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Reflections on innovation policy after Covid-19: What does the microeconometric evidence tell us?

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The Institute of Political Economy, Governance, Finance and Accountability (PEGFA)

2 July 2020

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R&D investment, productivity, knowledge externalities, intellectual property protection, subsidies: Implications for post-Covid innovation policy

I draw on joint research with Sefa Awaworyi, Hoang Luong, Edna Solomon and Eshref Trushin from 2016-2020

Our evidence is based on

- Firm-level data for ~45K UK firms from 1998-2012
- Meta-analysis data from ~250 studies

Methods

- Dynamic panel-data and survival analysis
- Meta-regression analysis

Main take-away

- The benefits of business R&D investment are oversold

Business R&D and Productivity 1: Heterogeneity in firm-level evidence

Based on Solomon (2020) - forthcoming in *Economics of Innovation and New Technology*

- Diminishing marginal returns to total R&D – inverted-U relationship between returns and R&D intensity – 'fishing out' effect.
- Complementarity between intramural and extramural R&D and between basic and applied/experimental research.
- Returns to publicly funded R&D are insignificant and there is neither complementarity nor substitution between publicly and privately funded R&D.
- Returns to R&D differ by industry/sector and firm type
- Returns are higher among firms that are dominant suppliers of technology (Pavitt class 2) and scale-intensive large firms (Pavitt class 3).

Business R&D and Productivity 2: Heterogeneity in published evidence

Meta-analysis evidence based on Ugur et al. (2016) - Published in *Research Policy*

Meta-analysis evidence, based on 1,253 estimates from 65 primary studies that adopt the primal approach to R&D and productivity

Main findings:

- Estimates are smaller and more heterogeneous than what has been reported in prior reviews;
- Residual heterogeneity among firm-level estimates remains high even after controlling for moderating factors;
- Firm-level and industry-level (social) returns do not differ significantly despite theoretical predictions of higher social returns;
- Estimates are based on revenue productivity – hence reflect both efficiency gains and market power.

Business R&D and Productivity 2: Heterogeneity in meta-analysis evidence

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Evidence of heterogeneity publication selection bias

	Elasticity estimates at firm level	Elasticity estimates at industry level	Rate-of-return estimates at firm level	Rate-of-return estimates at industry level
Effect of R&D on productivity or rate of return	0.073***	0.066***	0.089***	0.115***
	(0.015)	(0.022)	(0.018)	(0.037)
Publication bias	0.479	0.501	1.404***	0.746***
	(0.531)	(0.392)	(0.290)	(0.270)
Heterogeneity	98%	86%	81%	17%
Observations	773	135	192	153

- Publication selection bias is severe (1.4) or large (0.74) in reported rate-of-return estimates
- Unexplained heterogeneity is high in 3 out of 4 evidence clusters
- Industry-level estimates do not indicate larger productivity due to intra-industry spillovers
- Policy implications: Avoid short-cuts on R&D and productivity; contingent productivity effects

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The search for R&D spillovers (externalities)

Meta-analysis evidence based on Ugur et al (2019) – published in *Research Policy*

Theory

- R&D investment is associated with positive externalities
- Spillover effects on productivity are larger than the effect of own R&D
- Hence: Direct and indirect public support for R&D investment is welfare-improving.

