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Catapulting into the Innovation System: Direct and Indirect Local Knowledge Spillovers from Innovation Hubs

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Catapulting into the Innovation System: Direct and Indirect Local Knowledge Spillovers from Innovation Hubs

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ABSTRACT

Tech or industry specific innovation centres could help to spur innovation across firms, in particular outside the traditional research-intensive regions and industries, encouraging R&D collaborations especially for those firms that do not have the resources to independently start new R&D processes. In this paper we investigate the indirect, local spillover effects of Catapults, a network of technology-focused innovation hubs scattered across the country. First, we investigate how Catapults knowledge spills over to unsupported firms closely located, and secondly we assess to what extent Catapults-supported firms might also generate local spillovers. We apply a novel approach of the regression discontinuity design, where we consider the discontinuity in the distance from the Catapults centre, or in the statistical significance of the spatial agglomeration of Catapults-supported firms. Our results show that Catapults innovation centres provide a source of knowledge externalities for unsupported businesses located nearby, mainly by increasing the likelihood of firms to collaborate with Catapults and receive public R&D funding. This in turn stimulates the birth of new start-ups and the economic performance of businesses in terms of employment and productivity. After controlling for the spillovers from catapults centres, we identify positive externalities also from Catapults-supported firms, although weaker in magnitude, in particular for unengaged firms located nearby high clusters of Catapult-supported businesses. These operate mainly through the stimulation of unsupported firms to engage with the Catapults network, and encouraging productivity growth.

JEL Classification: O32, O38, R12.

Keywords: Knowledge spillovers, innovation hubs, research centres, public R&D.

CONTENTS

1. INTRODUCTION

A large literature has looked at the importance of different policy tools to spur research and development (R&D) investment and innovation among firms. Several studies provide strong evidence that R&D tax credit policies are powerful and efficient tools to encourage private R&D (Bloom et al., 2019; Teichgraeber and Van Reenen, 2022). Similarly, other tools financing directly innovative firms through research grants have been found to efficiently stimulate innovation (Howell, 2017) and business growth (Vanino et al., 2019) among directly targeted firms, and to generate substantial spillovers both across geographical and technological spaces (Becker et al., 2021; Myers and Lanahan, 2022).

However, there are concerns that many of these instruments are highly imbalanced and follow a "picking-the-winner" strategy, whereby the intention is to target and support firms already intensive in R&D activities, strengthening the technological levels in large firms that often belong to high- or medium-high technology sectors (Blanes and Busom, 2004; Antonelli and Crespi, 2013; García-Quevedo and Afcha, 2016), and thus leading to a vicious circle that widens the productivity gap between industry leaders and laggards and reinforces regional productivity inequalities (Forth and Jones, 2020). As a consequence, there is an increasing attention on exploring new strategies to stimulate engagement with the innovation system in particular in small and low-tech businesses, especially promoting indirect targeting and knowledge spillovers form public and private R&D intensive organisations.

For instance, the UK Government is developing a strategy to spur innovation across firms, in particular outside the traditional research-intensive regions and industries, with regional innovation hubs and sector or tech specific innovation centres scattered across the country. The accelerators could be drivers of innovation and economic growth, capitalising on existing clusters of businesses in their areas that have cutting edge expertise in specific technologies. Industrial research centres could become a vehicle for driving up business spending on R&D, encouraging collaborations between businesses, especially those who do not have the resources to independently start new R&D processes, leading to new ideas, innovation adoption, and the generation of new products (Yu, 2020). Sector and technology specific R&D and innovation support has emerged relatively recently in the UK. One of the key support measures is the Catapult network, a group of nine technology and innovation centres supported through Innovate UK and private funding. Initially introduced starting from 2011, the Catapult network provides physical R&D facilities to collaborate with and support business innovation across a range of sectors including life sciences, semiconductors, transports digital technologies, renewable energy systems, and satellite applications.

Previous studies have provided documented evidence of direct positive effects of this type of innovation support on engaged businesses (Roper and Vanino, 2023). Building on that evidence, in this paper we investigate the indirect, local spillover effects of the Catapults network, in terms of stimulating start-ups, future engagement with the public science system, and eventually the productivity growth of unengaged firms located nearby. In particular, we address two main research questions. First, we investigate how does the Catapults knowledge spills over through space and along the supply chain to unsupported firms located nearby the centres and industrially related the Catapults technological specialisation (direct spillover). Secondly, we assess to what extent do Catapults-supported firms generate local spillovers themselves for other unsupported local firms (indirect spillovers). In particular, we want to identify if there are peer effects or other types of knowledge spillovers from Catapult-supported firms to other local businesses operating in related sectors. This consists in a geographical analysis of Catapult-assisted firms and their local impact. To do so, we use longitudinal granular data on the location of Catapult centres, supported and unsupported firms, and on their R&D activities and business performance over the period 2010-2019. We apply a novel approach of the regression discontinuity design (RDD), where we consider the discontinuity in the distance from the Catapults centre, or in the statistical significance of the spatial agglomeration of Catapults-supported firms. Our results show that Catapults innovation centres provide a source of knowledge externalities for unsupported businesses located nearby, mainly by increasing the likelihood of firms to collaborate with Catapults and receive public R&D funding. This in turn stimulates the birth of new start-ups and the economic performance of businesses in terms of employment and productivity. After controlling for the spillovers from catapults centres, we identify positive externalities also from Catapults-supported firms, although weaker in magnitude, in particular for unengaged firms located nearby high clusters of Catapult-supported businesses. These operate mainly through the stimulation of unsupported firms to engage with the Catapults network, encouraging productivity growth, upscaling and increasing start-up rates in surrounding areas.

Our findings are related to several strands of the literature in the urban economics and the economics of innovation fields. The existence and magnitude of knowledge spillovers is a long-standing issue since the seminal work of Marshall (1890). There is mounting empirical evidence of how knowledge moves and flows unintentionally "as it were in the air", crossing "hallways and streets more easily than oceans and continents" (Glaeser et al, 1992), and becoming the source for further new ideas. This is the case within academia (Waldinger, 2012; Moser et al., 2014; Iaria et al., 2018), but also among firms operating within the same industry (Arora, Belenzon, and Sheer, 2021), with different mechanisms at play such as R&D collaborations (De Fuentes and Dutrénit, 2012), human capital flows (Perkmann et al., 2013; Ankrah and Omar, 2015), and other informal channel such as publication of papers and patents, participation to conferences and interpersonal exchanges (Cohen et al., 2002; Agrawal and Henderson, 2002). Of particular interest is the case for knowledge spillovers from the public research sector to private firms, a question that has received particular attention since the seminal work of Jaffe (1989). Kantor and Whalley (2014) used for instance national shocks on stock-return, affecting the value of university endowments, to instrument university spending, and found modest but significant local effects on non-research wages. Another strand of the literature has studied the local impact of public spending in R&D, notably for military purposes (Moretti et al., 2019; Kantor and Whalley, 2022) or in terms of R&D grants provided to local universities (Becker et al. 2021). In a recent study Azoulay et al. (2019) have shown a link between public R&D grants, the publications they generate and the patents in the biotechnology and pharma industries. With a spatial focus, Hausman (2021) studies how universities can be a driver of industrial agglomeration and shows that after the Bayh Dole Act, allowing the commercialisation of patents derived from public R&D grants, the industries closest technologically to the local university witness a growth in employment and innovative outcomes. Focusing more specifically on the spillovers from public R&D labs and innovation centres, Bikard and Marx (2020) have shown the importance of hubs in the use of academic science by firms. Similarly, Bergeaud et al. (2022) have provided evidence of spillovers from academic research to private sector firms by looking at a financing program of academic clusters in France, mainly through R&D public-private partnerships.

