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More knowledge, more entrepreneurs? An investigation of the science and cluster policy mix in Germany

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Abstract The relationship between knowledge and entrepreneurship has been extensively studied, with the knowledge spillover theory of entrepreneurship (KSTE) providing a key theoretical framework. However, the assumption that increasing knowledge stocks and flows inevitably leads to higher levels of entrepreneurship remains contested. This study examines how the mix of science and cluster policies in Germany influences entrepreneurial activity by shaping knowledge spillovers. While science policies aim to advance research and knowledge creation, cluster policies primarily enhance knowledge flows by fostering collaboration among firms, universities, and research institutions. Following the rationale of KSTE, we test whether regions exposed to both types

of policy exhibit higher levels of innovation and innovative entrepreneurship than control groups, that is, regions treated only by one or by neither policy. Contrary to KSTE predictions, our findings reveal that knowledge spillovers do not automatically result in increased innovative entrepreneurship but instead primarily fuel intrapreneurship. We thus argue that simply increasing knowledge production is insufficient to drive innovation and innovative entrepreneurship; rather, the way in which knowledge is transferred and absorbed plays a crucial role.

Plain English Summary This study shows that increasing knowledge does not automatically lead to more start-ups; instead, it benefits incumbent firms. We examine how two major German innovation policies—one promoting scientific excellence and the other strengthening networks among regional actors—affect entrepreneurship. While regions exposed to both policies experienced higher levels of business registration, this was not accompanied by an increase in high-tech start-ups. Instead, innovation activity appears to have occurred primarily within incumbent firms through intrapreneurship. These findings challenge common assumptions about how knowledge spillovers drive entrepreneurship. Simply producing more knowledge is not enough; new ventures also require supportive environments to turn ideas into businesses. The key policy implication is clear: to boost innovative entrepreneurship,

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governments must invest not only in research and collaboration but also in the entrepreneurial ecosystems that enable new firms to emerge and thrive.

Keywords Knowledge spillover theory of entrepreneurship · Entrepreneurship · Intrapreneurship · Cluster policy · Science policy · Policy mix

JEL Classification L26 · L52 · O31

1 Introduction

In the context of rising global competition, the Draghi Report (Draghi, 2024) calls for a strategic shift to close Europe's innovation gap with the USA and China, particularly in advanced technologies, by fostering innovation through better exploitation of knowledge and by encouraging entrepreneurial activities that translate knowledge spillovers into commercial value. This study examines whether and how policies that foster both the creation of knowledge spillovers and their absorption and exploitation affect entrepreneurial activity, thereby contributing to the literature on the evaluation of entrepreneurship policies. Existing empirical evidence on policies aimed at fostering innovative entrepreneurship is somewhat ambiguous, reporting positive results, namely that such policies foster entrepreneurship (e.g., Albanese & Bronzini, 2025; Audretsch et al., 2016; Guo et al., 2016; Rigby & Ramlogan, 2016), negative results (Dai & Guo, 2025; Lehmann & Menter, 2018b), or that such policies do not impact entrepreneurial activity (e.g., Amorós et al., 2019; Cumming & Li, 2013; Fotopoulos & Storey, 2019; Meoli et al., 2019; Qin et al., 2025).

The reasons for these ambiguous results are manifold and intensively discussed in the literature (Wang et al., 2023; Wurth et al., 2023). They include technical errors in policy design, such as misguided incentives, adverse effects, insufficient funding, or substitution effects caused by other policies. They also reflect an insufficient theoretical understanding of the relevant policy levers and the mechanisms through which they operate to achieve desired results. In addition, problems arise in the evaluation of such measures, such as the delineation of policies, the effects of parallel policies, and the empirical basis. This study aims

to make an important contribution to the understanding of innovative entrepreneurship policy by focusing in particular on the latter two issues, namely the theoretical basis and the mode of action of a policy mix.

Over the past 30 years, the knowledge spillover theory of entrepreneurship (KSTE) has become the theoretical basis for explaining the relationship between the existence of knowledge spillovers and their commercialization through new company creation (see Acs et al., 2009, 2013). By arguing that the creation of knowledge leads to new ideas in the form of new products, processes, methods of buying and selling, or business models (Bradley et al., 2021), the KSTE has emerged as the prevailing approach and logic for formulating and justifying policies aimed at fostering innovative entrepreneurship through knowledge spillovers generated by public and private research institutes and universities (for a literature review, see Acs et al., 2009; Audretsch & Lehmann, 2005a; Ghio et al., 2016; Qian & Jung, 2017). Consequently, from a policy perspective, this implies that fostering innovative entrepreneurship requires both increasing knowledge production and strengthening the mechanisms that facilitate the absorption and exploitation of knowledge spillovers (Greco et al., 2020; Meissner & Kergroach, 2021). Rather than testing the KSTE's general validity, this study takes its core theoretical logic as given and focuses on the policy-induced conditions under which knowledge spillovers are generated and absorbed. Specifically, we conceptualize knowledge production and absorptive capacity as the two central, policy-relevant mechanisms shaping entrepreneurial outcomes (Audretsch & Lehmann, 2005a; Buffart et al., 2020; Civera et al., 2024; Griliches, 1979; Magro & Wilson, 2019; Qian & Acs, 2013).

Focusing on two interrelated policies—one designed to foster knowledge spillovers and the other aimed at stimulating the creation of new and innovative firms to absorb and exploit these spillovers—this study addresses long-standing ambiguities in the literature on innovative entrepreneurship policies. Empirically, we examine two major German policy programs that target these mechanisms in line with the logic of the KSTE. First is the Excellence Initiative, which was created and implemented to strengthen academic research and, consequently, regional knowledge production through selecting leading universities in a “winner-takes-it-all” contest and funding their

research structures (Civera et al., 2020; Lehmann & Stockinger, 2019). The second policy, the Leading-Edge Cluster Competition, was also designed as a “winner-takes-it-all” contest, selecting promising and innovative regional clusters to intensify collaboration among firms, universities, and research institutions and thereby stimulate new venture creation in innovative and future-oriented industries (Audretsch et al., 2016; Lehmann & Menter, 2018a).

With these two policies and the KSTE as the underlying theoretical logic, our empirical strategy is straightforward: regions in which both policies were implemented—promoting the production of knowledge spillovers while simultaneously stimulating new venture creation—should outperform control groups on measures such as the creation of new and innovative firms. The control groups consist of regions in which either only one of the two policies was implemented or of regions that received no funding at all.

