Is public support for business R&D optimal? UK evidence from business microdata.

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Use of ONS datasets does not imply endorsement of the interpretation or analysis of the data by the data owner or the UK Data Service at the UK Data Archive.

ONS datasets may not exactly reproduce National Statistics aggregates

Information asymmetry, risk aversion and R&D subsidies:

Highlights

1. We draw on two ONS datasets: BERD and BSD
2. We utilise a sample of sample of 43,650 British firms from 1998-2012 and entropy balancing (EB) methodology
3. The average treatment effect on the treated (ATT) is:
   - ***(a)*** ***insignificant or small*** during crisis episodes or when investment is in basic research;
   - ***(b)*** ***insignificant*** among larger and older firms and firms closer to R&D frontier;
   - ***(c)*** ***positive and larger than average*** among small and young firms and firms further away from the R&D frontier.
4. **Policy conundrum:** Most of (~ 90%) of R&D subsidies are allocated to firms that do not create R&D additionality.

The BSD Dataset: Number of Enterprises

Year	Number of Enterprises
1997	2,179,819
1998	2,305,177
1999	2,498,186
2000	2,514,591
2001	2,545,284
2002	2,587,018
2003	2,843,291
2004	2,931,311
2005	2,974,762
2006	3,256,644
2007	3,574,241
2008	3,868,126
2009	3,853,913
2010	4,072,041
2011	2,842,778
2012	2,884,285
2013	2,883,914
Total Enterprise-Year observation	**50,615,381**

6,810,147 distinct enterprises appear at least once.

The BERD Database: Number of Enterprises

Year	Number of Enterprises
1997	7,836
1998	8,932
1999	8,217
2000	9,207
2001	9,182
2002	11,510
2003	9,954
2004	12,235
2005	13,503
2006	17,400
2007	20,541
2008	17,393
2009	19,435
2010	18,890
2011	20,801
2012	22,403
Total Enterprise-year observation	227,439