The rest of the paper is structured as follows. The next section presents the data used, while section 3 discusses the methodology applied in our study. Section 4 reports the main findings, while section 5 concludes presenting the policy implications.

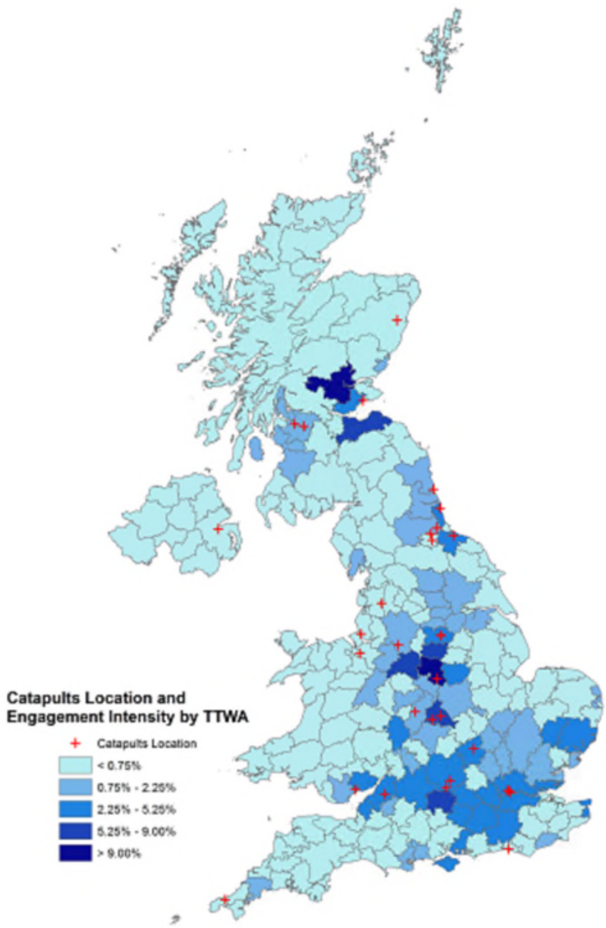
2. DATA

For our analysis we draw on administrative data provided by the Catapult network on the list of businesses that have engaged with each single Catapult over the period 2010-2019, listing the time and intensity of engagement (Roper and Vanino, 2023). In addition, using an unique corporate reference number, we link this to public funding and partnership data from the Gateway to Research (GtR) database, which provides information on all R&D public funding provided by the UK Research and Innovation agency UKRI over the 2004 to 2016 period. The GtR data provides information about approximately 34,000 organisations that participated in publicly-funded innovation and R&D projects, including details on the number and value of funded projects, the number and characteristics of partners, the topics and outcomes of the research projects, the value of grants awarded per year, the Research Council providing the funding, and information about each projects' leaders (Vanino et al., 2019). Finally, we merge these two datasets with data on business performance taken from the Business Structure Database (ONS, 2022), which provides longitudinal data and information for all firms in the UK, including employment, turnover, location, industry classification, age, foreign ownership, group affiliation, and other firms characteristics.

The Catapult network is a group of nine technology and innovation centres supported through Innovate UK and private funding initially introduced starting from 2011. The network provides physical R&D facilities to collaborate with and support business innovation across a range of sectors including life sciences, semiconductors, transports digital technologies, renewable energy systems, and satellite applications. There are currently operating 9 centres spanning over 50 locations across the UK, including the High Value Manufacturing (HVM), which was the first to open in Warwickshire in 2011, the Cell & Gene Therapy (CGTC), the Digital Catapult (DIG), the Offshore Renewable Energy (ORE), the Satellite Applications (SAC), the Energy Systems (ESC), the Medicines Discovery (MDC), the Compound Semiconductor Applications (CSA), and the Connected Places (CPC) that opened last in 2019. Each centre received "core" funding of £10 million per year for five years via Innovate UK, with the long-term intention that the budget would be one-third core funding, one-third commercial funding, and one-third collaborative (public and private) R&D funding.

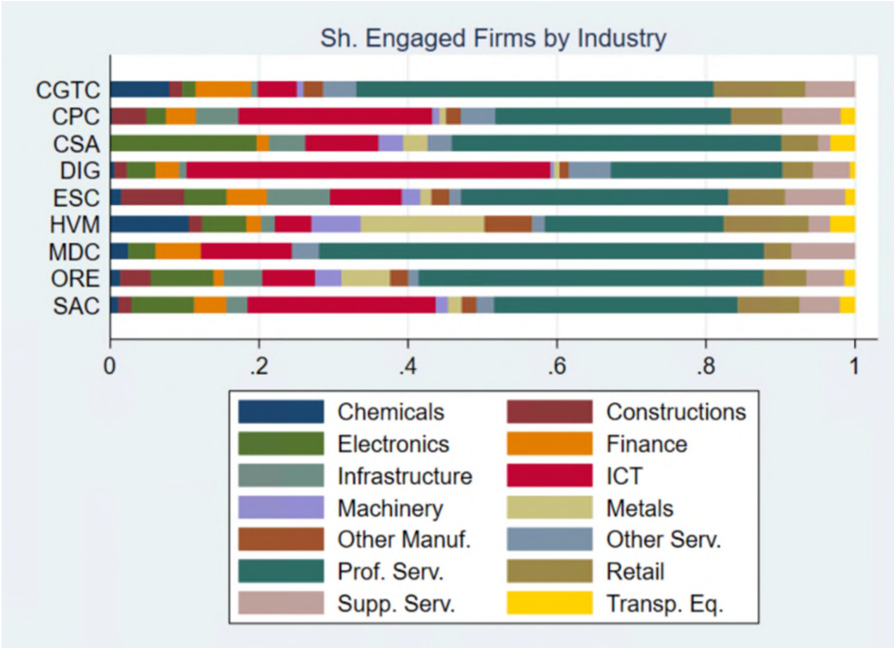
As seen in Figure 1, while Catapults are scattered across the country in multiple locations, supported firms tend to be highly spatially clustered in specific areas, probably reflecting industrial districts and comparative specialisation of some areas in specific sectors, and only in some instances they tend to cluster around certain specific Catapults. The uneven distribution of supported firms is not only spatial, but as shown in Figure 2 also from an industrial point of view, following the sector and technology specialisation of specific Catapults activities, as for instance the high concentration of ICT companies engaging with the Digital Catapult (DIG), firms operating in electronics collaborating with the Compound Semiconductor Applications (CSA) Catapult, or the main focus of the High Value Manufacturing (HVM) Catapult in supporting businesses in the chemicals, electronics, metals, machineries and other manufacturing sectors.

Figure 1: Spatial distribution of Catapults locations and firms' engagement intensity by TTWA over the period 2011-2019.



Notes: Firms' engagement intensity measured as the total employment of Catapults-supported firms over total employment in the Travel to Work Area (TTWA).

Figure 2: Share of engaged businesses by industry for each Catapult over the period 2011-2019.



Notes: Cell & Gene Therapy (CGTC), Connected Places (CPC), Compound Semiconductor Applications (CSA), Digital Catapult (DIG), Energy Systems (ESC), High Value Manufacturing (HVM), Medicines Discovery (MDC), Offshore Renewable Energy (ORE), and Satellite Applications (SAC).

