$

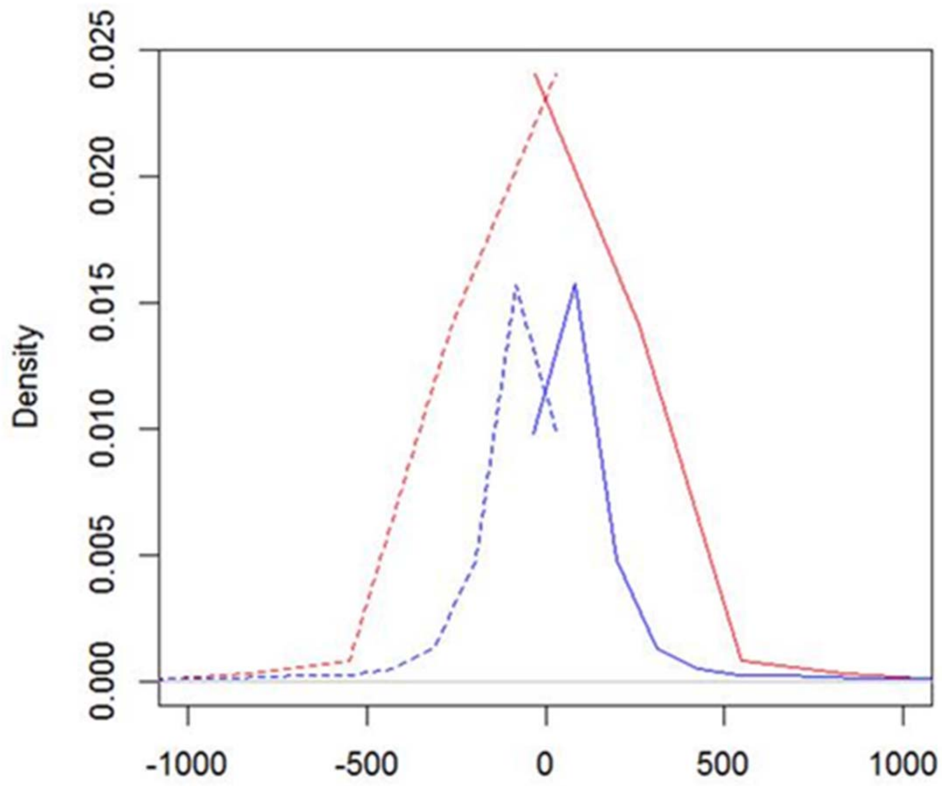
Step 3: intersect bounds obtained for each cell

$$(\beta_2^L)^c \leq \beta_2 \leq \left(\beta_2^U\right)^c, \; c = 1, \ldots, C$$

$$\rightarrow \max_{c=1,\ldots,C} (\beta_2^L)^c \leq \beta_2 \leq \min_{c=1,\ldots,C} \left(\beta_2^U\right)^c$$

Preliminary results on the bounds (I)

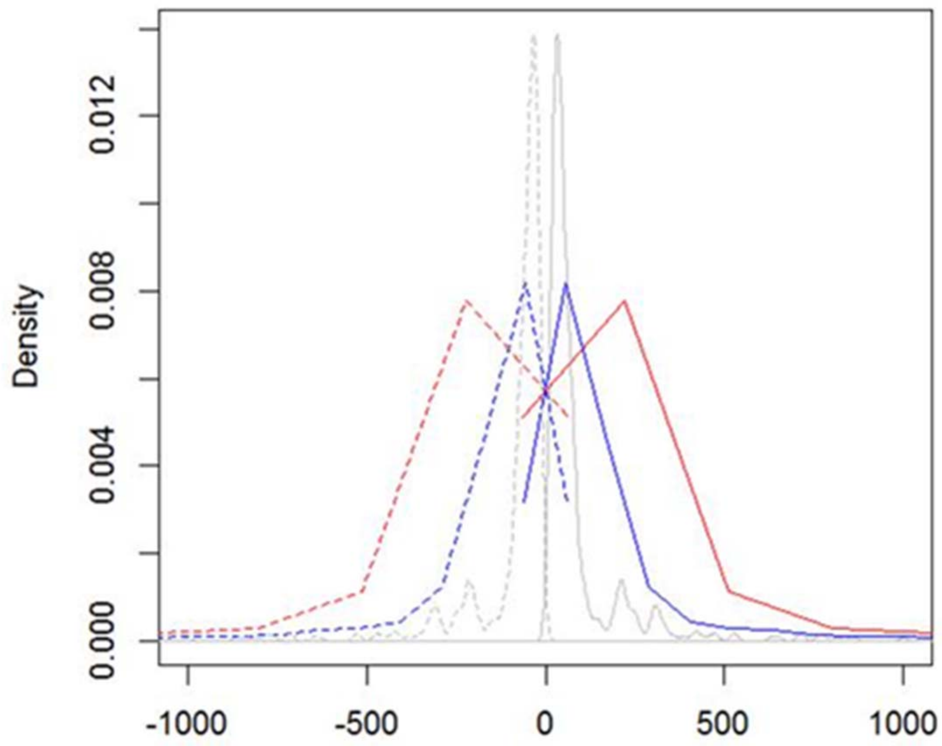
Step 1: obtain bounds for each cell and each t=2,…,T