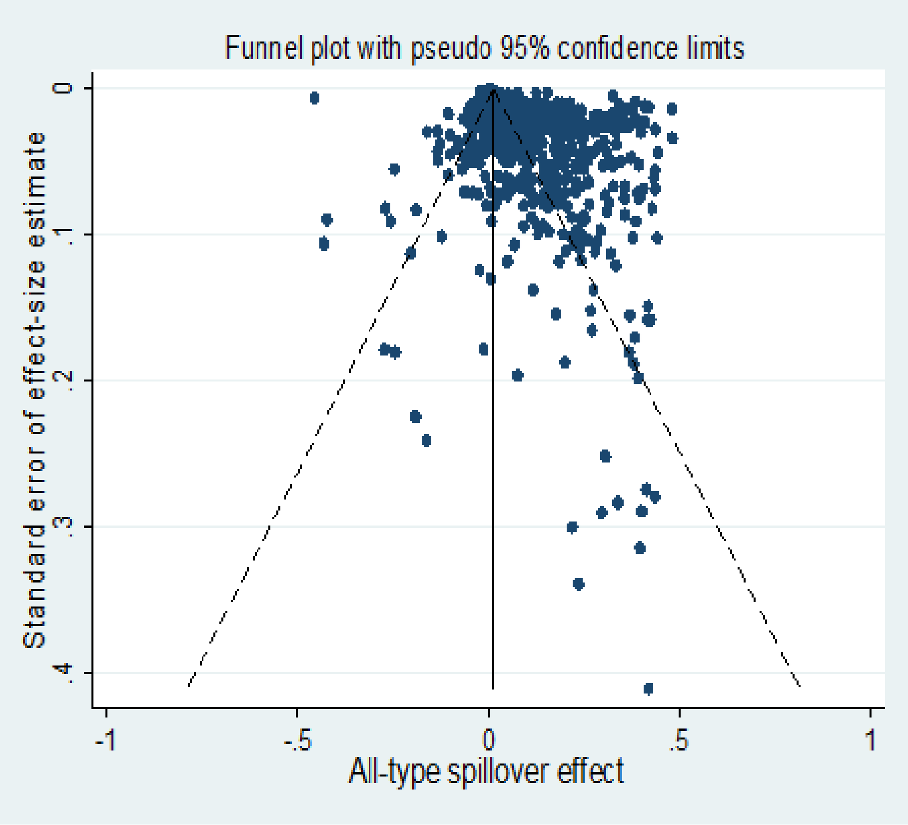
Meta-analysis findings based on 983 spillovers and 501 own-R&D effect-size estimates from 60 empirical studies

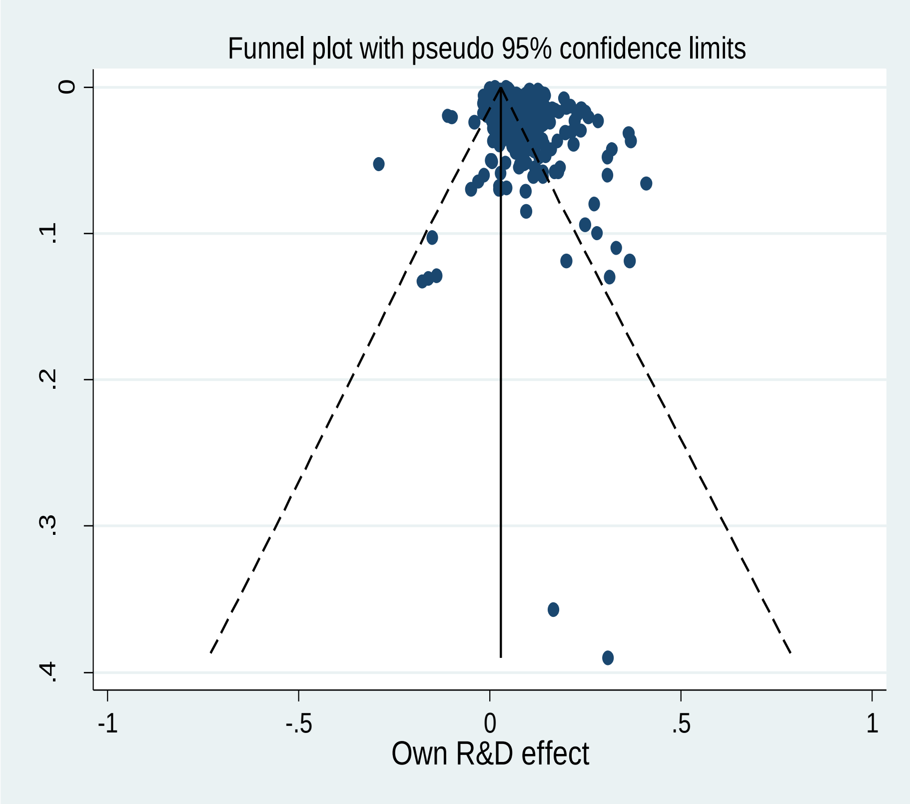
The 'average' productivity effect of spillovers:

- is smaller than what is reported in most narrative reviews;
- is usually smaller than that of own-R&D;
- differs by spillover types; and
- is practically insignificant when only adequately-powered evidence is considered.

Percentage of adequately-powered evidence is low (30% - 55%).

Publication selection bias and heterogeneity





Spillover effecst

Own R&D effects

Heterogeneity is high as most observations are outside the 95% confidence intervals (dashed lines)

Publication selection bias is likely as most observations are above the fixed-effect average (the vertical line)

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Average effect size estimates by spillover type and own RD

	Knowledge Spillovers	Mixed Spillovers	Rent Spillovers	All Spillovers	Own R&D
Effect size	0.048***	0.074	0.007	0.038***	0.064***
	(0.017)	(0.050)	(0.023)	(0.014)	(0.012)
Selection bias	2.065***	1.377	2.751***	2.195***	0.808***
	(0.572)	(1.030)	(0.541)	(0.380)	(0.402)
Heterogeneity	98.1%	98.1%	98.1%	98.1%	97.9%
Observations	557	96	327	983	501
Adequately powered	41%	31%	33%	30%	73%

- Spillover effects are smaller than own-R&D effects
- Heterogeneity is high
- Statiscal power is lower in the spillover evidence pool
- **The case for public support for business R&D and patent protection is weak.**

Does intellectual property protection (IPP) deliver economic benefits?

Meta-analysis evidence based on Ugur et al (2020) – work in progress

Theory

- Knowledge externalities: Knowledge is a non-excludable public good
- Without IPP, knowledge production is sub-optimal
- IPP corrects for market failure, but may cause distortions due to monopoly power
- Hence, IPP is potentially welfare-improving.

Meta-analysis findings based on 1,620 effect-size estimates from 92 empirical studies investigating the effect of IPP on **growth, productivity, innovation, and technology diffusion.**

Overall picture:

- No effect – except diffusion
- The diffusion effect is conceptually problematic (see below)
- High levels of heterogeneity and selection bias.