Our results show that, although beneficial in isolation, the combination of policies increases regional entrepreneurship but not high-tech entrepreneurship. Moreover, increases in regional innovation appear to require the combination of both policies, since single-policy initiatives do not yield significant effects. Taking the rationale and logic of the KSTE as granted, the finding that the combined effect of the two policies on high-tech entrepreneurship is not statistically significant reveals a puzzling effect, suggesting the results may not be generally transferable to other countries and instead remain a German-specific artifact.

To shed light on this puzzle, we revisit the conventional view that knowledge spillovers primarily fuel the creation of new firms. Our analysis suggests a more nuanced mechanism: knowledge spillovers are not only absorbed and commercialized by new ventures through entrepreneurship but are also systematically exploited by incumbent firms through intrapreneurial activities. Our post-hoc analyses show that established firms substantially benefit from these spillovers, indicating that incumbents are effective absorbers of external knowledge. This implies that intrapreneurship may partially crowd out entrepreneurial entry rather than complement it. These findings challenge a central assumption underlying many innovation and entrepreneurship policies, namely that knowledge spillovers predominantly translate into new firm formation. Instead, our results highlight

intrapreneurship as an important—yet often overlooked—channel through which knowledge spillovers are realized, particularly relevant in institutional contexts characterized by a strong small and medium-sized enterprise (SME) sector, such as Germany. Consequently, the effectiveness of policies aimed at fostering innovative entrepreneurship cannot be assessed independently of national industrial structures and incumbent firms’ absorptive capacities; it must be interpreted within the specific country context.

The remainder of the paper is structured as follows. Section 1 outlines the rationales and relevance of the policy mix, considering the assumptions underlying the knowledge spillover theory of entrepreneurship. Section 4.2 proposes hypotheses on why and how two distinct types of policies promoting innovation and innovative entrepreneurship in the German context may complement each other. Section 6 describes the data and explains our methodological approach. The results are presented in Section 6, followed by an in-depth discussion in Section 7. The concluding section offers several recommendations for both future research and policymakers.

2 Theoretical background

Innovation activities depend on new economic knowledge and tend to cluster geographically (Audretsch & Feldman, 1996, 2004; Feldman, 1999). The core rationale of the knowledge spillover theory of entrepreneurship is that new economic knowledge created by one economic agent spills over to another economic agent, who exploits these knowledge spillovers for innovative activity (Jaffe, 1986, 1989). Research has identified two broad prerequisites. First, research and development (R&D) is required, along with institutions that encourage economic agents to explore and invest in new knowledge creation and innovative activities. Second, environments that support and stimulate economic agents to exploit new knowledge are required (Shepherd et al., 2019).

While early growth models suggested a direct link between knowledge production and innovation (Griliches, 1979; Romer, 1986), subsequent research has shown that new knowledge does not automatically translate into innovative or entrepreneurial activity. This disconnect is captured by the concept of the “knowledge filter,” which impedes the immediate

transformation of knowledge into economic value (Acs et al., 2004); Ghio et al., 2016; Qian & Acs, 2013). As a result, additional mechanisms are required to convert newly created knowledge into innovation and societal value (Audretsch & Keilbach, 2008).

The KSTE assigns a central role to small and new entrepreneurial firms in converting regional knowledge stocks into innovations (e.g., Acs et al., 2009; Audretsch & Lehmann, 2005a). Entrepreneurship thus functions as a conduit for knowledge spillovers. Qian and Acs (2013) argue that newly created knowledge does not necessarily lead to entrepreneurship and that additional “entrepreneurial absorptive capacities” are needed to transform knowledge into innovation. Accordingly, the absorptive capacity theory of knowledge spillover entrepreneurship suggests that “the extent to which the market value of new knowledge is discovered and exploited depends on the capability of entrepreneurs to recognize such opportunities and to mobilize resources to bring new inventions into the market” (Qian & Acs, 2013: 191). Entrepreneurs must therefore possess sufficient absorptive capacity to capture and exploit knowledge spillovers. From a policy perspective, this implies that stimulating knowledge-based entrepreneurship requires investment not only in knowledge production but also in regional human capital and entrepreneurial capabilities.

While the KSTE provides a strong theoretical rationale for how knowledge creation and absorptive capacity shape knowledge-based entrepreneurship, the design of policies targeting these mechanisms—and especially their interaction within policy mixes—remains only weakly understood (Calza & Goedhuys, 2016; Magro & Wilson, 2013). Different policy instruments may reinforce one another, but they may also generate offsetting, crowding-out, or neutralizing effects, depending on how they are designed and combined across stages of the knowledge spillover process (Athey & Stern, 1998; Flanagan et al., 2011; Maor, 2020; Meissner & Kergroach, 2021; Wang et al., 2023). Despite the growing relevance of policy mix approaches, systematic empirical evidence on how knowledge-oriented policy designs interact in practice remains limited. Against this background, we take the KTSE’s core theoretical logic and main empirical implications as given and focus explicitly on the interaction between policy instruments targeting knowledge creation and knowledge diffusion.

To empirically examine these interaction effects, we draw on two major German policy interventions that target these mechanisms from different angles. The Excellence Initiative primarily aims to strengthen regional knowledge production through top-level research and the funding of leading universities and research structures. In contrast, the Leading-Edge Cluster Competition is designed to foster the diffusion and exploitation of knowledge by intensifying collaboration among firms, universities, and research institutions within geographically bounded clusters. The joint analysis of these two programs allows us to assess the entrepreneurial effects of a knowledge-oriented policy mix.

3 Contextual setting and development of hypotheses

We first examine the Excellence Initiative, a program designed to increase knowledge production and, consequently, knowledge spillovers (for further details, see Lehmann & Stockinger, 2019; Menter et al., 2018). The Excellence Initiative offered funding to the best-performing German universities to strengthen their research capabilities and optimize internal organizational structures. The program disbursed a total of €1.9 billion of funding across two rounds, covering the periods 2006/2007 to 2012 and 2012 to 2017 (IEKE, 2016). To motivate the entire German higher education sector, the Excellence Initiative was designed as a competition open to all research fields. The call for strategy proposals encouraged the development of not only innovative but also unconventional ideas during the application process. The “Future Concepts” funding line encouraged a transition toward an entrepreneurial paradigm by strengthening universities as institutions, with a particular focus on administration, autonomy, and strong leadership. It called for structural reforms, such as the introduction of university-based entrepreneurship, aimed at supporting strategy-oriented profile development and establishing freedom to research new areas. This approach was expected to improve collaboration both within the university and with non-university research institutions, thereby increasing the international visibility and attractiveness of individual universities. Such collaboration was intended to foster technology transfer, academic spin-offs, and the international visibility of both the institutions and their associated regions. To achieve the goal of increased international visibility,

measures are selected according to the most prestigious rankings, such as the Times Higher Education World *University Rankings* or the *QS World University Rankings*, as well as measures covering publications in leading academic journals, citations, licenses, patents, and spin-offs (see Civera et al., 2020; Daraio et al., 2019; Menter et al., 2018). Collectively, these activities result in knowledge production and thus form the basis for knowledge spillovers.