Densities of both the upper (solid) and lower (dashed) bounds both before 2008 (in blue) and after 2008 (in red):

Preliminary results on the bounds (II)

Step 1: obtain bounds for each cell and each t=2,…,T



Densities of both the upper (solid) and lower (dashed) bounds for different countries: Belgium in blue, Germany in red and Italy in grey

Challenges and next steps

1. Estimating the bounds:

✓ done

Confirmation of our intuition for the method:

- by taking the intersection of the bounds across time and cells, we can sharpen the bounds.

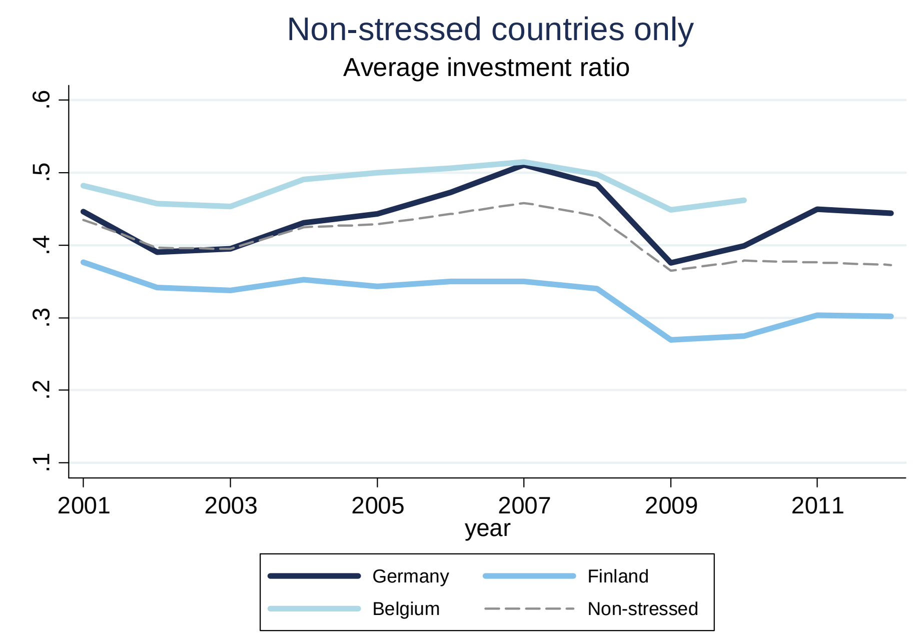
However, <u>for now</u>, the estimated bounds contain zero (the estimated lower bounds are always negative and the estimated upper bounds are always positive).