3. METHODOLOGY

In order to consider both the direct knowledge spillovers originating from the Catapult centres, and the indirect effects from Catapults-supported firms, we apply a regression discontinuity design based on the specific research question addressed. First, to estimate the spillovers from Catapults to nearby unsupported firms, we start by identifying the location and time of opening of all Catapults premises. Then, using geographic information system (GIS) mapping, we measure the distance between all unsupported firms and the closest Catapult centre, and consider as treated all firms *i* located within the 1-kilometres distance *k* boundary from an operating Catapult *c* (CC_{itc}^{k}). We then also calculate the distance of firms from the 1-kilometres distance boundary *k* from a Catapult *c* and its squared value (CCB_{ic}^{k} and $CCB_{ic}^{k\,2}$), and repeat the same exercise for other distance bandwidths *k*, as 5- and 10-kilometres distances, following the evidence on the rapid decay of knowledge spillovers with distance (Bergeaud et al., 2022).

Second, to assess the local spillovers to unsupported firms generated from Catapult-supported firms, we start by identifying the location and time of engagement of all Catapults-supported firms using administrative data from the Catapults network. Using GIS mapping techniques, we calculate the total employment of Catapults-supported businesses in each Middles Super Output Area (MSOA) neighbourhoods[1] and year. Based on this, we calculate the level of spatial clustering of Catapults-supported firms across neighbourhoods using the Getis-Ord G statistics, indicating the presence and intensity of positive, negative or insignificant spatial clustering. The Getis and Ord (1995) local statistic G identifies if specific values of a variable cluster spatially. It does so by looking at each observation within the context of its neighbours. If an observation has a high value of a variable and is surrounded by observations with also high values of a variable, then it belongs to a cluster. Then, the G statistic constructs the local sum of values for all observations and their neighbours. In our case, the higher is the employment of Catapults-supported businesses in an area, and the closer they are located to each other, the larger will be the value of the Getis-Ord G statistics. The output of that summation is then compared to the summations for all observations. If the local sum is statistically different from the expected local sum, and if that difference is too big to result from randomness, a local cluster is identified. Given that this statistic is normally distributed, a z-score higher than 1.65 indicates the presence of positive spatial clustering at the 10% significance level. Following previous studies applying a similar methodology (Koster et al., 2012; Hidano et al., 2015), we use this information to consider as treated unsupported firms located in MSOAs *n* with positive and statistically significant spatial clustering of Catapults-supported firms (CS_{int}), based on whether the z-score of the Getis-Ord G statistic is above or below the 1.65 significance threshold. We then also calculate for each MSOA the distance of the spatial clustering z-score from the 10% significance level threshold of 1.65 and its squared value (CSB_{int} and CSB_{int}^2), to consider the overall level of spatial clustering in a neighbourhood.

We perform a boundary discontinuity design analysis as follows:

$$y_{it} = \alpha_0 + \alpha_1 CC_{itc}^k + \alpha_2 CCB_{ic}^k + \alpha_3 {CCB_{ic}^k}^2 + \alpha_4 CS_{int} + \alpha_5 CSB_{int} + \alpha_6 CSB_{int}^2 + X_{it} + \gamma_i + \gamma_{zt} + \gamma_{st} + u_{it}$$

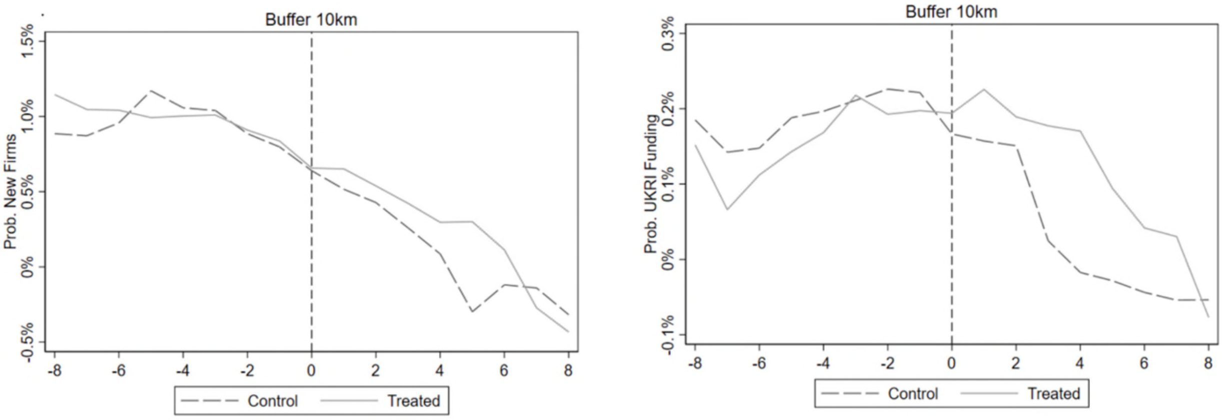
[1] Neighbourhoods are defined using the ONS Middle Super Output Area (MSOA) nomenclature reflecting on average 7,000 residents (3,000 residential buildings).

where we estimate the difference in several outcome variables y_{it}between firms within or outside a 1-kilometer radius of an operating Catapult centre (CC_{itc}^{k}), and between firms located in or outside of a cluster of Catapult-supported firms (CS_{int}). We control as well for the distance from the respective two boundaries: the distance of firms from the 1-kilometres distance boundary k from a Catapult (CCB_{ic}^{k}), and the distance of the spatial clustering z-score from the 10% significance level threshold of 1.65 (CSB_{int}). In addition, we control for several firm-level and time variant characteristics X_{it} , including firm size, labour productivity, age, foreign ownership, and group affiliation, together with firm ideocratic time-invariant fixed-effects (γ_i). We also include several fixed-effects to control for unobservable characteristics, such as commuting zone (TTWA) time trends (γ_{zt}), and SIC 2-digit industry time trends (γ_{st}).

We take into consideration several outcome variables of interest y_{it} . First, we are interested in finding whether proximity to Catapults centres or Catapults-supported firms stimulates future engagement with the Catapults network. In this regard, we consider the future engagement with Catapults of unsupported firms, before distinguishing between low and medium-high level of engagement, as described by the Catapults. Secondly, we analyse whether direct and indirect local knowledge spillovers from Catapults stimulate unsupported firms to engage with the wider public science system, estimating the effect on the probability of securing UKRI grants and the number of funded projects. Third, we investigate the impact of these knowledge externalities on business performance, first of all analysing whether Catapults spillovers promote entrepreneurship and start-up rates, and secondly considering several other measures of business performance including employment, turnover and productivity growth.