Following the KSTE and our theoretical line of argument, we assume that the Excellence Initiative stimulates innovative entrepreneurship via university research and the associated knowledge spillovers. Given the tacit knowledge characteristics of spillovers, we further assume that regions hosting universities selected under the Excellence Initiative exhibit higher levels of entrepreneurial activity than non-funded regions. We therefore hypothesize:

H1: The Excellence Initiative induced higher regional levels of innovative entrepreneurship in regions that received such funding compared with regions that did not.

Second, we focus on the Leading-Edge Cluster Competition, initiated in 2007 to foster collaboration and associated knowledge flows by promoting regional industry clusters based on new and promising technologies (BMBF, 2015). The core idea of this public policy was to subsidize emerging industries or sectors by encouraging collaboration not only across industries but also between academia and industry. The initiative further aimed to synergize research and innovation, stimulating the creation and development of new entrepreneurial ecosystems (see Lehmann & Menter, 2018a, 2018b). This policy program provided the resources and mechanisms required to facilitate local knowledge spillovers and their exploitation through place-based entrepreneurship. In this way, it emulated an entrepreneurial ecosystem by providing the majority of resources and mechanisms required to initiate technology-driven businesses. Central to this approach was the development of bridges between science and industry to better use researchers' knowledge alongside organizational expertise in commercialization.

Using the same format as the Excellence Initiative, the Leading-Edge Cluster Competition was a nationwide contest among German regions and funded by the Federal Ministry of Education and Research, with a total

budget of €600 million. Across three waves, the program supported a total of 15 cluster initiatives targeting a wide range of technologies (e.g., biotechnology, renewable energy, software, and materials science), with the aim of enabling them to emerge as international leaders in their respective fields. The underlying idea of this competition was to encourage regions to sustainably mobilize their economic potential, support regional strategy-making, connect regional actors, and enhance local innovation and the creation of new businesses (see Rothgang et al., 2017).

While the Excellence Initiative primarily focused on knowledge production resulting from university research, the Leading-Edge Cluster Competition encouraged the flow of knowledge among economic actors. Regional absorptive capacities were expected to overcome the “knowledge filter,” thereby promoting knowledge spillovers via the establishment of technological and entrepreneurial clusters. Following the KSTE and our line of argument, this should have resulted in higher levels of innovative entrepreneurship activity in regions supported by the Leading-Edge Cluster Competition compared with those that were not supported. Thus, we hypothesize:

H2: The Leading-Edge Cluster Competition induced higher regional levels of innovative entrepreneurship in regions that received such funding compared with regions that did not.

Finally, in line with the KSTE, we assume that both the production of knowledge and associated knowledge spillovers, as well as their absorption resulting in new firm creation and entrepreneurship, should work together. The increase in knowledge spillovers, boosted on one hand by governmental funding and incentives and on the other by increased absorptive capacities fostering new venture creation, should lead to higher levels of innovative entrepreneurship in regions where both the Excellence Initiative and the Leading-Edge Cluster policies coincide. Although increasing entrepreneurial activity was not a primary objective of either policy—yet mentioned as a secondary goal—we argue that regions awarded both policy initiatives can expect higher levels of innovative entrepreneurship than regions that received funding solely from the Excellence Initiative or from the Leading-Edge Cluster Competition, and hypothesize:

H3: The Excellence Initiative complemented the Leading-Edge Cluster Competition, inducing higher

regional levels of innovative entrepreneurship in regions that received both types of funding compared with regions subsidized by a single policy.

In summary, following indications from the KSTE, we expect that regional levels of innovative entrepreneurship are statistically significant in regions where the policy mix either encourages knowledge spillovers through the Excellence Initiative or fosters absorptive capacities through the Leading-Edge Cluster Competition. In addition, innovative entrepreneurship is expected to be the highest in regions where both policies coincide.

4 Methodology and data sample

To empirically assess the impact of the policy mix and its effect on innovative entrepreneurship, we employ difference-in-differences estimations to capture the effects of both the Excellence Initiative and the Leading-Edge Cluster Competition. The difference-in-differences approach offers several advantages. First, it measures differences between the two groups and how those differences change over time (see Gobillon & Magnac, 2016; Lechner, 2011). Second, it controls for unobserved (permanent) differences that could be correlated with outcomes. Third, it mitigates biases resulting from comparisons over time (time-constant differences).

We use a hand-collected panel dataset covering 96 German planning regions (*Raumordnungsregionen*; [RORs]),¹ spanning 19 years from 1998 to 2016,² providing sufficient observations before (1998–2007) and after (2007–2016) the policy went into effect. Considering our treatment groups—regions that received funding—we categorize the German planning regions as follows: (1) regions funded by both the Excellence Initiative and the Leading-Edge Cluster Competition (20 RORs), (2) regions funded only by the Excellence Initiative (17 RORs), (3) regions funded only by the Leading-Edge Cluster Competition (10 RORs), and (4) regions funded by neither (49 RORs). Treatment status was assigned by mapping funded institutions—universities

and cluster management organizations—to their respective RORs. RORs represent stable functional spatial units based on commuting and labor market integration and are widely used in regional policy analysis (BBSR, 2021). Award data were obtained from official documentation by the Federal Ministry of Education and Research (BMBF, 2015) and the Independent Commission for the Evaluation of the Excellence Initiative (IEKE, 2016). An ROR was classified as treated if at least one major institution within the ROR received policy funding under the relevant initiative.

Figure 1 illustrates the funding landscape of German planning regions for both policy programs. Southern and western parts of Germany substantially benefited from both policy programs, whereas northern and eastern German states were funded rather selectively (e.g., Hamburg, Berlin, Thuringia, and Saxony). As shown in Fig. 1, most funded regions, whether receiving a policy mix or a single policy, already had a historically strong industrial base (e.g., North Rhine-Westphalia, Baden-Württemberg, the metropolitan area of Munich, and the region around Wiesbaden and Mainz).