Heterogeneity and selection bias in the evidence on IPP's economic benefits

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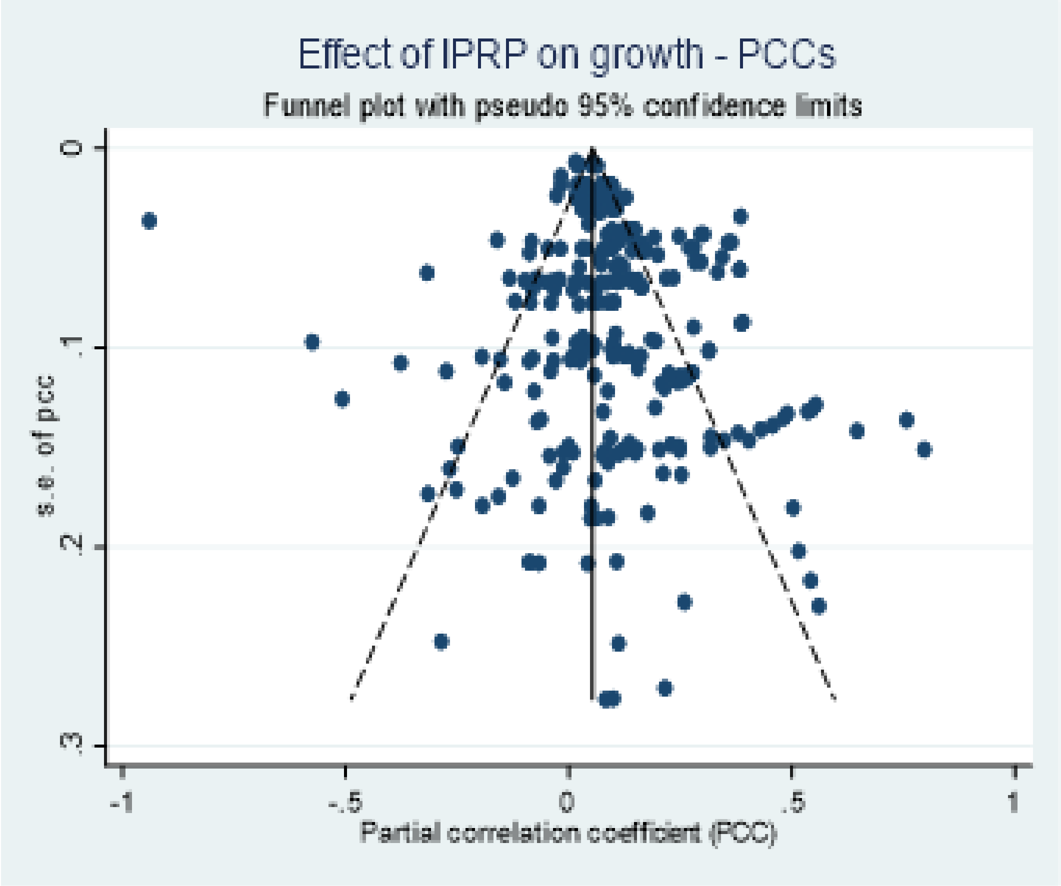
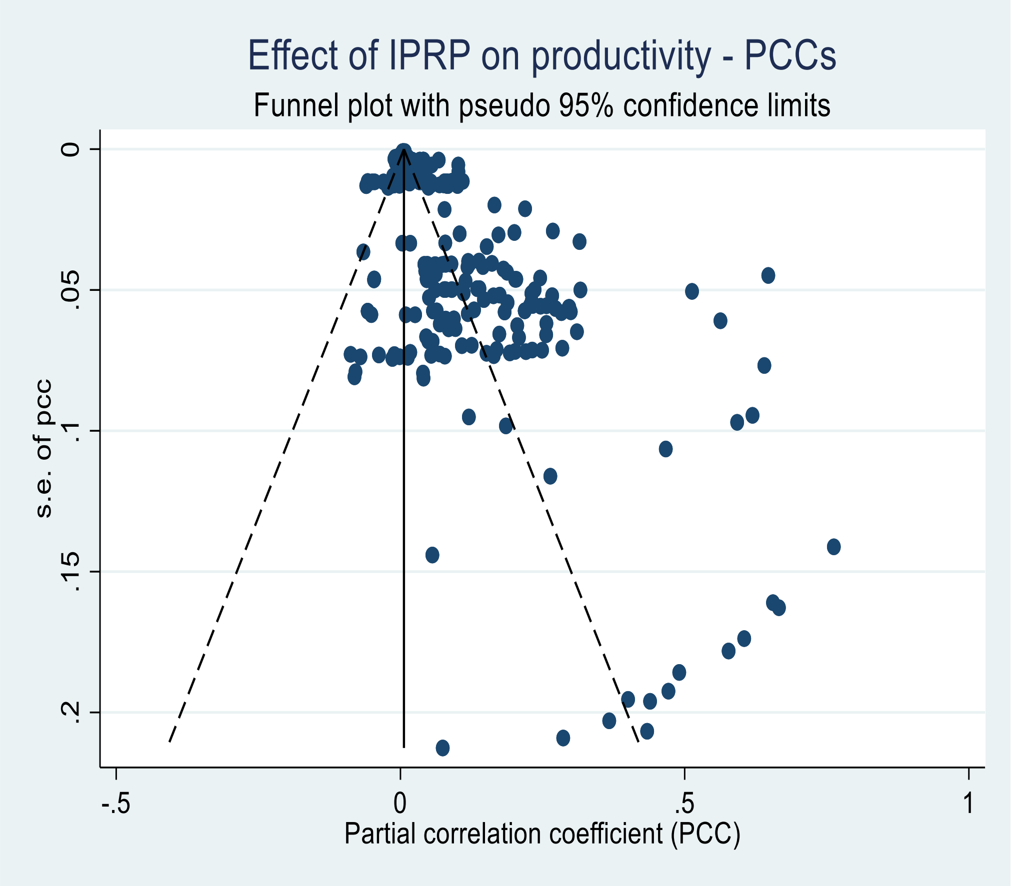
Effect of IPP on economic growth