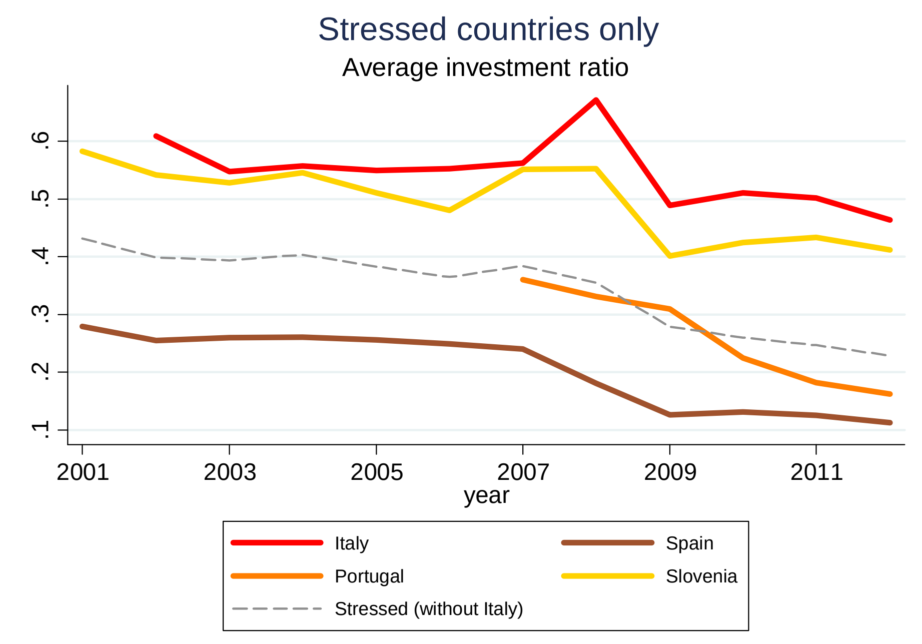
2. Next steps: Inference for the bounds

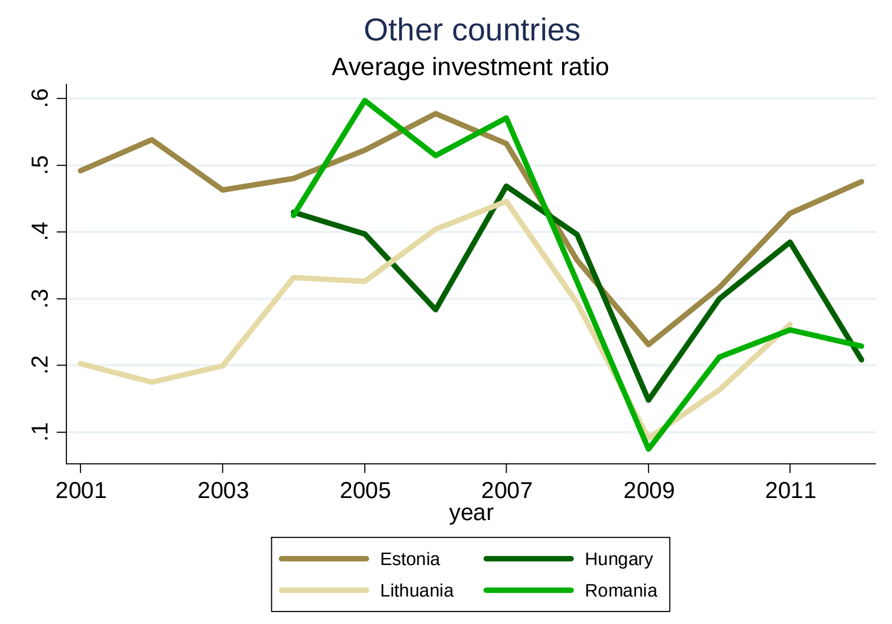
✓ Confidence interval: to be done

Determinants of corporate investment and role of leverage

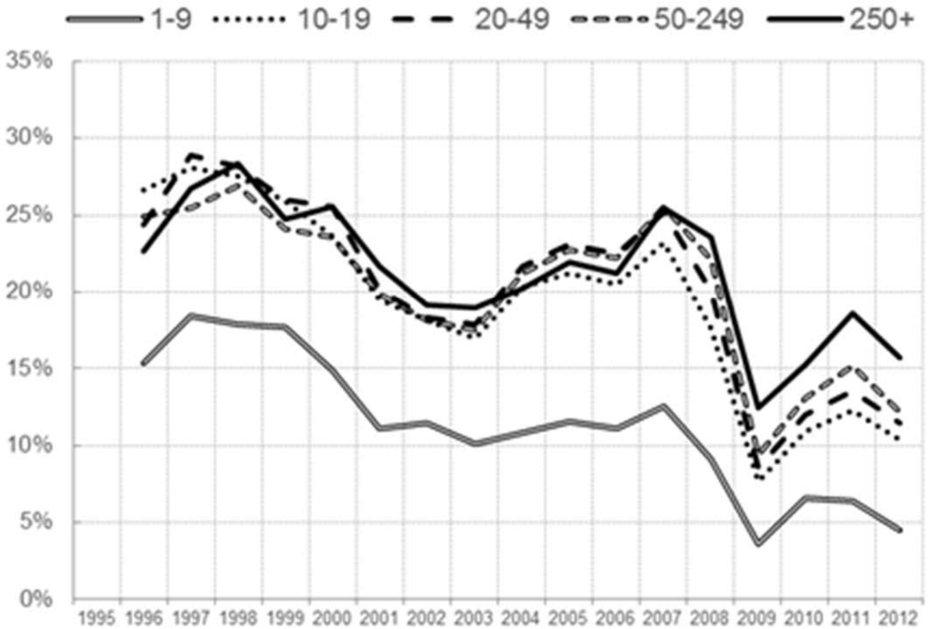
The 2009 investment collapse

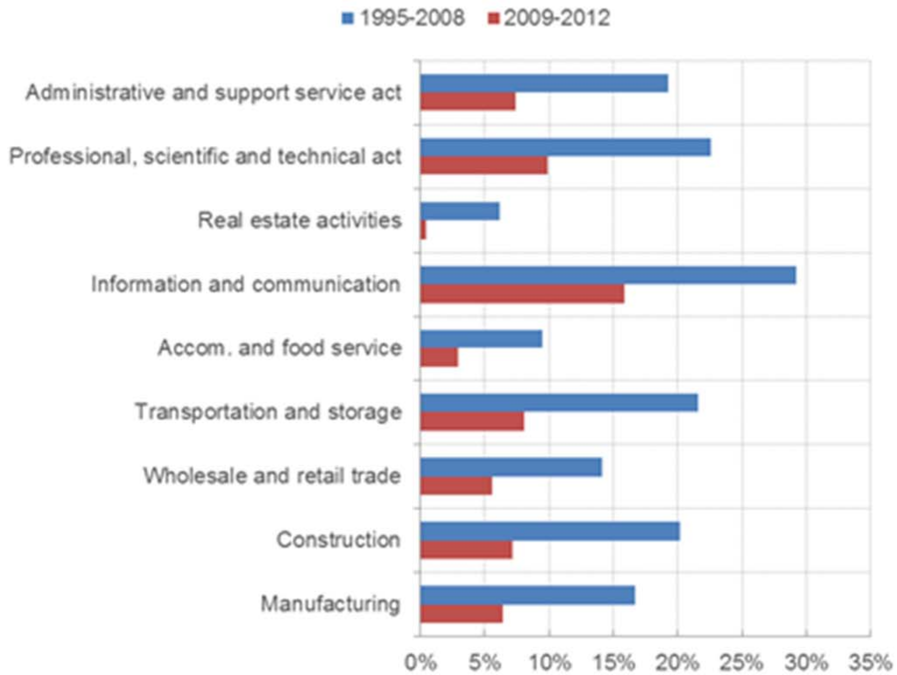






The 2009 investment collapse





Theory: fundamental vs. financial determinants

With perfect capital markets,

- Modigliani-Miller capital-structure irrelevance proposition.
- Tobin's q theory: present value of future marginal productivity of capital.

With capital markets imperfections (e.g. asymmetric information),

- Internal and external capital are not perfect substitutes.
- Liquidity and strength of balance sheet matter: dependence on external funds, external finance premium, collaterals
- Empirical literature on investment-cash flow sensitivity since Fazzari *et al*. (1988).

Fundamental	Financial
Sales growth	Liquidity Leverage
Cash flow	

Specific role of leverage

Financial accelerator (Bernanke-Gertler,1989) :