4.1 Variables and measurement

4.1.1 Dependent variables

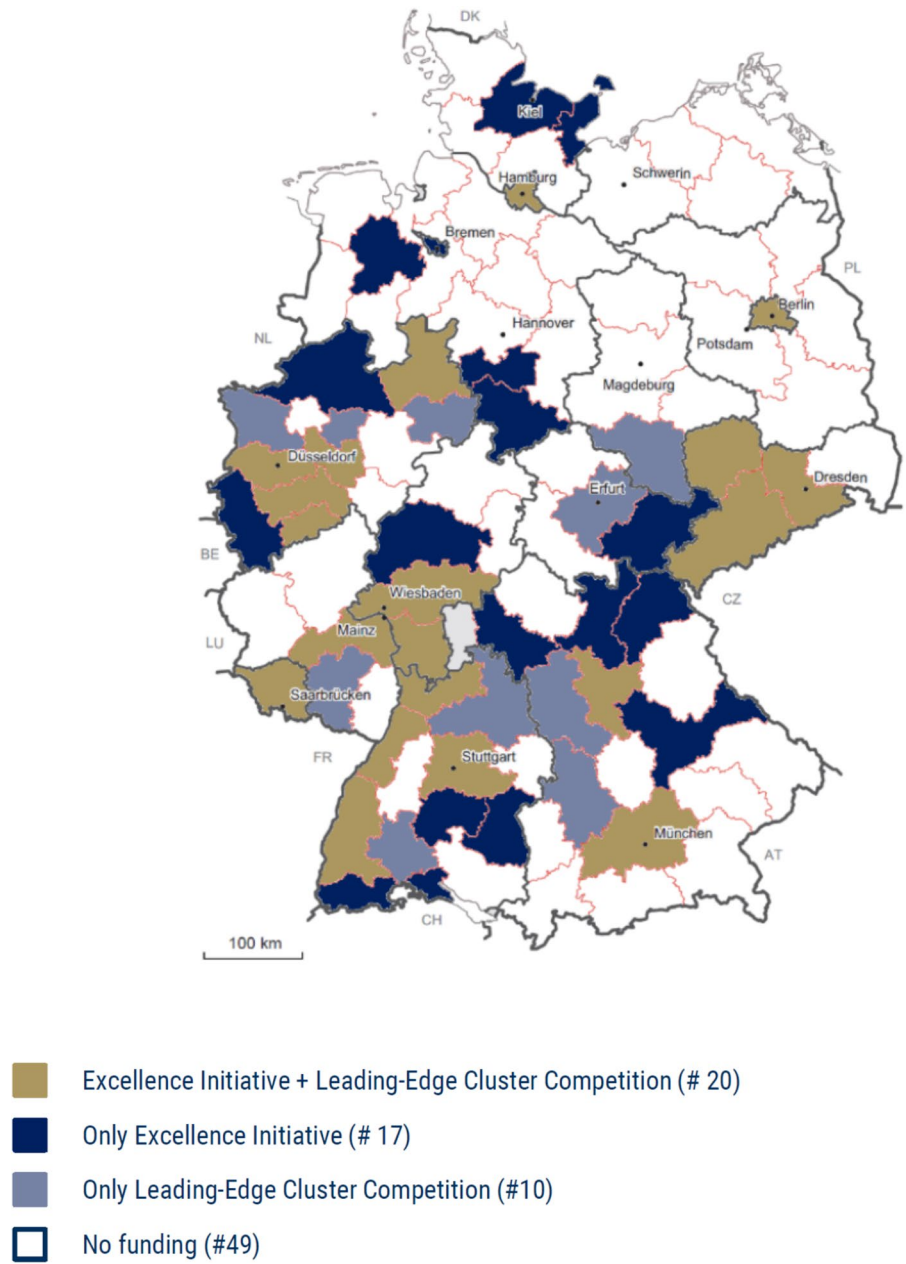
According to several definitions, entrepreneurship can take various forms in different contexts, from low-tech and main street ventures to innovative start-ups (Audretsch et al., 2021a, b). We therefore apply three distinct measures of entrepreneurship. First is the overall number of new businesses registered annually (per 10,000 employees), a general but well-established measure of entrepreneurial activity in each region (*regional entrepreneurship*). Second is the number of registered high-tech start-ups in the private sector (per 10,000 employees), a measure more closely related to technology-based entrepreneurship (*regional high-tech entrepreneurship*).³ Third, the number of filed patents (per 10,000 employees) serves as a measure of regional innovative activity (*regional innovation*) and the regional capacity to develop new markets, technologies, businesses, and service innovations (e.g., Katila, 2000; Low & Isserman, 2015).

¹ RORs are the areas into which the territory of the Federal Republic of Germany is divided for regional planning purposes. There are 96 spatial planning regions, of which the demarcation is country-specific. Consequently, RORs represent the observation and analysis framework for federal spatial planning (see BBSR, 2021).

² Due to data limitations, our dependent variable, “regional high-tech entrepreneurship,” is restricted to an end date of 2014.

³ The classification of high-tech start-ups is based on the definition of Legler and Frietsch (2006), as used by the Institute for Employment Research (IAB).

Fig. 1 Funding landscape of German planning regions



4.1.2 Independent variables

Following Angrist and Pischke (2009), we examine the impact of the two policy interventions as treatment effects, estimating the change in outcomes before and after our treatments (first difference) versus the control group (second difference) by introducing time and group effects that capture these differences. The dummy variable *treatment period*

differentiates the pre-treatment period (before 2007) from the post-treatment period (after 2007), taking the value 1 for the post-treatment period (2007–2016) and 0 otherwise. The dummy variable *treatment group* takes the value 1 if a region received funding from a policy and 0 otherwise. A value of 1 represents a region in our treatment group; a value of 0 depicts a region in our control group. We consider four comparisons: (1) regions funded only by the Excellence

Initiative (treatment group) compared with regions that received no funding (control group), (2) regions funded only by the Leading-Edge Cluster Competition (treatment group) compared with regions that received no funding (control group), (3) regions funded by both policies (treatment group) compared with regions funded only by the Excellence Initiative (control group), and (4) regions funded by both policies (treatment group) compared with regions funded only by the Leading-Edge Cluster Competition (control group). To assess these policy impacts using the difference-in-differences estimate, we interact the two dummy variables *treatment period* and *treatment group*. This interaction term captures the treatment effect, our main variable of interest.