Effect of IPP on productivity



Heterogeneity and selection bias in the evidence on IPP's economic benefits

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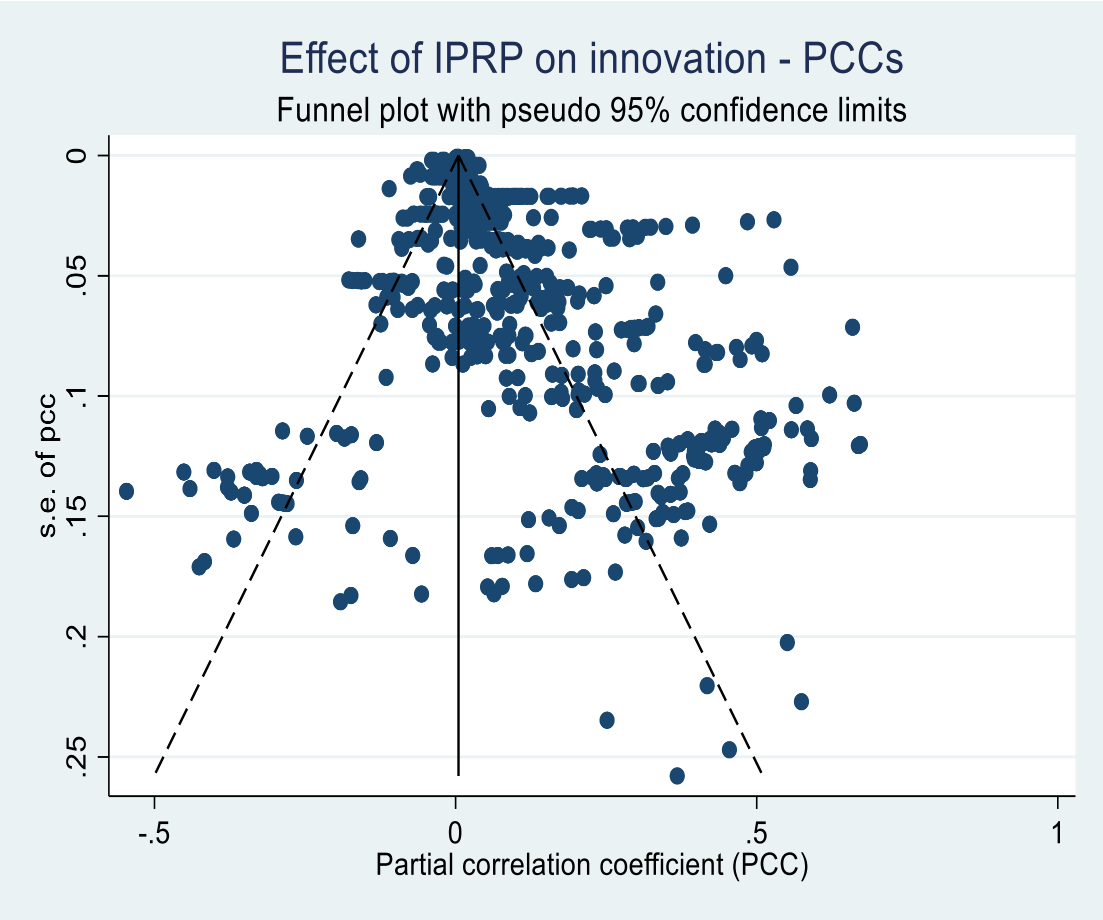
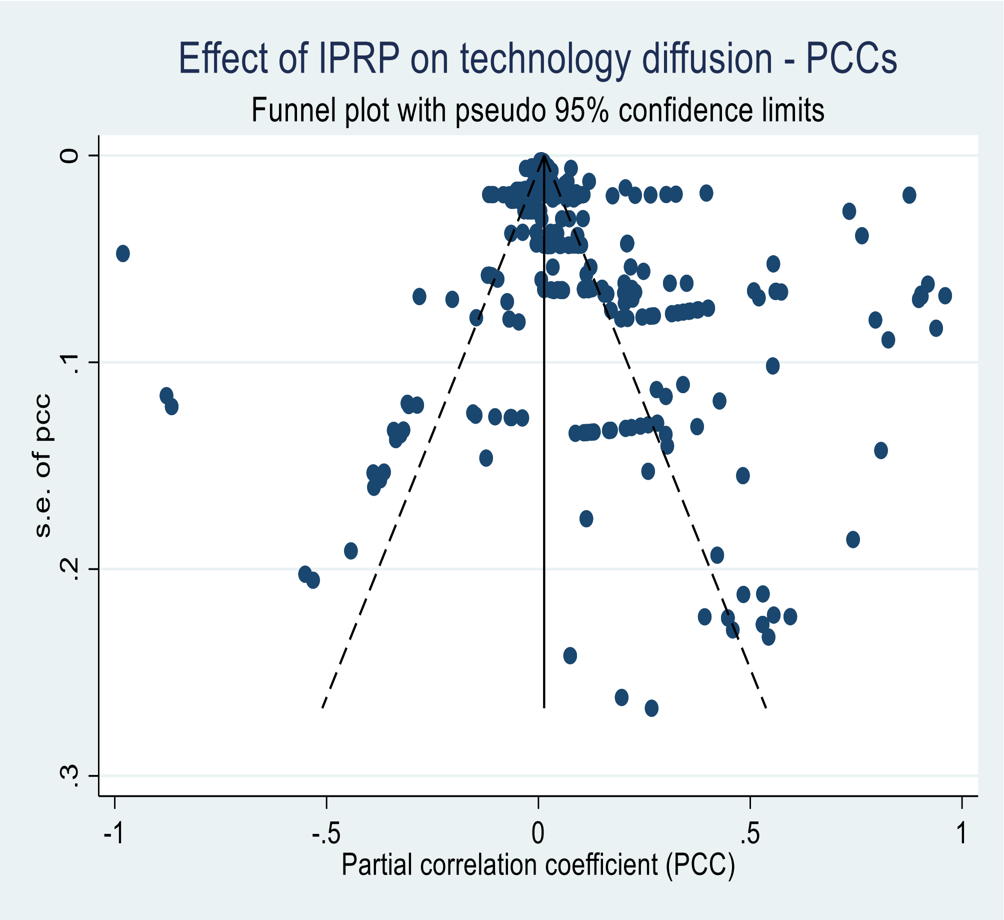
Effect of IPP on innovation



Effect of IPP on technology diffusion



Multi-outcome meta-regression evidence

	Effect size standardised as partial correlation coefficient	Effect size standardised as Fisher's Z
Effect size - Growth	0.0359	0.0371
	(0.0241)	(0.0236)
Effect size - Productivity	0.0161	0.0142
	(0.0195)	(0.0191)
Effect size - Innovation	-0.0052	-0.0042
	(0.0142)	(0.0141)
Effect size - Diffusion	0.0444***	0.0487***
	(0.0166)	(0.0164)
Publication bias - Growth	0.557	0.641
	(0.829)	(0.699)
Publication bias - Productivity	2.482**	2.748***
	(1.092)	(0.917)
Publication bias - Innovation	1.985***	1.977***
	(0.716)	(0.600)
Publication bias - Diffusion	2.201***	1.613**
	(0.834)	(0.696)
Observations	1618	1619

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What do learn from the evidence on economic benefits of IPP ?