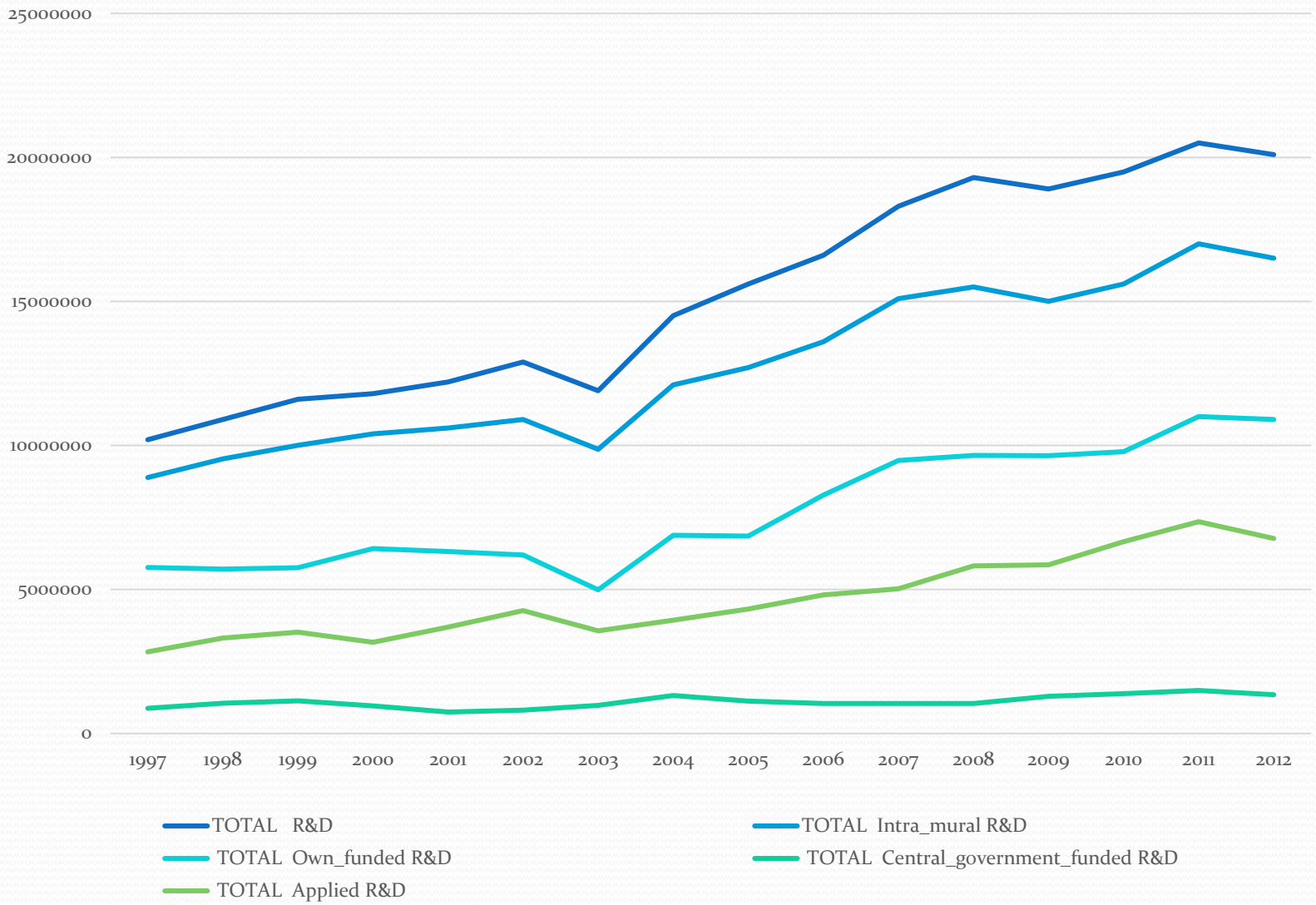
46, 627 distinct enterprises

BSD-BERD linked Dataset: Number of Enterprises

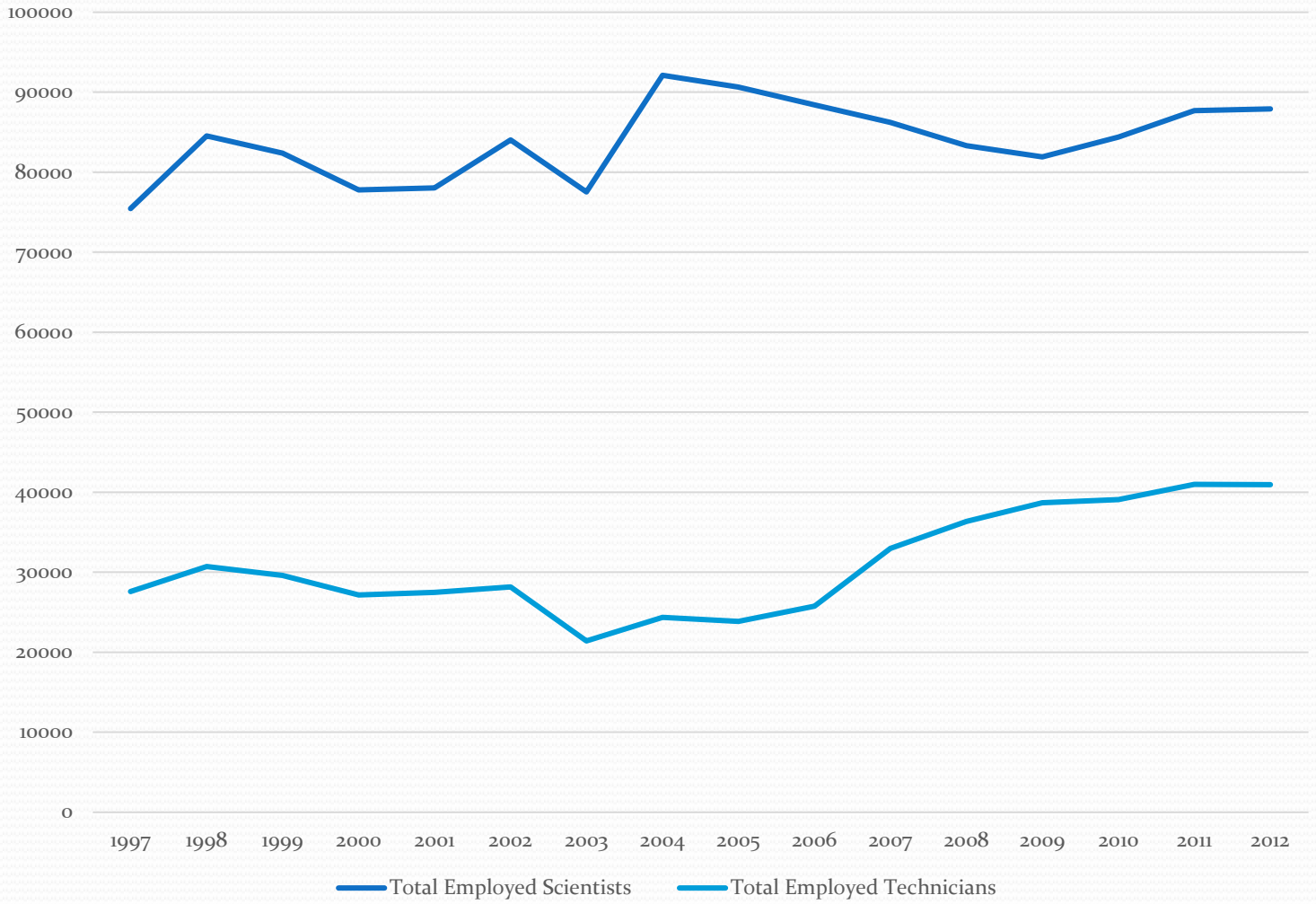
Year	Number of Enterprises
1997	7,302
1998	8,350
1999	7,678
2000	8,630
2001	8,656
2002	10,930
2003	8,926
2004	11,752
2005	12,969
2006	16,849
2007	19,911
2008	16,970
2009	19,046
2010	18,592
2011	20,556
2012	22,169
Total enterprise-year observation	**219, 286**