4.1.3 Control variables

Several variables are included to capture regional heterogeneity and reduce variance caused by factors other than our explanatory variables. First, as demonstrated by previous studies, variability in regional financial capacities may at least partially explain the varying performance of German regions, as a fluid financial sector is a prerequisite for knowledge-intensive activities and high-tech entrepreneurship (e.g., Audretsch & Keilbach, 2007; Huggins et al., 2018). We therefore include gross value added per workforce in the financial industry (*regional financial capacity*) as a proxy for the availability of financial resources, including access to venture financing and R&D investments. While it primarily reflects sector productivity, it also captures capital circulation and access to external financing within the regional economy. Second, following evidence from the KSTE, we control for the level of knowledge creation and spillovers within each region. To do this, we consider the research potential of a university within a region (Audretsch et al., 2005), measured by the number of academic research fellows per professor (*university research focus*). In addition, we capture the intensity of university–industry collaborations as an indicator of a region’s capacity for technology transfer (Cunningham & Menter, 2021; Lehmann & Menter, 2016), measured by the net amount of third-party funding per professor (*university industry focus*). We further control for the absorption of created knowledge spillovers. Tacit knowledge only spills over short distances, known as the word-of-mouth radius (see Audretsch & Lehmann, 2005a). Thus, we assume that agglomeration

effects lower the costs of transmitting and absorbing tacit knowledge by increasing the likelihood of matching relevant partners. The quality of local knowledge spillover infrastructure (see Audretsch et al., 2015; Audretsch & Belitski, 2023; Audretsch & Lehmann, 2016) is measured by agglomeration effects, namely the number of citizens per square kilometer (*regional density*). Next, we control for the level of regional human capital (e.g., Colombo & Piva, 2020) by including the number of students per region to capture size effects (*students*). Finally, an East–West dummy variable (*east*) is included to account for the long-lasting effects of Germany’s political history (see Fritsch, 2004). The summary of descriptive statistics in Table 1 provides an overview of all variables used, their measurement, and corresponding sources, highlighting the unequal distribution across German regions.

4.2 Descriptive statistics and methodological approach

To examine potential changes caused by the two policy interventions, we first conduct one-way analyses of variance (ANOVA) and Bonferroni tests for multiple comparisons before (see Table 2) and after (see Table 3) policy implementation. The comparisons reveal a decline in innovative entrepreneurship (across all operationalizations) over time, regardless of the type of regional funding. Before policy implementation, non-funded regions exhibited the highest levels of innovative entrepreneurial activity (for both regional entrepreneurship and regional high-tech entrepreneurship). By contrast, after implementation, dual-funded regions appear to both exhibit more innovative entrepreneurs on average than all other types of regions and represent the most innovative regions.

The correlation matrix (see Table 4) shows the expected bivariate relationships, such as the effect of regional density on entrepreneurial activities and regional innovation activities, as well as the association between higher university–industry engagement and research impact within the region.

We find robust evidence that the parallel trends assumption is satisfied in our setting: the graphs show parallel curves (see Appendix 1 for a visual confirmation). Both the treatment and control groups follow the same trend, and treatment and econometric tests further support the parallel trends assumption. No statistically significant differences in trends were

Table 1 Descriptive statistics

Variable	Obs.	Mean	Std. Dev.	Min.	Max.	Description/source
Regional entrepreneurship (abs.)	1694	7.322	6.181	0.663	61.319	Number of newly registered businesses in the private sector (manufacturing, services, construction) per 10,000 employees. Source: German Federal Statistical Office, German Start-up Compendium
Regional high-tech entrepreneurship (abs.)	1614	0.094	0.171	0.001	2.789	Number of high-tech start-ups in the private sector per 10,000 employees. Source: German Federal Statistical Office, Institute for Employment Research (IAB)
Regional innovation (abs.)	1713	28.07	43.59	0.175	291.67	Number of filed patents per 10,000 employees. Source: OECD REGPAT 2018, German Federal Statistical Office
Regional density	1792	329.57	489.95	40.94	3981	Number of citizens per square kilometer. Source: German Federal Statistical Office
Regional financial capacity	1636	91,747	17,163	51,030	142,904	Gross value added per workforce in the financial industry. Source: German Federal Statistical Office
Students	1704	23,417	26,381	15	174,973	Number of students. Source: German Federal Statistical Office
University research focus	1694	5.979	2.386	1	13.99	Number of research fellows per professor. Source: German Federal Statistical Office
University industry focus (abs.)	1611	19.833	17.978	0	125.642	Amount of third-party funding per professor (in 1,000 EUR). Source: German Federal Statistical Office
East	1824	0.229	0.420	0	1	Dummy variable (East = 1; West = 0)

This table reports descriptive data for 96 German planning regions (RORs) observed from 1998 to 2014/2016

observed for the treatment and control groups before the treatment event, satisfying the parallel trends assumption.

Based on our classification of German planning regions, we run four estimation models for our three dependent variables—*regional entrepreneurship*, *regional high-tech entrepreneurship*, and *regional innovation*.⁴ (1) Model I/V/IX analyzes the effectiveness of the Excellence Initiative, comparing regions funded solely by the Excellence Initiative with regions that received no funding. (2) Model II/VI/X

examines the effectiveness of the Leading-Edge Cluster Competition, comparing regions funded solely by the Leading-Edge Cluster Competition with regions that received no funding. (3) Model III/VII/XI investigates the complementary relationship between the Excellence Initiative and the Leading-Edge Cluster Competition by comparing dual-funded regions with regions funded solely by the Excellence Initiative. (4) Model IV/VIII/XII investigates the complementary relationship between the Excellence Initiative and the Leading-Edge Cluster Competition by comparing dual-funded regions with regions funded solely by the Leading-Edge Cluster Competition. We employ the following estimation model:

$$\begin{aligned}
 Y_{rt} = & \beta_0 + \beta_1 \text{Treatment group}_r + \beta_2 \text{Treatment period}_{rt} \\
 & + \beta_3 \text{Treatment period}_{rt} \times \text{Treatment group}_r \\
 & + \beta_4 X_{rt-1} + \beta_5 Z_{rt-1} + \varepsilon_{rt}
 \end{aligned}$$

⁴ Our focus was on analyzing the policy mix and its added effect in regions exposed to a single policy, particularly in terms of cross-fertilization effects due to the policy mix. Given this objective, a direct comparison with non-funded regions was not our primary research focus. Instead, we specifically examined how the combination of policies amplifies knowledge spillover effects beyond those observed in regions with only one policy in place.