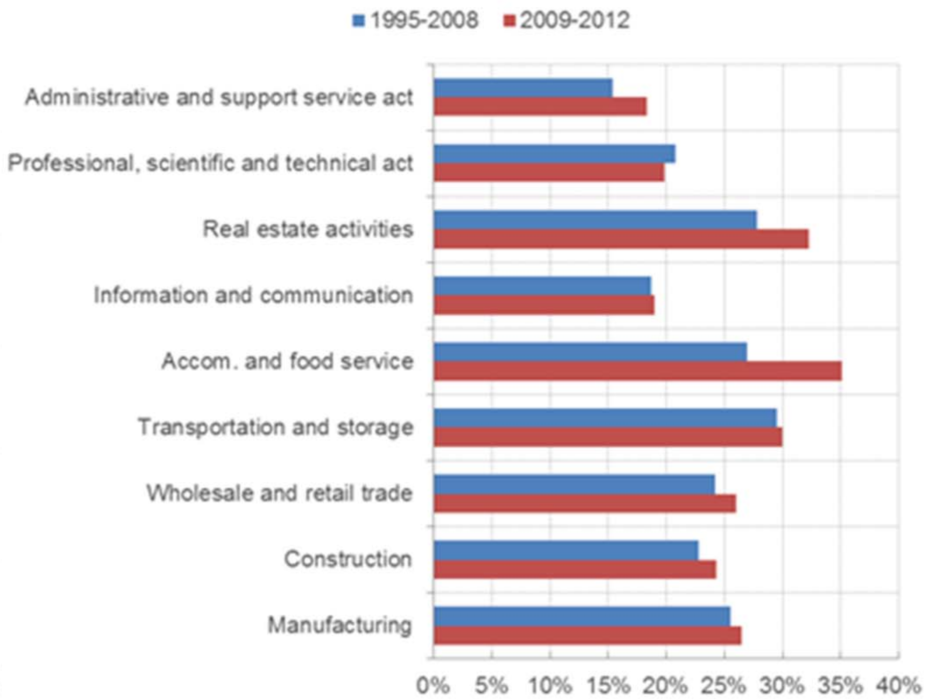
- Greater access to bank credit/ diversification of funding options
    - *boost productivity levels/reduction macro volatility*

- Excess indebtdeness can more than offset benefits
    - *raise corporate vulnerabilities/ amplify firms‘ sensitivity to income and interest shocks.*

- **Important asymmetric effects between investment decisions and balance sheet positions**
    - *(Cecchetti, Mohanty and Zampolli, 2010, Coricelli et al., 2010, Buca and Vermeulen, 2013, Goretti and Souto, 2013, Ferrando, Marchica and Mura, 2014, SIR 2015)*

- **Firms‘ high leverage is legacy of pre-crisis period** *(SIR 2013, Kalemli- Ozcan, Laeven and Moreno, 2015)*

Leverage across firm size and sectors



Analysis of Investment determinants in the financial module

$$\bar{\dot{IK}}_{ct} = \beta_1 \overline{IK}_{ct-1} + \beta_{21}\overline{SG}_{ct} + \beta_{22}\overline{SG}_{ct}\text{x } 1\{t \geq 2009\} + \beta_{31}\overline{CFK}_{ct-1} + \beta_{32}\overline{CFK}_{ct-1}\text{x } 1\{t \geq 2009\} + \beta_{41}\overline{Lev}_{ct-1} + \beta_{42}\overline{Lev}_{ct-1}\text{x } 1\{t \geq 2009\} + \bar{\mu}_c + \bar{v}_{ct}$$

	(A)	(B)
IK_{it-1}	0.0148	0.148*
SG_{it}	0.211*	0.292**
SG_{it} x $1\{t \geq 2009\}$	-0.109	-0.134
CFK_{it-1}	1.354*	0.833
CFK_{it-1} x $1\{t \geq 2009\}$	0.0546	-1.691***
Lev_{it-1}	-0.236	2.394**
Lev_{it-1} x $1\{t \geq 2009\}$	-0.132	1.873***
Lev^2_{it-1}		-0.0482**
Lev^2_{it-1} x $1\{t \geq 2009\}$		-0.0489***
Observations	1,049	1,049
Number of cells	157	157
Number of instruments	35	39
AR2(p-value)	0.878	0.579
H-test(p-value)	0.0182	0.953

Cell-based model for 4 countries (BE, DE, ES and IT) over the 2000-2012 period, 9 macro-sectors and 5 size classes.