We perform several additional analyses to explain the motivations and mechanisms of the Catapults spillovers for unsupported firms. First, we consider whether the positive spillovers for unsupported firms are conditional or not on future engagement with Catapults. In the former case, any significant effect would have to be considered as a consequence of the direct support of the innovation hub, rather than an unexpected externality. Secondly, we check if the opening of Catapults centre and the emergence of Catapults-supported clusters trigger a change in the composition of local firms, and if this affects our estimates, by distinguishing between established and new firms. We then consider several mechanisms through which Catapults centres and clusters of supported firms could be the source of local spillovers for unsupported businesses. First, we consider industrial agglomeration to check if the presence of an industrial cluster is conducive to the propagation of spillovers. Secondly, we try to identify if the spillovers are linked to knowledge externalities from Catapults centres or if instead they are linked to different type of economic interactions. To this end, we measure the share of firms engaged with each Catapult by industry as shown in Figure 2, and use this as a proxy of technological proximity of each industry to the Catapults innovation activities. We then test if the effect of Catapults direct and indirect spillovers are mediated by the strength of the technological proximity of unsupported firms. This would be an evidence of knowledge externalities based on the technological focus of Catapults and nearby located firms. Alternatively, we use a simple measure of industrial relatedness based on input-output linkages to test if instead the Catapults direct and indirect spillovers are mediated by the strength of the input-output relationships between Catapult-supported customers and unsupported suppliers. In this case, most of the benefits would derive from an increased demand of intermediate inputs by Catapults supported firms, generating externalities through input-output linkages. Similarly, we followed the Mian and Sufi (2014) methodology to identify locally consumed (untradable) services, and check whether the spillover effects are stronger in these industries, and thus be likely to be linked to an increased local demand by Catapults and supported businesses and their employees. We also test the heterogeneity of our results, distinguishing between unsupported firms in manufacturing and service industries, between high-tech and low-tech sectors, considering differences between small and larger firms, and distinguishing between independent businesses and groups subsidiaries.

Figure 3: Differences in trends in start-up rate and probability of UKRI funding between treated and control firms before and after the opening of a Catapult centre.



Notes: Firms considered as treated if located within a 1-kilometers radius from a Catapult centre. Catapult centre opening year set at time *t=0*.

We conduct several sensitivity tests to check the robustness of our results. First, as briefly shown in Figure 3, we want to check that the pre-treatment parallel trend assumption is met for the outcome variables used in our analysis when estimating the difference between treated and control firms of the effect of both direct and indirect Catapults spillovers. We formally test this with an event study analysis, testing the statistical significance of our estimated coefficients before and after the opening of a Catapult centre or the emergence of a Catapult-supported cluster. Secondly, test the sensitivity of the BDD analysis by limiting the sample of observations to firms in the immediate proximity of the two discontinuity boundaries, considering only firms within a maximum 1-, 5- or 10-kilometres distance from the Catapult centre, and firms located in neighbourhoods with a z-score for catapults-supported clusters ranging from 1.95 (positive spatial clustering at the 5% significance level) to 1.44 (statistically insignificant spatial clustering - 15% significance level), or from 2.57 (positive spatial clustering at the 1% significance level) to 1.28 (statistically insignificant spatial clustering - 20% significance level). This will limit the probability of comparing very different sets of treated and control businesses which are far away from the discontinuity boundaries.

4. RESULTS

We start our analysis by distinguishing in Table 1 the effect of direct and indirect spillovers from Catapults on the engagement with the public innovation system of unsupported local firms, and the consequent effects on firms' performance. We find evidence that Catapults innovation centres provide a significant source of externalities for unsupported businesses located nearby, mainly by increasing their likelihood to collaborate in the future with the Catapult network. Our results suggest that firms within a 1-kilometre radius from a Catapult centre are 0.1% more likely to engage with the Catapults network in the future. From column 2 we can observe that this probability is lower in the case of medium-high intensity engagements, although still statistically significant, indicating that proximity to Catapults centre is more likely to promote less intense types of relationships with local businesses. This evidence is corroborated by the results in columns 3 and 4, as we do not identify and significant effect of Catapults spillovers on the probability and number of public R&D grants received by firms from UKRI Research Councils and Innovate UK. Overall, this seems to suggest a weak knowledge externality effects, promoting engagement with the innovation system, but not enough to lead on its own to future publicly funded R&D projects. In columns 5 to 7, we can observe if these knowledge externalities eventually translate into an improvement of business performance for firms that were initially unsupported, through both an upscaling in terms of employment and turnover growth, and an increase in labour productivity. We find evidence of positive externalities in terms of employment, turnover and labour productivity growth for unsupported firms, with similar effects in terms of employment and turnover size, resulting in a 2% increase in productivity for unsupported firms after the opening of a Catapult centre within a 1-kilometer radius.

We focus then on the indirect spillovers originating from clusters of Catapult-supported businesses. Also in this case, we find positive and significant effects for the future engagement of unsupported businesses, although smaller in magnitude in respect to the direct effects, promoting mainly low-intensity engagement. However, being co-located in a cluster of Catapult-supported firms increase the probability of securing and the number of publicly funded R&D projects. As shown in Roper and Vanino (2023), Catapults-supported firms are more likely to receive UKRI funded R&D grants and, as these are usually collaborative projects in nature, might be more likely to look for potential partners among nearly located companies. Also in this case, these indirect externalities are conducive to better firm performance in terms of employment, turnover and productivity, although smaller in magnitude. The rest of the firm-level control variables are statistically significant with the expected sign. The variables of the distances from the two boundaries are also behaving as expected, showing evidence of non-linear relationships. Regarding distance from the 1-kilometer boundary around Catapult centres, after a generally positive relationship as we get closer to the Catapult centre, the effect turns negative for businesses that are further away (as distance for treated firms is bounded to maximum 1 kilometre from the boundary). On the contrary, for distance from the 1.65 significance level for spatial clustering, after an initial negative relationship, the effect is positive for more distant observations (as distance for untreated firms is bounded between 0 and 1.64, while it could go up to 90 for treated firms).

Table 1: Direct and indirect spillover effects from Catapults on nearby unsupported businesses.

	(1) Cat. Eng.	(2) High Cat. Eng.	(3) P(UKRI)	(4) No. UKRI	(5) Employment	(6) Turnover	(7) Productivity
Catapult Centre	0.000943***	0.000238**	0.000244	-0.000261	0.00799***	0.00786***	0.0207***
	(0.000209)	(0.000129)	(0.000366)	(0.000345)	(0.00220)	(0.00251)	(0.00360)
CC Distance	0.000304	0.000120	-0.000725	-0.000854	0.0128***	0.0163***	0.0221***
	(0.000249)	(0.000165)	(0.000576)	(0.000593)	(0.00265)	(0.00305)	(0.00449)
CC Distance^2	-0.000007	-0.0000007	0.00005	0.00005	-0.00157***	-0.00193***	-0.00217***
	(0.00001)	(0.00001)	(0.00003)	(0.00003)	(0.000180)	(0.000207)	(0.000305)
Cat. Supp. Cluster	0.00308***	0.00146***	0.000492**	0.000455**	0.00577***	0.00675***	0.00938***
	(0.000149)	(0.00009)	(0.000209)	(0.000206)	(0.00101)	(0.00118)	(0.00178)
CS Distance	-0.00285***	-0.00121***	-0.000608*	-0.000906***	-0.00264	-0.00403**	-0.0105***
	(0.000222)	(0.000147)	(0.000341)	(0.000336)	(0.00162)	(0.00188)	(0.00288)
CS Distance^2	0.000536***	0.000237***	0.000101	0.000176***	0.000262	0.000511	0.00241***
	(0.00004)	(0.00003)	(0.00006)	(0.00006)	(0.000373)	(0.000431)	(0.000666)
Group	0.000843***	0.000230***	0.00102***	0.000855***	0.118***	0.128***	0.0800***
	(0.000104)	(0.00006)	(0.000253)	(0.000228)	(0.00113)	(0.00129)	(0.00176)
Foreign Owned	0.000752***	0.000346*	-0.00131**	-0.00204***	-0.00539**	-0.00757**	0.0264***
	(0.000280)	(0.000189)	(0.000665)	(0.000639)	(0.00260)	(0.00295)	(0.00431)
Age	-0.000663***	-0.000287***	0.000256*	0.000346***	0.172***	0.204***	0.157***
	(0.00003)	(0.00002)	(0.000139)	(0.000132)	(0.000648)	(0.000746)	(0.000993)
Productivity	0.000139***	0.00005***	0.000194***	0.00009**	-0.105***	0.907***	
	(0.00001)	(0.00001)	(0.00004)	(0.00003)	(0.000403)	(0.000498)	
Employment	0.000869***	0.000354***	0.000988***	0.000891***			-0.348***
	(0.00003)	(0.00002)	(0.00008)	(0.00008)			(0.00129)
No. UKRI Projects			0.0284***	0.117***			
			(0.00443)	(0.00513)			
Firm FE	Y	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y	Y
SIC2-Year FE	Y	Y	Y	Y	Y	Y	Y
TTWA-Year FE	Y	Y	Y	Y	Y	Y	Y
Observations	15,369,239	15,364,086	7,637,286	7,637,286	15,369,239	15,369,239	15,369,239
R-squared	0.235	0.222	0.711	0.848	0.921	0.968	0.843