Table 2 One-way analyses of variance (ANOVA): before treatment

Variable	Type of funding	Summary			Comparison of means		
		Mean	Std. Dev.	Freq.	(1)	(2)	(3)
Regional entrepreneurship (abs.)	None (1)	9.755	6.674	384	-		
	Leading-Edge Cluster Competition (2)	6.767	3.194	88	-2.989***	-	
	Excellence Initiative (3)	7.842	5.085	151	-1.913**	1.076	-
	Both (4)	9.837	10.512	171	0.082	3.071***	1.995*
	<i>Total</i>	<i>9.078</i>	<i>7.242</i>	<i>794</i>			
Regional high-tech entrepreneurship (abs.)	None (1)	0.162	0.271	429	-		
	Leading-Edge Cluster Competition (2)	0.097	0.109	88	-0.065*	-	
	Excellence Initiative (3)	0.115	0.159	151	-0.047	0.018	-
	Both (4)	0.141	0.175	180	-0.021	0.044	0.026
	<i>Total</i>	<i>0.142</i>	<i>0.223</i>	<i>848</i>			
Regional innovation (abs.)	None (1)	10.404	11.259	384	-		
	Leading-Edge Cluster Competition (2)	16.115	7.388	88	5.712	-	
	Excellence Initiative (3)	25.560	14.989	151	15.156***	9.444	-
	Both (4)	85.336	73.964	180	74.933***	69.221***	59.777***
	<i>Total</i>	<i>30.676</i>	<i>47.170</i>	<i>803</i>			
Regional density	None (1)	162.0	150.3	415	-		
	Leading-Edge Cluster Competition (2)	332.1	323.8	90	170.1***	-	
	Excellence Initiative (3)	304.3	362.9	147	142.3***	-27.814	-
	Both (4)	752.9	809.4	180	590.9***	420.8***	448.6***
	<i>Total</i>	<i>333.4</i>	<i>489.6</i>	<i>832</i>			
Regional financial capacity	None (1)	91,679	18,309	343	-		
	Leading-Edge Cluster Competition (2)	86,970	18,778	70	-4709	-	
	Excellence Initiative (3)	91,984	15,336	119	305	5014	-
	Both (4)	91,614	17,238	144	-65	4644	-370
	<i>Total</i>	<i>91,231</i>	<i>17,666</i>	<i>676</i>			
Students	None (1)	6772	6299	379	-		
	Leading-Edge Cluster Competition (2)	15,815	11,344	90	9043***	-	
	Excellence Initiative (3)	23,464	13,339	153	16,693***	7650***	-
	Both (4)	50,184	28,861	180	43,411***	34,368***	26,719***
	<i>Total</i>	<i>20,715</i>	<i>23,328</i>	<i>802</i>			
University research focus	None (1)	4.171	2.012	371	-		
	Leading-Edge Cluster Competition (2)	4.851	1.335	90	0.680***	-	
	Excellence Initiative (3)	6.767	1.158	153	2.596***	1.916***	-
	Both (4)	6.573	1.371	180	2.402***	1.722***	-0.194
	<i>Total</i>	<i>5.292</i>	<i>2.043</i>	<i>794</i>			

Table 2 (continued)

Variable	Type of funding	Summary			Comparison of means		
		Mean	Std. Dev.	Freq.	(1)	(2)	(3)
University industry focus (abs.)	None (1)	8.220	9.072	320	-		
	Leading-Edge Cluster Competition (2)	11.636	9.832	89	3.416	-	
	Excellence Initiative (3)	25.793	18.678	152	17.573***	14.156***	-
	Both (4)	25.310	13.978	179	17.090***	13.673***	-0.483
	<i>Total</i>	<i>16.374</i>	<i>15.312</i>	<i>740</i>			

This table reports mean comparisons for our variables of interest before the implementation of the two investigated policy interventions (pre-treatment period, 1998 to 2006), based on our classification of German planning regions (RORs): (1) RORs funded by neither the Excellence Initiative nor the Leading-Edge Cluster Competition (49 RORs in total); (2) RORs funded solely by the Leading-Edge Cluster Competition (10 RORs); (3) RORs funded solely by the Excellence Initiative (17 RORs); and (4) RORs funded by both the Excellence Initiative and the Leading-Edge Cluster Competition (20 RORs). Asterisks *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively

where Y_{rt} represents the innovative entrepreneurship activity in region r at time t . The coefficient β_1 signifies the mean difference between the treatment and control groups before policy intervention(s). The coefficient β_2 refers to the mean difference before and after policy intervention(s) for the control group. Finally, the coefficient β_3 represents the difference-in-differences between the treatment and control groups after policy intervention(s), namely, our treatment effect. Vector X_{rt-1} includes lagged region-specific variables, and vector Z_{rt-1} represents lagged university-specific variables. As always, ε_{rt} represents the error term. We derive the logarithm for the following variables: *regional entrepreneurship*, *regional high-tech entrepreneurship*, *regional innovation*, and *university industry focus* to stabilize variance and reduce the influence of outliers. We apply a lag structure to the control variables in our estimation models to account for time effects for policy instruments to materialize, as we do not expect immediate policy impacts on actual outcomes—especially in the context of innovative entrepreneurship.

5 Empirical results

Our first two hypotheses, H1 and H2, assume that the Excellence Initiative (H1) and the Leading-Edge Cluster Competition (H2) each increase levels of innovative entrepreneurship. Hypothesis 3 then proposes that both policy initiatives together lead to higher levels of

innovative entrepreneurship compared with regions receiving a single subsidy. As described above, to capture heterogeneity in innovative entrepreneurship, three distinct measures are applied: (1) regional entrepreneurship, (2) regional high-tech entrepreneurship, and (3) regional innovation.

5.1 The policy mix effect on regional entrepreneurship

First, we observe a negative overall trend in entrepreneurship in Germany during the observed period (see Appendix 1). Innovative entrepreneurship, whether measured as new business formation or as high-tech entrepreneurship, declines over the lengthy observation period. In light of the overwhelming success of the entrepreneurial wave in the USA, entrepreneurship and new venture creation have become leading approaches for policymakers seeking to strengthen regional competitiveness and social welfare. However, in Germany, an increasing trend for fostering entrepreneurship could not be observed; we instead observed the opposite pattern. Second, during the short period between 1997 and 2000—the years in which the new stock market segment “Neuer Markt” was created to foster access to equity capital for new ventures and exit options for investors—a peak in new firm creation can be observed (Audretsch & Lehmann, 2008). Nevertheless, this window of opportunity led to adverse selection effects, resulting in the breakdown of this stock market segment and a strong reluctance to found