43, 650 distinct enterprises

R&D expenditure: 1997-2012 (£ '000)



Employed scientists and technicians, total: 1997-2012



Challenges encountered in Appending Databases

1. Differences in data types for the same variable across years or databases.

2. Differences in the naming of variables across years

3. Differences in foreign ownership coding. (Mapping tables provided)

4. Dealing with demographic events (the *demvar* variable in BSD is unreliable)

5. Differences in sic coding across years: sic92; sic 2003; sic 2007 (from 2008)
   – concordance table from Company House.

Challenges encountered in Merging Databases

1. Size issues
    1. BSD – 16 gigabytes

2. Some differences in variable names - needed renaming
3. Incorrect *rurefs* for some reporting units (BERD)
4. Matches between BERD & BSD is very good – 96% of BERD enterprises were matched.
5. However, it is difficult to verify the R&D (and subsidy) status of firms without R&D data in BSD (or in ARD)
6. Finally, matches between BERD and ARD/ABS is low – ~50% of BERD reporting units do not match with ARD/ABS reporting units.

The UK funding regime

- **Objectives of UK subsidies:**
  - To stimulate R&D and innovative activity
  - Encourage the development of innovative products, process and services with future commercial potential

- **Grading of applications (Market Readiness Level - MRL)**
  - Basic research –MRL score 1-2: 100% funding
  - Product/Process innovations – MRL score 3-6: 50-60% funding

- **Government funding (subsidy) in BERD** records payments conditional on R&D expenditures incurred in relation to funded R&D project(s)

- **Monitoring** is based on current and past R&D investment by funded firms

Motivation for the research:

Stylised facts about UK business R&D landscape

- Subsidies for Business R&D is 0.2% of GDP – higher than most other OECD countries except the US, Korea, Canada & France

- Business R&D expenditure in the UK is low by international standards - even after adjusting for structural differences.