Notes: Estimation based on administrative Catapults data, Gateway to Research (GtR) and the Business Structure Database (BSD). Robust standard errors reported in parentheses. *** p<0.001, ** p<0.01, * p<0.05.

Given that both direct and indirect spillovers increase the probability for unsupported firms to engage with the Catapult network, we would like to make sure that the effects we estimate in terms of firms' performance are not driven in reality by the future direct support received by some of these businesses from Catapults. We investigate this in Table A1 in the Appendix, where we analyse whether the positive spillovers for unsupported firms are conditional or not on future engagement with Catapults. When differentiating between unsupported firms based on their future engagement with Catapults, we show that our baseline results are mainly driven by firms that never engaged with Catapults during the period of analysis, evidence of a significant spillover effect and not of the direct support from the innovation hubs.

Table 2: Direct and indirect spillover effects from Catapults on start-up rates.

	(1) General	(2) Manuf.	(3) Services	(4) High-Tech	(5) Low-Tech	(6) Single-Plant	(7) Multi-Plant
Catapult Centre	0.0139***	0.00453	0.0155***	0.0161***	0.0129***	0.0136***	0.000229
	(0.00295)	(0.00480)	(0.00341)	(0.00572)	(0.00343)	(0.00295)	(0.000189)
Cat. Supp. Cluster	0.00337**	0.000848	0.00405**	0.00335	0.00341**	0.00341**	-0.0000009
	(0.00138)	(0.00185)	(0.00171)	(0.00262)	(0.00162)	(0.00138)	(0.000101)
MSOA-SIC4 FE	Y	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y	Y
SIC2-Year FE	Y	Y	Y	Y	Y	Y	Y
TTWA-Year FE	Y	Y	Y	Y	Y	Y	Y
Observations	3,129,434	541,386	2,511,261	836,898	2,292,536	3,129,434	3,129,434
R-squared	0.249	0.206	0.253	0.233	0.254	0.249	0.118

Notes: Estimation based on administrative Catapults data, Gateway to Research (GtR) and the Business Structure Database (BSD). Robust standard errors reported in parentheses. *** p<0.001, ** p<0.01, * p<0.05.

Innovation hubs and industrial research centres have also been found in previous literature to stimulate entrepreneurship spin-off of new start-ups (Yu, 2020). In Table 2 we investigate this by looking at effects on start-up rates in the near proximity of newly opened Catapults centre and of Catapults-supported business clusters. In column 1 we find that Catapults stimulate the birth of new start-ups in the immediate proximity of their centres. In fact, there is a 1.4% increase in the number of new start-ups after the opening of a Catapult centre within a 1-kilometre radius. We do observe also a positive effect in terms of indirect spillovers from Catapult-supported businesses clusters, promoting the opening of new ventures around these cluster, but at a much smaller scale. Interestingly, we can see from columns 2-7 that these effects are heterogeneous across firms start-ups characteristics. In particular, spillover effects from Catapults are particularly important for the opening of new ventures in services industries, while there is no effect for manufacturing. In terms of sectoral composition, the effect is relatively larger for high-tech companies, although the coefficient is not statistically different from the one estimated for low-tech industries, while indirect spillovers from Catapults-supported clusters seem relevant only for start-ups in low-tech sectors. In addition, this effect is mainly driven by the opening of independent new ventures, rather than by subsidiaries of larger multi-plant groups. This could indicate a positive role played by Catapults centre in promoting local entrepreneurship and spin-offs of high-tech firms, generating new economic and employment growth, which is not driven simply by the reallocation of resources from one plant to another by larger firms.

Based on this evidence, we test in Table A2 in the Appendix if the spillover effects estimated so far are driven by new start-ups or by firms established before the opening of a Catapult centre or the emergence of a Catapult-supported cluster. Our results show that the direct spillover effect from Catapult centres opening is purely driven by established firms benefiting from this new source of innovation support. However, both established firms and start-ups seem to equally benefit from indirect spillovers generating from Catapults-supported clusters, in particular in terms of future catapult engagement and business performance.

We investigate further the heterogeneity of our results in Table 3, in order to identify the categories of firms for which direct and indirect spillovers from Catapults are mostly important. In terms of sectoral heterogeneity, results from the first four columns show that the effects are significantly stronger and positive for firms operating in service industries and in high-tech sectors, in particular in terms of future engagement with Catapults, employment and productivity growth. However, it seems that both direct and indirect Catapult spillovers are important to increase the probability of firms in manufacturing sectors to secure public R&D funding from UKRI. This evidence might reflect the fact that UKRI funding, especially from the EPSRC and from Innovate UK, are more likely to be assigned to manufacturing firms, and the knowledge externalities from Catapults could be beneficial only for this set of companies. In terms of firms specific characteristics, we distinguish between small and large firms based on their total employment, and between independent and multi-plant firms. Findings in Table 3 highlight how the spillover effects are mainly relevant for smaller firms (below 50 employees), both in terms of future engagement with the Catapult network and of business performance. However, despite the difference in these effects based on size, we do not observe significant differences in the effects of Catapults spillovers between independent and multi-plant firms. Thus, although spillovers from Catapults mainly promote the emergence of new independent businesses, they are then beneficial for both type of firms, both those independently managed and those part of a larger business group.

There are several mechanisms through which Catapults centres and clusters of supported firms could be the source of local spillovers for unsupported businesses. Previous studies have mainly considered 3 main mechanisms of spatial externalities, through labour pooling and movement of workers across spatially clustered businesses, input-output linkages between suppliers and customers nearly located, or knowledge externalities arising from informal interaction and the unintended exchange of tacit, uncodified knowledge (Glaeser et al., 1992). Opening the spillover black-box o investigate the potential mechanisms has always been challenging, given that spillovers are by definition unmeasurable. However, we try to consider some of these mechanisms by exploiting the nature of the observable interactions between unsupported firms and Catapults or Catapult-supported businesses. In Table 4, we try to identify if the direct and indirect spillovers are linked to knowledge externalities from Catapults centres or if instead they are linked to different type of economic interactions. To this end, we consider a measure technological proximity of each industry to the main Catapults innovation activities, as discussed in Figure 3. We then test if the effect of Catapults direct and indirect spillovers are mediated by the strength of the technological proximity of unsupported firms. This would be an evidence of knowledge externalities based on the technological focus of Catapults and nearby located firms. In addition, we use a measure of industrial relatedness between Catapult-supported customers and unsupported suppliers based on input-output linkages to test if instead the Catapults direct and indirect spillovers are mediated by the strength of the input-output relationships. In this case, most of the benefits would derive instead from an increased demand of intermediate inputs by Catapults supported firms, generating externalities through input-output linkages.