Table 3 One-way analyses of variance (ANOVA): after treatment

Variable	Type of funding	Summary			Comparison of means		
		Mean	Std. Dev.	Freq.	(1)	(2)	(3)
Regional entrepreneurship (abs.)	None (1)	5.866	3.471	440	-		
	Leading-Edge Cluster Competition (2)	4.259	1.955	100	-1.607***	-	
	Excellence Initiative (3)	5.346	3.776	170	-0.520	1.087	-
	Both (4)	6.737	7.263	190	0.872	2.478***	1.391**
	<i>Total</i>	<i>5.773</i>	<i>4.535</i>	<i>900</i>			
Regional high-tech entrepreneurship (abs.)	None (1)	0.042	0.044	390	-		
	Leading-Edge Cluster Competition (2)	0.031	0.018	80	-0.011*	-	
	Excellence Initiative (3)	0.035	0.024	136	-0.008	0.004	-
	Both (4)	0.048	0.033	160	0.006	0.017***	0.014***
	<i>Total</i>	<i>0.041</i>	<i>0.037</i>	<i>766</i>			
Regional innovation (abs.)	None (1)	8.972	9.552	440	-		
	Leading-Edge Cluster Competition (2)	14.869	7.258	100	5.897	-	
	Excellence Initiative (3)	21.283	12.635	170	12.311***	6.414	-
	Both (4)	71.986	64.145	200	63.014***	57.117***	50.703***
	<i>Total</i>	<i>25.769</i>	<i>40.045</i>	<i>910</i>			
Regional density	None (1)	156.8	140.7	490	-		
	Leading-Edge Cluster Competition (2)	324.2	315.0	100	167.4***	-	
	Excellence Initiative (3)	302.2	361.4	170	145.4***	-21.984	-
	Both (4)	762.9	829.3	200	606.1***	438.7***	460.7***
	<i>Total</i>	<i>326.2</i>	<i>490.5</i>	<i>960</i>			
Regional financial capacity	None (1)	92,874	17,563	490	-		
	Leading-Edge Cluster Competition (2)	87,233	16,895	100	-5641**	-	
	Excellence Initiative (3)	93,007	13,646	170	132	5774**	-
	Both (4)	91,917	16,965	200	-957	4684	-1090
	<i>Total</i>	<i>92,111</i>	<i>16,800</i>	<i>960</i>			
Students	None (1)	8,919	8,301	432	-		
	Leading-Edge Cluster Competition (2)	20,231	13,875	100	11,312***	-	
	Excellence Initiative (3)	28,989	16,043	170	20,069***	8758***	-
	Both (4)	62,427	35,427	200	53,507***	42,196***	33,438***
	<i>Total</i>	<i>25,820</i>	<i>28,625</i>	<i>902</i>			
University research focus	None (1)	5.019	2.093	430	-		
	Leading-Edge Cluster Competition (2)	6.460	1.792	100	1.441***	-	
	Excellence Initiative (3)	8.459	1.483	170	3.439***	1.999***	-
	Both (4)	8.421	1.913	200	3.402***	1.961***	-0.038
	<i>Total</i>	<i>6.585</i>	<i>2.501</i>	<i>900</i>			

Table 3 (continued)

Variable	Type of funding	Summary			Comparison of means		
		Mean	Std. Dev.	Freq.	(1)	(2)	(3)
University industry focus (abs.)	None (1)	12.143	12.983	401	-		
	Leading-Edge Cluster Competition (2)	20.766	15.306	100	8.623***	-	
	Excellence Initiative (3)	36.000	22.020	170	23.857***	15.235***	-
	Both (4)	33.840	17.104	200	21.697***	13.074***	-2.160
	<i>Total</i>	<i>22.771</i>	<i>19.498</i>	<i>871</i>			

This table reports mean comparisons for our variables of interest after the implementation of the two investigated policy interventions (post-treatment period, 2007 to 2014/2016) based on our classification of German planning regions (RORs): (1) RORs funded by neither the Excellence Initiative nor the Leading-Edge Cluster Competition (49 RORs in total); (2) RORs funded solely by the Leading-Edge Cluster Competition (10 RORs); (3) RORs funded solely by the Excellence Initiative (17 RORs); and (4) RORs funded by both the Excellence Initiative and the Leading-Edge Cluster Competition (20 RORs). Asterisks *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively

and invest in new companies (Audretsch & Lehmann, 2005b). The declining trend over the whole period must be considered when presenting and interpreting our statistical results.

Our first empirical results show a positive policy effect for single-funded regions on *regional entrepreneurship*. We find support for all three hypotheses (see Table 5): the Excellence Initiative (H1), the Leading-Edge Cluster Competition (H2), and the policy mix (H3) foster regional entrepreneurship. Model I and Model II demonstrate that, in regions that received funding from either of the two policy initiatives, the number of new businesses per capita declines to a lesser extent than in non-funded regions. This pattern is reflected in the positive and statistically significant interaction terms, that is, our treatment effect coefficients, for Model I ($\beta=0.134$; $p<0.01$) and Model II ($\beta=0.0871$; $p<0.01$). We can therefore confirm H1 and H2. Based on the reported treatment effect sizes, we can conclude that the policy effect for regions funded by the Excellence Initiative is approximately -8% ($-0.216+0.134=-0.082$). Regions funded by the Excellence Initiative thus experience a decline of only 8% in new business registrations, compared with a decrease of approximately 22% of the initial value in non-funded regions. The overall policy effect for the Leading-Edge Cluster Competition is smaller but evident: in these regions, new business registrations per capita decrease by approximately 13%, compared with a decrease of approximately 22% in non-funded regions.

We also find empirical support for H3, our policy mix argument. The positive and highly significant interaction terms—our treatment effect coefficients—reported in Model III ($\beta=0.0446$; $p<0.05$) and Model IV ($\beta=0.0746$; $p<0.01$) indicate an “added value” for dual-funded regions. Regions supported by both the Excellence Initiative and the Leading-Edge Cluster Competition therefore exhibit higher levels of regional entrepreneurship activity than regions funded solely by a single-policy program. The overall “added value” of the policy mix amounts to approximately 4.5% in Model III and 7.5% in Model IV. This indicates that dual-funded regions benefit and report declines of nearly 9% (Model III, $-0.133+0.0446=-0.0884$) and 10% (Model IV, $-0.176+0.0746=-0.101$) in new business registrations per capita. During the same period, single-funded regions face an average decline of approximately 13% (Model III, $\beta=-0.133$) and approximately 18% in new business registrations (Model IV, $\beta=-0.176$).

We thus conclude that not only the policy mix but also each policy treatment positively affects the number of newly registered businesses per capita. Despite the general decline in regional entrepreneurship activity across all regions over time, as indicated by the negative and highly significant coefficient for the variable *treatment period*, the policy interventions induce a compensatory effect. Consequently, single-funded and dual-funded regions experience a smaller decline in regional entrepreneurship activity than non-funded and single-funded regions, respectively.