- Business R&D and subsidy in the UK is concentrated among large firms – top 10% account for more than 90% of total subsidy and business R&D.

Identifying subsidy status

- The subsidy (treatment) status in each year is determined by whether the firm receives UK funding in that year.
- The subsidy in any year is a re-imbursement of the R&D expenditures *incurred* for implementing supported R&D project(s) during the year.
- The amounts of subsidy and R&D investment are recorded in BERD.
- BERD breaks down R&D investment by type – basic research, applied research, capital investment in R&D (labs, etc.), number of scientists and technicians, etc.

Method - 1

- Effect-size estimator is the average treatment effect on the treated (ATT)
- ATT = the conditional difference in mean outcomes for treated (subsidized) and untreated (non-subsidized) firms.

$$E[ATT] = \mathrm{E}[\mathbf{Y_{it}}(1) \mid \mathbf{X_{it-1}}, D_{it}=1] - \mathrm{E}[\mathbf{Y_{it}}(0) \mid \mathbf{X_{it-1}}, D_{it}=1]$$

- $\mathbf{Y_{it}}(0)$ is counterfactual outcome
- Outcome measure, $\mathbf{Y_{it}}$, is growth rate of the firm's R&D intensity
- First-differencing eliminates the firm-specific fixed effects.
- Conditional on firm characteristics before subsidy ($\mathbf{X_{it-1}}$), the subsidy status is orthogonal to the outcome

Method - 2

- The counterfactual outcome is obtained by balancing the covariates ($\mathbf{X_{it-1}}$) through entropy balancing (Hainmueller, 2012; Hainmueller and Xu, 2013)

$$E[\mathbf{Y_{it}}(0) | \mathbf{X_{it-1}}, D_{it}=1] = -\frac{\sum_{\{it|D=0\}} Y_{it} w_{it}^{eb}}{\sum_{\{it|D=0\}} w_{it}^{eb}}$$

- Entropy-balanced weights, w_{it}^{eb}, minimizes the dissimilarity between probability distributions of the control and treated firms.

- EB weights are obtained to balance 139 pre-treatment covariates capturing firm, industry, technology class, year information; receipt of subsidy form EU sources; and change in the R&D tax credit regime.

Effect-size heterogeneity - 1

The case of crisis periods or basic R&D

Little or no additionality effects during crises or when investment is in basic R&D

Subsidy effects on growth of:	Full sample	Dot-com crisis 2000-2002	Global financial crisis 2008-2010
Private R&D intensity	.0457***	.0217	.0235***
	(.0060)	(.0167)	(.0075)
R&D personnel intensity	.0456***	.0129	.0365***
	(.0066)	(.0151)	(.0111)
Basic R&D intensity	.0063***	.0113***	.0019***
	(.0015)	(.0040)	(.0005)
Applied R&D intensity	.0244***	.0153*	.0077
	(.0036)	(.0092)	(.0079)

Effect-size heterogeneity - 2

Heterogeneity by proximity to R&D frontier

NO additionality among firms nearer the R&D frontier (quartiles 1 and 2)

Above average additionality among firms in proximity quartile 4

Near average additionality among firms in proximity quartile 3

Proximity to R&D frontier	Growth of private R&D intensity	Growth of R&D personnel intensity	Growth of applied R&D intensity	Growth of basic R&D intensity
Proximity Quartile 1	-.0007	.0085	.0007	-.0016
N_0= 2782; N_1= 22173	(.0084)	(.0077)	(.0029)	(.0025)
Proximity Quartile 2	.0037	.0068	.0018	.0003
N_0= 1301; N_1= 23655	(.0053)	(.0051)	(.0023)	(.0005)
Proximity Quartile 3	.0248***	.0249***	.0112***	.0018
N_0= 485; N_1= 24470	(.0055)	(.0055)	(.0033)	(.0015)
Proximity Quartile 4	.495***	.0611***	.0263***	.0134***
N_0= 470; N_1= 24486	(.0134)	(.0158)	(.0099)	(.0031)

Effect-size heterogeneity - 3

Heterogeneity by firm size (employment)