Table 3: Direct and indirect spillover effects from Catapults on nearby unsupported businesses: Heterogeneity analysis.

				Catapult Engagement				
	Manuf.	Services	Low-Tech	High-Tech	Small	Large	Single-Plant	Multi-Plant
Catapult Centre	-0.000141	0.000950***	0.000245	0.00159***	0.001000***	-0.00135	0.000717***	0.000966**
	(0.00156)	(0.000209)	(0.000202)	(0.000392)	(0.000188)	(0.00179)	(0.000242)	(0.000411)
Cat. Supp. Cluster	0.0172***	0.00221***	0.00202***	0.00497***	0.000570***	0.0428***	0.000485***	0.00798***
	(0.00145)	(0.000137)	(0.000147)	(0.000325)	(0.000100)	(0.00194)	(0.000113)	(0.000366)
Observations	991,628	13,364,350	12,002,634	3,318,382	14,922,629	423,186	9,842,399	5,399,616
R-squared	0.235	0.243	0.198	0.268	0.250	0.264	0.303	0.216
				P(UKRI)				
	Manuf.	Services	Low-Tech	High-Tech	Small	Large	Single-Plant	Multi-Plant
Catapult Centre	0.00692**	-0.00008	0.000581	-0.000125	0.000210	-0.000107	-0.00008	0.000477
	(0.00281)	(0.000364)	(0.000400)	(0.000643)	(0.000318)	(0.00279)	(0.000429)	(0.000623)
Cat. Supp. Cluster	0.00374**	0.000344*	0.000482**	0.000633	0.000234	0.00396**	0.000186	0.000716*
	(0.00166)	(0.000198)	(0.000209)	(0.000448)	(0.000176)	(0.00182)	(0.000213)	(0.000373)
Observations	541,235	6,503,800	6,038,758	1,577,189	7,377,921	246,790	4,235,544	3,357,989
R-squared	0.715	0.713	0.680	0.739	0.680	0.768	0.697	0.727
				Employment				
	Manuf.	Services	Low-Tech	High-Tech	Small	Large	Single-Plant	Multi-Plant
Catapult Centre	-0.0252***	0.00871***	-0.00161	0.0162***	0.00400**	-0.0110*	0.00898***	0.0106***
	(0.00933)	(0.00227)	(0.00284)	(0.00330)	(0.00195)	(0.00658)	(0.00282)	(0.00294)
Cat. Supp. Cluster	0.00311	0.00601***	0.000846	0.0156***	0.00347***	0.000984	0.00663***	0.00398***
	(0.00364)	(0.00106)	(0.00120)	(0.00175)	(0.000890)	(0.00324)	(0.00123)	(0.00134)
Observations	991,628	13,364,350	12,002,634	3,318,382	14,922,629	423,186	9,842,399	5,399,616
R-squared	0.960	0.917	0.924	0.928	0.896	0.939	0.842	0.965
				Productivity				
	Manuf.	Services	Low-Tech	High-Tech	Small	Large	Single-Plant	Multi-Plant
Catapult Centre	-0.0108	0.0205***	0.00976**	0.0354***	0.0175***	0.00799	0.0206***	0.0181***
	(0.0148)	(0.00371)	(0.00453)	(0.00549)	(0.00367)	(0.0132)	(0.00437)	(0.00564)
Cat. Supp. Cluster	-0.000820	0.00961***	0.00545***	0.0146***	0.00638***	0.00760	0.00387*	0.00745**
	(0.00614)	(0.00186)	(0.00203)	(0.00319)	(0.00180)	(0.00644)	(0.00201)	(0.00293)
Observations	991,628	13,364,350	12,002,634	3,318,382	14,922,629	423,186	9,842,399	5,399,616
R-squared	0.842	0.844	0.851	0.849	0.846	0.872	0.853	0.867

Notes: Estimation based on administrative Catapults data, Gateway to Research (GtR) and the Business Structure Database (BSD). Robust standard errors reported in parentheses. *** p<0.001, ** p<0.01, * p<0.05.

Results in Table 4 provide significant evidence for the knowledge externality mechanism. In fact, it is possible to notice that both direct and indirect spillovers are in general positively mediated by the strength of the technological relatedness between firms unsupported and supported by Catapults. This is particularly the case for the direct spillovers on entrepreneurship and employment growth, and in the case of indirect externalities affecting future engagement with Catapults and productivity growth. On the contrary, input-output linkages between Catapult-supported customers and unsupported suppliers negatively mitigates the positive externalities arising from Catapults, indicating weaker positive effects along the supply-chain.

Table 4: Direct and indirect spillover effects from Catapults on nearby unsupported businesses: Knowledge externalities and input-output linkages mechanisms.

	Catapult Engagement		UKRI		Start-Up		Employment		Productivity	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Catapult Centre	0.000723	0.00187*	0.000377	0.000424	0.0106***	0.0120***	-0.00388	0.0127***	0.0229***	0.0299***
	(0.000775)	(0.00112)	(0.000423)	(0.000447)	(0.00307)	(0.00346)	(0.00252)	(0.00289)	(0.00407)	(0.00474)
CC x Tech. Rel.	0.0109		-0.00223		0.162**		0.353***		-0.0666	
	(0.00970)		(0.0118)		(0.0664)		(0.0384)		(0.0621)	
CC x IO Link.		0.000124		-0.000109		0.00143		-0.00273**		-0.00528***
		(0.000299)		(0.000179)		(0.00167)		(0.00116)		(0.00203)
Cat. Supp. Cluster	0.00295***	0.00735***	0.000493*	0.000793***	0.00275*	0.00232	0.00554***	0.00725***	0.0128***	0.0137***
	(0.000762)	(0.000708)	(0.000270)	(0.000240)	(0.00146)	(0.00155)	(0.00118)	(0.00125)	(0.00203)	(0.00215)
CS x Tech. Rel.	0.0278**		-0.000179		0.0359		0.00537		0.133***	
	(0.0116)		(0.00903)		(0.0418)		(0.0243)		(0.0450)	
CS x IO Link.		-0.000931***		-0.000189***		0.000864		-0.000886*		-0.00260***
		(0.000175)		(0.00007)		(0.000759)		(0.000455)		(0.000847)
Observations	15,369,239	15,369,180	7,637,286	7,637,279	3,129,434	3,129,393	15,369,239	15,369,180	15,369,239	15,369,180
R-squared	0.277	0.277	0.711	0.711	0.249	0.249	0.921	0.921	0.843	0.843
Firm FE	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
SIC2-Year FE	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
TTWA-Year FE	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y

Notes: Estimation based on administrative Catapults data, Gateway to Research (GtR) and the Business Structure Database (BSD). Robust standard errors reported in parentheses. *** p<0.001, ** p<0.01, * p<0.05.