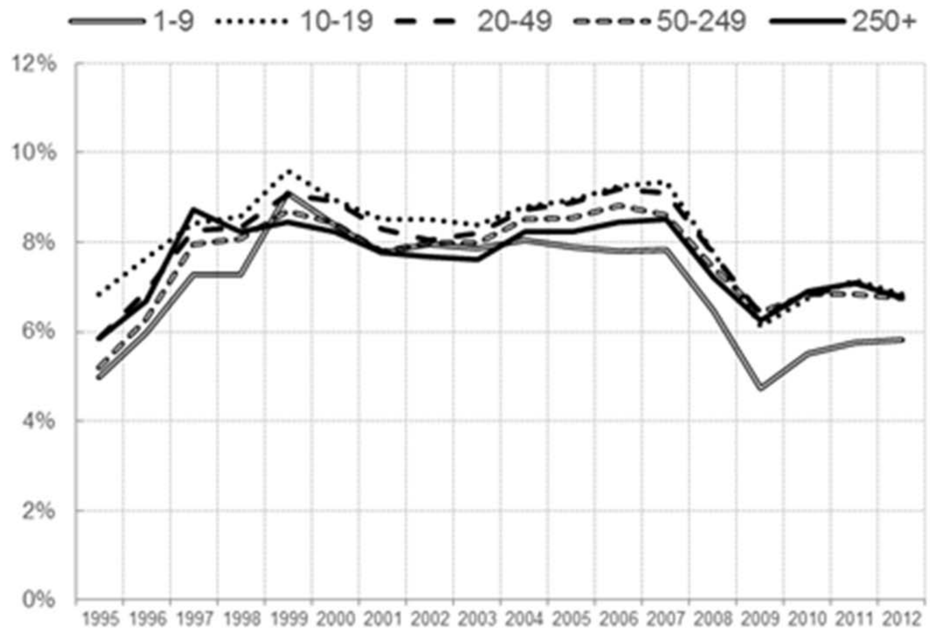
Conclusions

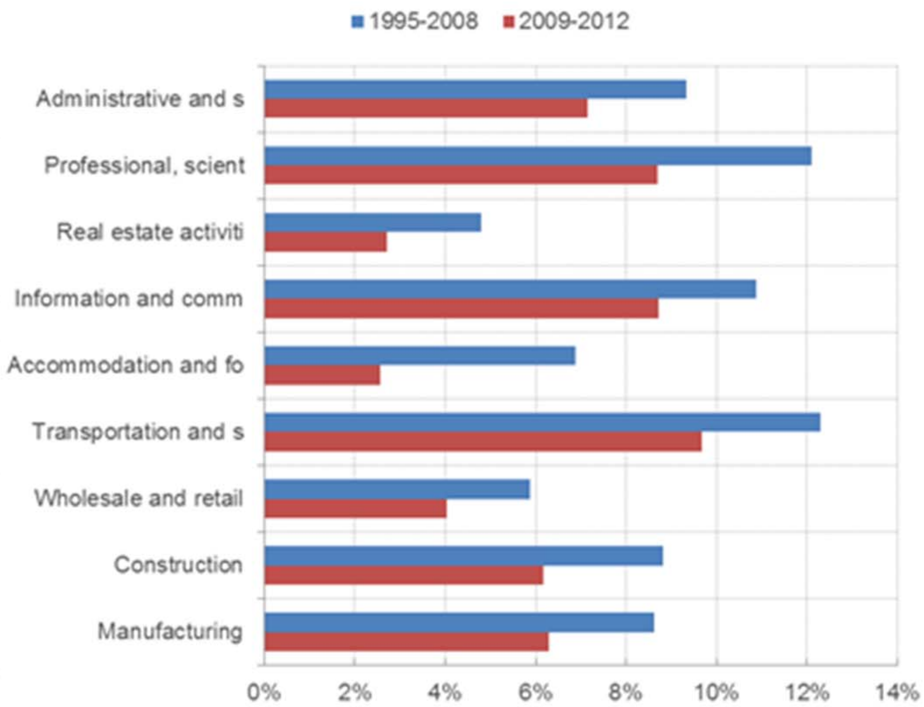
- Non-linearities at the firm level imply that the aggregate relationship differ from the individual relationship evaluated at the average.
- Points identified if all moments are known but this information is partly missing in micro-aggregated databases like CompNet
- **Partial identification** is the best we can do.
- **New methodology** to find bounds for $E\left(Y_{it_2}X_{it_2}\right)$ using information on $F_{Y_{t_2}}$ and $F_{X_{t_2}}$:
  1. We apply interpolation techniques using percentiles of the distribution available in CompNet
  2. We apply precision-correction techniques to control for sampling errors