No additionality among large firms (above median size)

Above average additionality among firms in size quartile 1

Near-average additionality among firms in size quartile 2

Size (employment) quartile	Growth of private R&D intensity	Growth of R&D personnel intensity	Growth of applied R&D intensity	Growth of basic R&D intensity
Size Quartile 1	.0849***	.0853***	.0482***	.0052***
(Smallest	(.0142)	(.0142)	(.0140)	(.0016)
Size Quartile 2	*.0275***	*.0387****	*.0012*	*.0030***
	(.0137)	*(.0136)*	*(.0006)*	*(.0014)*
Size Quartile 3	.0004	.0001	-.0019	-.0004
	(.0003)	(.0005)	(.0029)	(.0008)
Size Quartile 4	.0063	.0046	.0009	-.0007
(Largest)	(.0039)	(.0028)	(.0012)	(.0006)

Effect-size heterogeneity

Heterogeneity by firm age

No additionality among older firms (above median age)

Above average additionality among firms in age quartile 1

Near-average additionality among firms in age quartile 2

Age quartile	Growth of private R&D intensity	Growth of R&D personnel intensity	Growth of applied R&D intensity	Growth of basic R&D intensity
Quartile 1	.0648***	.0611***	.0466***	.0059***
	(.0133)	(.0153)	(.0155)	(.0017)
Quartile 2	.0443***	.0483***	.0094	.0020
	(.0116)	(.0132)	(.0060)	(.0012)
Quartile 3	.0198	.0189*	.0015	-.0001
	(.0138)	(.0109)	(.0024)	(.0011)
Quartile 4	-.0003	.0018	.0005	-.0004
	(.0006)	(.0011)	(.0009)	(.0003)

Subsidy allocations and Policy conundrums

Subsidy Allocations

- By size

	R&D	Subsidy
Share of top 50%	**98.7%**	**98.4%**
Share of top 30%	**96.7%**	**96.9%**
Share of top 10%	**88.23%**	**93.32%**

- By Age

	R&D	Subsidy
Share of top 50%	**82.5%**	**85.3%**
Share of top 30%	**59.8%**	**63.4%**
Share of top 10%	**30.47%**	**23.37%**

Policy conundrums: 85% - 98% of subsidy allocated to firm types that do not generate R&D additionality

Drivers of heterogeneity: Information asymmetry and risk aversion

1. Information asymmetry about firms' R&D productivity and risk aversions inform theoretically-underpinned firm-type classification
2. **Firm type by age, size, and proximity to R&D frontier** are theoretically tractable source of heterogeneity in the effectiveness of R&D subsidies
3. **R&D return uncertainty** is a theoretically tractable source of heterogeneity in the effectiveness of R&D subsidies on **basic research**
4. Subsidy does not generate R&D additionality among larger and older firms and firms closer to the R&D frontier (R&D-intensive firms)
5. Subsidy is ineffective in boosting basic research or in increasing R&D investment in general during downturns in the business cycle.
6. **Policy conundrum: Funders try to maximise welfare by funding firms with proven track record and when investment is in basic research, but subsidy is less effective in generating additionality under these conditions.**

NOTES

Theoretical underpinnings of heterogeneity and their mapping on to firm types and R&D type

Information asymmetry, risk aversion and R&D subsidies:
The case for R&D subsidies is contingent

- **The case for R&D subsidies**: Public good character of knowledge, spillovers, incomplete appropriability. (Nelson, 1959; Arrow, 1962; 1996). Hence: Public support is necessary as an incentive correcting intervention.
- **Early qualifications**
  - **Evolutionary perspective**: Knowledge from R&D active firms can only be absorbed by other firms who invest in R&D (Cohen & Levinthal, 1989)
  - **Patent races**: Competition among firms for obtaining intellectual property rights protection might lead to R&D overinvestment (Dasgupta & Stiglitz, 1980; Dasgupta, 1988)
  - **Intellectual property rights (IPR) protection**: Firms can protect its innovations using a wide variety of tools such as patents (Nadiri, 1993)