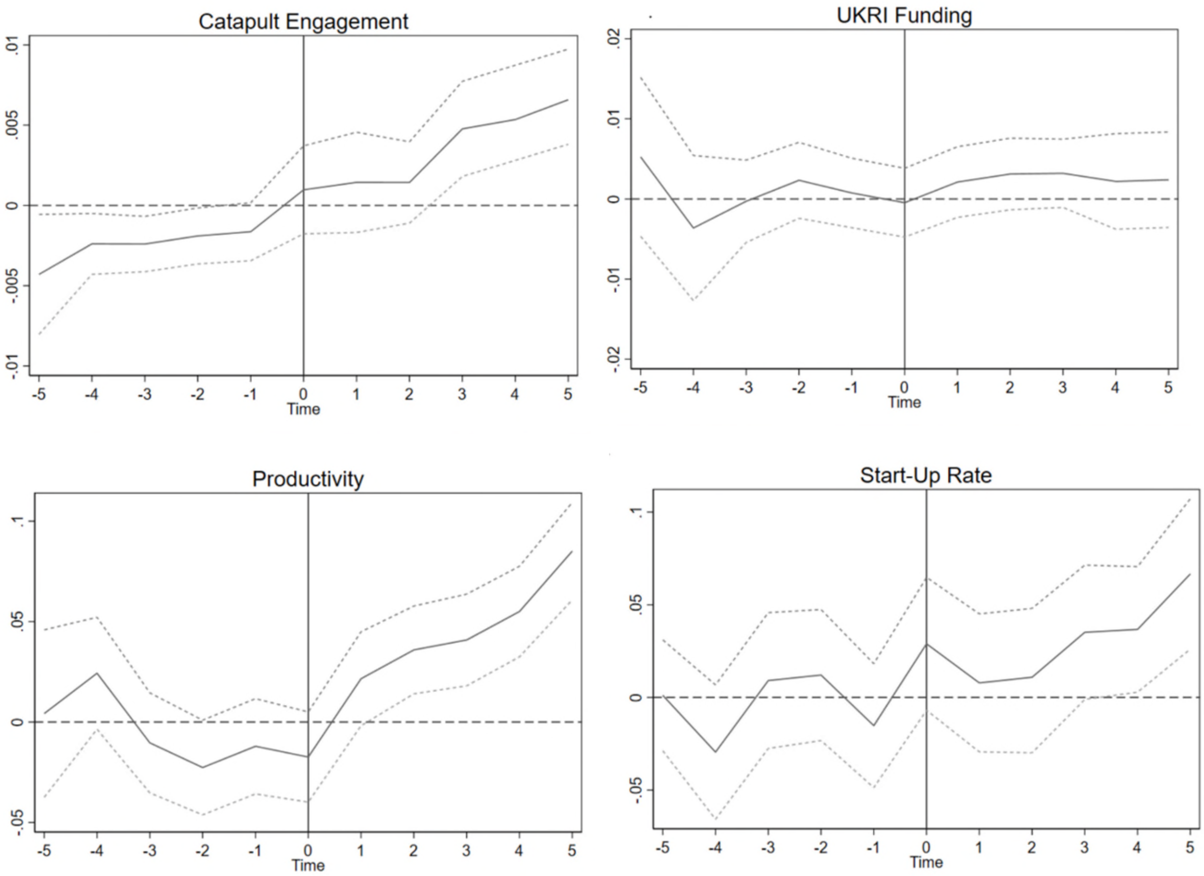
We further corroborate these results in Table A3 in the Appendix, where we follow the Mian and Sufi (2014) methodology to identify locally consumed (untradable) services, and check whether the spillover effects are stronger in these industries, and thus be likely to be linked to an increased local demand by Catapults, supported businesses and their employees, or if instead are driven by firms in tradeable industries. The findings of this analysis point to a much stronger effect of direct and indirect spillovers in tradeable industries, providing further evidence in favour of the knowledge or labour pooling externalities argument.

Overall, these results point to an important role played by Catapults centres in promoting business participation in the public science and innovation system, even beyond their direct engagement with firms. In particular, the presence of Catapults encourage nearby firms in seeking support and getting involved in R&D activities. Catapults centres are also catalysts for the creation of new businesses and for the upscale and productivity growth of existing ones. In addition, firms engaged with Catapults also promote the flow of knowledge spillovers from Catapult centres to unsupported firms, increasing their likelihood to engage with the network after learning from their neighbour peers.

We conduct several sensitivity tests to check the robustness of our results. First of all, in Figure 4 we perform an event study analysis, testing the statistical significance of our estimated coefficients before and after the opening of Catapult centres and the emergence of Catapult-supported clusters.[2]

[2] We report findings for direct spillovers from the opening of Catapult centres. Results for the indirect spillover effects from Catapult-supported cluster, and for the other main outcome variables of interest available from the authors upon request.

Figure 4: Direct and indirect spillover effects from Catapults on nearby unsupported businesses: Event study analysis.



Notes: Estimation based on administrative Catapults data, Gateway to Research (GtR) and the Business Structure Database (BSD). 95% confidence intervals reported.

Our results show that there was no statistically significant difference between treated and untreated unsupported firms for the main outcomes of interest before the opening of a Catapult centre. Only after the Catapult centres start operating we observe a significant positive effect of direct spillovers on unsupported businesses, in particular in terms of future engagement with Catapults, entrepreneurship rates, and productivity growth. In addition, we can notice that this is not a one-off impact, but a continuous positive effect on unsupported businesses which is increasing over time. In particular, in the bottom right panel we can observe that direct spillovers from Catapult centres start to stimulate local entrepreneurship only 3 years after the opening of a centre, highlighting a significant delay in the propagation of these knowledge externalities. Unreported evidence on the impact of indirect spillover from Catapult-supported cluster show instead that these effects are much more instantaneous, being significant on the year of the emergence of a cluster, but rapidly fading away. These contrasting findings suggest a potential fundamental difference in the types of spillovers originating directly from Catapult centre and indirectly from clusters of supported businesses, the former having a longer-term horizon while the latter having a more immediate but short lived impact.

Finally, in Table A4 in the Appendix we test the sensitivity of the BDD analysis by limiting the sample of observations to firms in the immediate proximity of the two discontinuity boundaries, considering only firms within a maximum 10-kilometres distance from the Catapult centre, and firms located in neighbourhoods with a z-score for catapults-supported clusters ranging from 2.57 (positive spatial clustering at the 1% significance level) to 1.28 (statistically insignificant spatial clustering - 20% significance level).[3] This approach limits the probability of comparing very different sets of treated and control businesses which are far away from the discontinuity boundaries. Results in Table A4 are consistent with our main findings, demonstrating the overall robustness of the BDD analysis in identifying the causal effect of both direct and indirect Catapults spillovers.

5. CONCLUSIONS

Earlier evidence suggests that firms engaging with Catapults grow significantly faster in terms of both employment and turnover than similar firms which are not engaging (Roper and Vanino, 2023). Here, we extend this earlier analysis to provide evidence on the positive spatial spillovers from the Catapults network, which arise both directly from the Catapult centres itself and through locally concentrated Catapult engaged firms. Our analysis suggests four key results. First, local knowledge spillovers from Catapult centres increase the likelihood that co-located, but un-connected firms will collaborate in the future with the Catapult network and are more likely to receive public R&D funding from UKRI. This type of dynamic benefits have been noted elsewhere in the context of regional R&D and innovation support measures (Roper and Vanino, 2023). Second, local knowledge spillovers from Catapult centres also lead to improvements in employment and turnover growth, and an increase in labour productivity. Interestingly, we also find that Catapults stimulate the birth of new start-ups in the immediate proximity of their centres. Third,

[3] Additional sensitivity tests further restricting to a maximum 1- or 5-kilometres distance from the Catapult centre, and to a z-score for catapults-supported clusters ranging from 1.95 (positive spatial clustering at the 5% significance level) to 1.44 (statistically insignificant spatial clustering - 15% significance level), are consistent and available from the authors upon request.

indirect spillovers through supported firms are also evident in stimulating unsupported firms to engage with the Catapult centres. This could be seen as a demonstration effect, i.e. unsupported firms see other local firms engaging and benefiting from engagement with the Catapult network and this encourages them then to engage. In addition, indirect spillovers through supported firms also have a positive impact on the productivity of unsupported businesses, increasing their efficiency as a result of these indirect externalities. In sum, Catapult centres generate positive local spillovers both directly and indirectly through the firms they work with.