- **We believe there is need to obtain more precision in the relationship between investment and leverage**

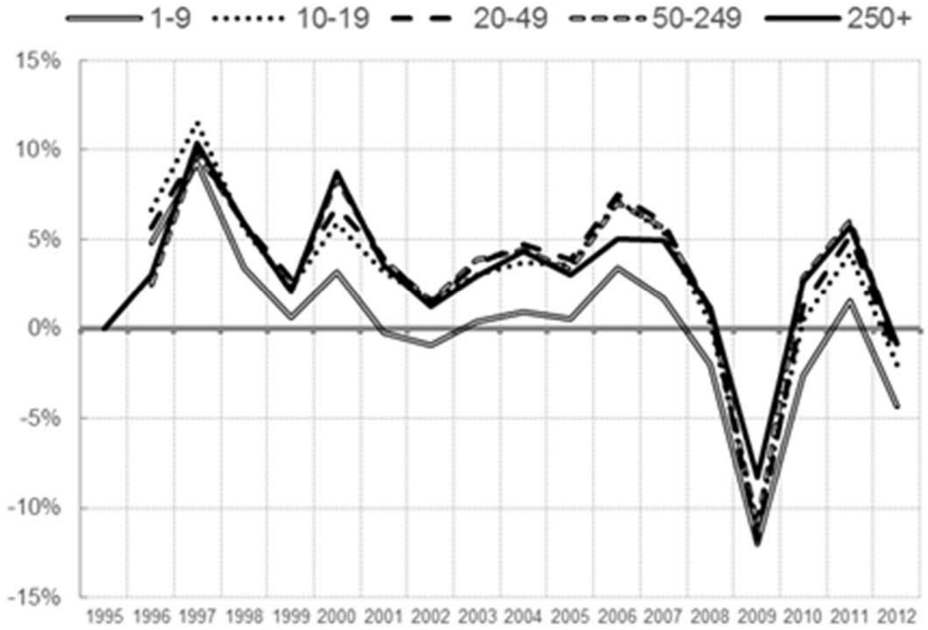
Thank you

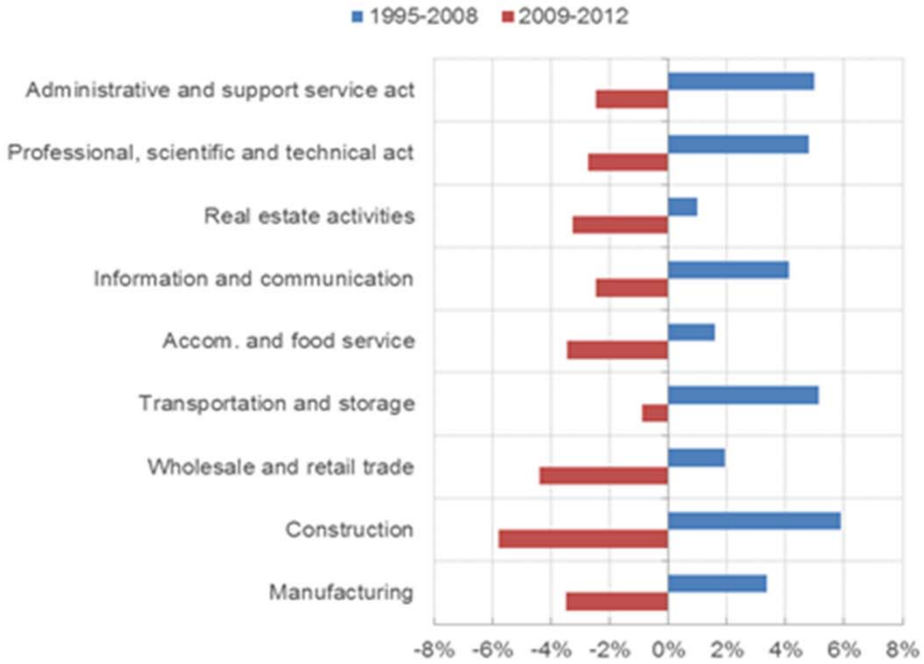
Explanatory variables: cash flow





Explanatory variables: sales growth





- Sales growth falls in 2009 and 2012.

Explanatory variables: Cash holding