Information asymmetry, risk aversion and R&D subsidies:

The case for R&D subsidies is contingent

- **Further qualifications**
  - **Measurement of knowledge externalities** is difficult (Griliches 1992, Hall et al 2010, Keller 2004)
  - **Lack of consensus on mechanism design and resource allocation.** The debate is still revolving around the Samuelsonian principle of public good provision (Samuelson 1954); the Pigouvian correction (Pigou 1932); and the Lindahl market mechanism (Lindahl 1958 [1919]) – all of which require **perfect information** and **enforceable inclusion/exclusion rules**
  - **The theory of contracts** predicts sub-optimal resource allocations and policy outcomes under information asymmetry, risk aversion and market power (Laffont and Martimort 2002; Akcigit et al, 2019)
  - **Schumpeterian models of innovation** predicts different R&D gaps for different firm types – depending on R&D productivity and risk aversion. (Aghion et al., 2014; 2015; Akcigit and Kerr, 2018; Strulik, 2007).

Information asymmetry, risk aversion and R&D subsidies: Heterogenous empirical findings

- **David et al. (2000)** – reviewed 14 studies
  - 3 reported complementarity (addionality)
  - 5 reported crowding out effects (substitution) – mainly US studies
  - 6 reported mixed findings.
- **Zúñiga-Vicente et al. (2014) –** narrative review of 77 empirical studies: 60% of the reported estimates indicate additionality effects; 40% indicate crowding-out or insignificant effects.
- **Dimos and Pugh (2016)** – meta analysis of 52 primary studies from 2000-2013
  - 164 effect-size estimates (55%) indicate additionality;
  - 130 effect–size esimates (45%) Indicate no effect or crowding out effect.

Information asymmetry, risk aversion and R&D subsidies:

In summary, the theory suggests that:

- Subsidies may be necessary to increase private investment in R&D, but:
  - Subsidy allocations are likely to be sub-optimal
  - The subsidy's effect depends on:
    - firm type in terms of R&D productivity and R&D gap;
    - information asymmetry between firms and the funder; and
    - risk aversion.

Yet the empirical literature remains theoretically detached – and explanations of heterogeneity remain *ad hoc*.

Can we bridge the theory-empirics gap?

Information asymmetry, risk aversion and R&D subsidies:

Implications of information asymmetry

- Firms have private information about their R&D productivity
- High-R&D-productivity firms:
  - Are closer to R&D frontier and have smaller R&D gaps
  - Survive longer and grow larger
  - Account for most of business R&D investment
- Hence:
  - Subsidy allocations are skewed (and potentially sub-optimal
  - R&D additionality is less likely

- Overall: Larger and older firms and firms closer to R&D frontier mimic low-R&D-productivity firms and extract informational rents.

(Akcigit et al, 2019; Aghion et al., 2014; 2015; Akcigit and Kerr, 2018; Strulik, 2007).

Information asymmetry, risk aversion and R&D subsidies:
Implications of risk aversion

IF firms are risk averse:

- R&D investment is less responsive to subsidy under uncertainty (Aristei et al., 2017; Czarnitzki and Toole, 2013; Bloom, 2007).
- Firm responses to crises are pro-cyclical (Fabrizio and Tsolmon, 2014).
- There may be increasing returns to 'waiting' under return uncertainty.
- Firms prefer to defer sunk-cost investments when there are positive returns to waiting (Bernanke, 1983; Bloom et al., 2007; Bouvatier and Lepetit, 2008).
- Overall: Due to higher levels of return uncertainty, business R&D investment is less responsive to subsidies during crisis episodes or when investment is in basic R&D.

Information asymmetry, risk aversion and R&D subsidies:

Three hypotheses

1) R&D subsidies are less effective in generating additionality effects during financial crises and/or when the investment is in basic R&D *(due to risk aversion and higher discount rates)*.

2) Firms closer to the R&D frontier in the industry have narrower R&D gaps and are less likely to generate R&D additionality.

3) Larger and older firms, and those with larger market shares, are better able to extract informational rents and less likely to generate R&D additionality.