This evidence on the positive spillovers – both direct and indirect – from Catapult centres reinforces the positive findings of earlier studies, which suggest that the positive effects of tech-specific innovation hubs and centres go beyond the directly engaged and supported firms. This type of policy initiatives, promoting R&D and innovation collaborations between industry and universities closely located could be important contributors to the efforts of many countries to "level up" left-behind areas and narrow the regional inequalities, by increasing innovation adoption and improving productivity outside of R&D intense regions. Industrial research centres can be an effective vehicle for driving up business spending on R&D, creating the opportunities to forge closer links between higher education and industry, and to tap into public R&D investment. These centres can become local drivers of innovation and economic growth, capitalising on existing clusters of businesses in their areas that have cutting edge expertise.

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APPENDIX

Table A1: Direct and indirect spillover effects from Catapults on nearby unsupported businesses conditional on future engagement.

	P(UKRI)	No. UKRI	Unengaged Employment	Turnover	Productivity
Catapult Centre	0.000402**	0.00005	0.00649***	0.00628**	0.0198***
	(0.000232)	(0.000297)	(0.00221)	(0.00253)	(0.00362)
Cat. Supp. Cluster	0.000237	0.000226	0.00473***	0.00562***	0.00862***
	(0.000180)	(0.000162)	(0.00102)	(0.00118)	(0.00179)
Observations	7,605,049	7,605,049	15,310,946	15,310,946	15,310,946
R-squared	0.671	0.790	0.919	0.968	0.843
	P(UKRI)	No. UKRI	Engaged Employment	Turnover	Productivity
Catapult Centre	-0.0200	-0.0200	-0.0298	-0.0358	-0.0117
	(0.0133)	(0.0135)	(0.0203)	(0.0227)	(0.0315)
Cat. Supp. Cluster	0.0111	0.00967	0.0388***	0.0452***	0.0226
	(0.00803)	(0.00921)	(0.0101)	(0.0119)	(0.0180)
Observations	32,055	32,055	58,023	58,023	58,023
R-squared	0.786	0.911	0.969	0.981	0.816
Firm FE	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y
SIC2-Year FE	Y	Y	Y	Y	Y
TTWA-Year FE	Y	Y	Y	Y	Y

Notes: Estimation based on administrative Catapults data, Gateway to Research (GtR) and the Business Structure Database (BSD). Robust standard errors reported in parentheses. *** p<0.001, ** p<0.01, * p<0.05.

Table A2: Direct and indirect spillover effects from Catapults on nearby unsupported businesses: start-ups versus established firms.

	START-UPS					
	Cat. Eng.	P(UKRI)	No. UKRI	Employment	Turnover	Productivity
Catapult Centre	-0.000376	0.00439	0.00251	0.00763	0.00974	0.0118
	(0.000792)	(0.00480)	(0.00339)	(0.00846)	(0.00955)	(0.0131)
Cat. Supp. Cluster	0.00390***	0.000457	0.000401	0.00367***	0.00393***	0.00960***
	(0.000209)	(0.000293)	(0.000300)	(0.00124)	(0.00143)	(0.00211)
Observations	13,974,126	6,878,066	6,878,066	13,974,126	13,974,126	13,974,126
R-squared	0.244	0.716	0.849	0.926	0.970	0.850
	ESTABLISHED					
	Cat. Eng.	P(UKRI)	No. UKRI	Employment	Turnover	Productivity
Catapult Centre	0.000949***	0.000262	-0.000247	0.00912***	0.00866***	0.0225***
	(0.000215)	(0.000367)	(0.000347)	(0.00225)	(0.00257)	(0.00372)
Cat. Supp. Cluster	0.00349***	0.000473**	0.000446**	0.00893***	0.0105***	0.0112***
	(0.000165)	(0.000214)	(0.000212)	(0.00105)	(0.00122)	(0.00186)
Observations	14,852,907	7,590,542	7,590,542	14,852,907	14,852,907	14,852,907
R-squared	0.223	0.710	0.847	0.923	0.969	0.844
Firm FE	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y
SIC2-Year FE	Y	Y	Y	Y	Y	Y
TTWA-Year FE	Y	Y	Y	Y	Y	Y

Notes: Estimation based on administrative Catapults data, Gateway to Research (GtR) and the Business Structure Database (BSD). Robust standard errors reported in parentheses. *** p<0.001, ** p<0.01, * p<0.05.

Table A3: Direct and indirect spillover effects from Catapults on nearby unsupported businesses: Local demand services mechanism.

	LOCAL DEMAND SERVICES				
	Cat. Eng.	P(UKRI)	Start-Up	Employment	Productivity
Catapult Centre	0.000511**	0.000209	0.0145***	0.00248	0.0135**
	(0.000248)	(0.000486)	(0.00519)	(0.00428)	(0.00596)
Cat. Supp. Cluster	0.000561***	0.000127	0.00298	0.00314*	0.00698**
	(0.000141)	(0.000209)	(0.00268)	(0.00182)	(0.00271)
Observations	4,645,007	2,178,243	1,001,947	4,645,007	4,645,007
R-squared	0.214	0.694	0.309	0.919	0.842
	TRADEABLE				
	Cat. Eng.	P(UKRI)	Start-Up	Employment	Productivity
Catapult Centre	0.00109***	0.000197	0.0129***	0.00888***	0.0238***
	(0.000271)	(0.000466)	(0.00361)	(0.00252)	(0.00432)
Cat. Supp. Cluster	0.00413***	0.000612**	0.00349**	0.00656***	0.00983***
	(0.000202)	(0.000278)	(0.00161)	(0.00118)	(0.00219)
Observations	10,666,974	5,433,863	2,122,536	10,666,974	10,666,974
R-squared	0.239	0.715	0.220	0.927	0.847
Firm FE	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y
SIC2-Year FE	Y	Y	Y	Y	Y
TTWA-Year FE	Y	Y	Y	Y	Y

Notes: Estimation based on administrative Catapults data, Gateway to Research (GtR) and the Business Structure Database (BSD). Robust standard errors reported in parentheses. *** p<0.001, ** p<0.01, * p<0.05.

Table A4: Direct and indirect spillover effects from Catapults on nearby unsupported businesses: Robustness test.

	(1) Cat. Eng.	(2) P(UKRI)	(3) Start-Up	(4) Employment	(5) Productivity
Catapult Centre	0.00122***	-0.000218	0.0127***	0.00191	0.169***
	(0.000222)	(0.000682)	(0.00299)	(0.00233)	(0.0538)
Cat. Supp. Cluster	0.00332***	-0.000634	0.156	0.0558***	0.0430
	(0.00127)	(0.00155)	(0.148)	(0.0193)	(0.0363)
Observations	50,293	50,293	2,010	50,293	50,293
R-squared	0.457	0.997	0.871	0.935	0.895
Firm FE	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y
SIC2-Year FE	Y	Y	Y	Y	Y
TTWA-Year FE	Y	Y	Y	Y	Y

Notes: Estimation based on administrative Catapults data, Gateway to Research (GtR) and the Business Structure Database (BSD). Robust standard errors reported in parentheses. *** p<0.001, ** p<0.01, * p<0.05.

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