- Countries/industries with higher levels of IPP does not secure higher levels of per-capita GDP growth, total factor productivity levels, or innovation (measured either input measures such R&D investment or output measures such as patents or trade-marks.
- IPP has a small effect on technology diffusion.
- However, diffusion is measured with royalty payments or FDI flows, which are not direct measures of technology diffusion.
- There is severe selection bias in the evidence base.
- The results remain very much the same when the evidence is analysed cluster by cluster.
- Our findings are congruent with narrative review findings.
- Hence: We conclude that the case for IPP is oversold.

Do R&D subsidies generate additionality effects?

Theory

- Knowledge externalities reduces the scope for appropriability of the returns on R&D investment
- R&D investment is risky and likely to be mispriced by the financial markets
- Hence, firms (particularly small and young firms) face a financing constraint
- Overall: Firm investment in R&D may remain sub-optimal; and public support is needed to correct market failures

Treatment-effect estimations based on ~45K UK firms

Based on Ugur et al (2020) – under review in *Economic Journal* indicate the following:

- Information asymmetry and risk aversion leads to suboptimal subsidy allocations and business R&D response to the subsidy
- The subsidy has practically insignificant or no effects on business R&D investment when:
  - **R&D investment is in basic research or undertaken during crisis periods (due to risk aversion)**
  - **Firms are large, old, and closer to the R&D frontier in the industry**

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Sub-optimal subsidy allocations

85% of the subsidy is allocated to firms above median age

	Private R&D	Private R&D intensity	Subsidy	Subsidy rate	Coverage
Subsidy allocations by age deciles	(£ bn.)	(Private R&D as % of turnover)	(£ bn.)	(Subsidy as % of private R&D)	(Subsidized firm-years as % of total firm-years)
1st decile: age ≤ 3 years	1.27	4.2	0.14	11	96
2nd decile: 3 < age ≤ 6 yrs.	3.25	3.8	0.14	4	94
3rd decile: 6 < age ≤ 9 yrs.	6.57	3.4	0.77	12	93
4th decile: 9 < age ≤ 11 yrs.	8.46	4.6	0.54	6	93
5th decile: 11 < age ≤ 14 yrs.	14.50	4.1	0.57	4	93
6th decile: 14 < age ≤ 17 yrs.	15.20	3.3	0.95	6	92
7th decile: 17 < age ≤ 22 yrs.	29.10	3.3	2.26	8	92
8th decile: 22 < age ≤ 26 yrs.	26.00	2.3	2.85	11	90
9th decile: 26 < age ≤ 31 yrs.	31.20	2.4	3.03	10	91
10th decile: age > 31 years	59.40	2.0	3.43	6	90
Share of top 50%	**82.5%**		**85.3%**		
Share of top 30%	**59.8%**		**63.4%**		
Share of top 10%	**30.47%**		**23.37%**		

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Sub-optimal subsidy allocations

98% of the subsidy is allocated to firms above median employment size

	Private R&D	Private R&D intensity	Subsidy	Subsidy rate	Coverage
Subsidy allocations by size deciles	(£ bn.)	(Private R&D as % of turnover)	(£ bn.)	(Subsidy as % of private R&D)	(Subsidized firm-years as % of total firm-years)
1st decile: 1 employee	0.23	1.5	0.03	14	96
2nd decile: 2 employees	0.25	6.1	0.03	12	97
3rd decile: 3 or 4 employees	0.31	3.6	0.04	12	96
4th decile: 4<employees ≤ 9	0.70	2.8	0.07	10	95
5th decile: 9<employees≤ 15	0.95	1.7	0.06	7	94
6th decile: 15<employees≤ 25	1.52	2.9	0.09	6	94
7th decile: 25<employees≤ 43	2.49	2.3	0.13	5	93
8th decile: 43<employees≤ 83	4.93	2.0	0.22	4	92
9th decile: 83<employees≤ 205	11.20	2.4	0.34	3	91
10th decile: >205 employees	172.00	2.6	13.70	8	80
Share of top 50%	98.7%		98.4%		
Share of top 30%	96.7%		96.9%		
Share of top 10%	88.23%		93.32%		

The subsidy is ineffective in inducing additionality in basic R&D and during crisis periods

Subsidy effects on growth of:	(1) Full sample	(2) dot-com crisis 2000-2002	(3) Global financial crisis 2008-2010
1. Private R&D intensity	.0457*** (.0060)	.0217 (.0167)	.0235*** (.0075)
1. R&D personnel intensity	.0456*** (.0066)	.0129 (.0151)	.0365*** (.0111)
1. Basic R&D intensity	.0063*** (.0015)	.0113*** (.0040)	.0019*** (.0005)
1. Experimental R&D intensity	.0158*** (.0072)	.0011 (.0104)	.0214*** (.0052)
1. Applied R&D intensity	.0244*** (.0036)	.0153* (.0092)	.0077 (.0079)
Observations in control sample	N_0 = 10282	N_0 = 1821	N_0 = 3510
Observations in treated sample	N_1 = 133563	N_1 = 15955	N_1 = 38934

- Subsidy's effect on basic R&D is practically insignificant – in the full sample and during crisis periods.
- The effect on all types of R&D inputs (except basic R&D) is smaller during crisis periods.
- This is due to risk aversion, which is known by the firm but not by the funder

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The subsidy is ineffective when firms are older, larger and closer to the R&D frontier

Quartile	Distance to R&D frontier	Age	Size
Quartile 1 N_0= 2782 N_1= 22173	-.0007 (.0084)	.0648*** (.0133)	.0849*** (.0142)
Quartile 2 N_0= 1301 N_1= 23655	.0037 (.0053)	.0443*** (.0116)	.0275** (.0137)
Quartile 3 N_0= 485 N_1= 24470	.0248*** (.0055)	.0198 (.0138)	.0004 (.0003)
Quartile 4 N_0= 470 N_1= 24486	.0495*** (.0134)	-.0003 (.0006)	.0063 (.0039)

Why the effects of R&D subsidies are inherently heterogenous?

- The source of heterogeneity is the second-best outcomes of contracting under information asymmetry and risk aversion
- Firms with private information about their R&D gaps and effort extract informational rents.
- Informational rents are extracted by firms with a history of success in converting R&D into innovative product lines.
- These firms are larger, older and closer to R&D frontier.
- When firms are risk-averse, their R&D investment is less responsive to policy interventions.
- Hence the policy conundrum in R&D subsidies: it is socially desirable to grant subsidies to basic research and when firms are successful innovators; but subsidies are less likely to be effective under these conditions.

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Conclusions

- The effects of R&D on productivity is positive, but highly heterogenous.
- Statement such as "innovation is the main driver of firm performance" are too general to be informative.
- R&D spillovers may exist, but their level of their productivity effects are unobserved.
- Hence, existing estimates are suggestive rather than conclusive.
- Firms need to invest in R&D to benefit from spillovers.
- Hence, the case for public support to business R&D is less clear-cut than what is reflected in current policy orientation.
- This is confirmed by sub-optimal subsidy allocations and second-best subsidy effect.

Discussion: Questions for future research

Questions raised by our findings include, but are not limited to, the following:

- **Is private R&D and scientific breakthroughs compatible?**
- **What does the response to Coivd-19 indicate about the role and limitations of private innovation?**
- **How to fund research aimed at building resilience against emergencies?**
- **What is the relationship between public support for business R&D and inequality?**
- **Is there opacity in national innovation systems and what can be done about it?**
- **Should we encourage collaboration between corporate and university research?**

These are old questions, but the evidence we have uncovered and the Covid-19 experience have increased their relevance.