Table 4 Correlation matrix

		1	2	3	4	5	6	7	8
1	Regional high-tech entrepreneurship	1							
2	Regional entrepreneurship	0.443	1						
3	Regional innovation	-0.054	-0.130	1					
4	Regional density	0.086	0.361	0.469	1				
5	Regional financial capacity	-0.055	-0.254	0.206	-0.014	1			
6	Students	-0.007	0.009	0.664	0.685	0.017	1		
7	University research focus	-0.098	-0.164	0.398	0.148	-0.083	0.476	1	
8	University industry focus	-0.083	-0.077	0.394	0.194	-0.077	0.479	0.687	1

This table reports the correlation coefficients among the dependent and independent variables employed in our regressions

5.2 The policy mix effect on regional high-tech entrepreneurship

We can also confirm H1 and H2 with respect to our measure for *regional high-tech entrepreneurship*. The coefficients for the interaction terms between *treatment*

group and *treatment period* in Models V and VI, presented in Table 6, are positive and statistically significant. Regions that receive funding from the Excellence Initiative ($\beta=0.137$; $p<0.01$) or from the Leading-Edge Cluster Competition ($\beta=0.0148$; $p<0.01$) report higher rates of new high-tech start-ups per capita than

Table 5 Difference-in-differences models estimating regional entrepreneurship

This table reports the results of our difference-in-differences estimation. We rely on a sample of data from 96 German planning regions (RORs) from 1998 to 2016. The dependent variable is regional entrepreneurship, measured as the logarithm of the number of start-ups in the private sector (manufacturing, services, construction) per 10,000 employees. Standard errors are reported in parentheses. Asterisks *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively. See Appendix 2 for the baseline model

ExIn Excellence Initiative, *LECC* Leading-Edge Cluster Competition

	Model I (<i>ExIn</i> vs. <i>None</i>)	Model II (<i>LECC</i> vs. <i>None</i>)	Model III (<i>Both</i> vs. <i>ExIn</i>)	Model IV (<i>Both</i> vs. <i>LECC</i>)
Public policy				
Treatment group	0.245* (0.134)	-0.174 (0.161)	-0.172 (0.121)	0.125 (0.139)
Treatment period	-0.216*** (0.0136)	-0.218*** (0.0145)	-0.133*** (0.0159)	-0.176*** (0.0208)
Treatment group x Treatment period	0.134*** (0.0214)	0.0871*** (0.0267)	0.0446** (0.0182)	0.0746*** (0.0221)
Region				
L.Density	0.001*** (0.000)	0.001*** (0.000)	0.001*** (0.000)	0.001*** (0.000)
L.Financial capacity	-4.648*** (0.966)	-5.734*** (1.094)	-4.311*** (0.931)	-6.964*** (1.110)
L.East	0.292** (0.138)	0.280** (0.139)	0.0562 (0.171)	0.0750 (0.160)
University				
L.Students	-0.000*** (0.000)	-0.000*** (0.000)	-0.000*** (0.000)	-0.000*** (0.000)
L.Research focus	-0.0634*** (0.00649)	-0.0691*** (0.00787)	-0.0432*** (0.00571)	-0.0489*** (0.00708)
L.Industry focus	-0.0296*** (0.00992)	-0.0161 (0.0106)	-0.0807*** (0.0129)	-0.0434*** (0.0150)
<i>N</i>	880	769	579	468
<i>n</i>	60	53	36	29
<i>R</i> ²	0.26	0.22	0.59	0.58

non-funded regions. In particular, while non-funded regions face a decline of approximately 4% in new high-tech start-ups per capita between the pre- and post-treatment periods, regions supported either by the Excellence Initiative (Model V, $-0.0388 + 0.0137 = -0.0243$) or by the Leading-Edge Cluster Competition (Model VI, $-0.039 + 0.0148 = -0.024$) decline by only approximately 2.4% during that period.

However, when considering the policy mix results, this rather positive picture diminishes. The coefficients of the interaction term in Models VII and VIII demonstrate that there is no “added value” for regions awarded funding from both policies. Instead, dual-funded regions exhibit lower levels of regional high-tech entrepreneurship than regions funded solely by a single-policy initiative. The interaction terms, our treatment effect coefficients, for Model VII ($\beta = -0.0109$; $p < 0.1$) and Model VIII ($\beta = -0.0161$; $p < 0.05$) are both negative and statistically significant. Therefore, we must reject H3 for regional high-tech entrepreneurship: funding through both initiatives does not lead to higher levels of regional high-tech entrepreneurship. This indicates that the desired synergistic effects of the policy mix cannot be achieved and may even disadvantage dual-funded regions. Compared with the pre-treatment period, dual-funded regions report a decline of approximately 4% in new high-tech start-ups per capita (Model VII, $-0.026 - 0.0109 = -0.037$; Model VIII, $-0.022 - 0.0161 = -0.0381$). In contrast, during the same period, single-funded regions in our dataset decline by only 2.6% (Model VII, $\beta = -0.0261$; $p < 0.01$) and 2.2% (Model VIII, $\beta = -0.0220$; $p < 0.01$), respectively.

We thus conclude that each individual policy treatment positively affects the number of high-tech start-ups per capita. Despite the general decline in regional high-tech entrepreneurship activity across all regions over time, as indicated by the negative and highly significant coefficient for the variable *treatment period*, the policy interventions induce a compensatory effect. Single-funded regions experience a smaller decline in regional high-tech entrepreneurship activity than non-funded regions, whereas dual-funded regions do not benefit from the policy mix and instead experience a larger decline in high-tech start-ups compared with single-funded regions.

5.3 The policy mix effect on regional innovation

Considering the estimation models for *regional innovation* as an outcome variable, we find no evidence that either policy has a statistically significant effect on patent activity in any region (see Table 7). Neither the regions funded solely by the Excellence Initiative (Model IX) nor those funded solely by the Leading-Edge Cluster Competition (Model X) show increased levels of regional innovation compared with regions funded by neither policy. We thus reject H1 and H2 with respect to regional innovation.

Although we do not find any statistically significant evidence for a “single-policy effect,” the estimations for the policy mix reveal an interesting picture. As shown by the positive and significant interaction term, our treatment effect coefficient, in Model XI ($\beta = 0.103$; $p < 0.05$), the policy mix appears to provide an “added value” for regional innovation. Regions funded by both policy initiatives thus exhibit an increase in the number of patent applications per capita compared with regions funded solely by the Excellence Initiative. While we do not find statistically significant evidence for Model XII, the direction and positive sign of the interaction terms in both models (Models XI and XII) suggest that—in contrast to regional high-tech entrepreneurship activities—a complementary mix of policies does impact regional innovation as measured by patent applications per capita.

Despite the general decline in regional innovation activity across all regions over time, the policy interventions induce a compensatory effect. Dual-funded regions benefit from the policy mix compared with other regions—their decline in regional innovation is smaller compared with the control groups of single-funded regions.

6 Discussion

The two policy programs were designed and initiated during a period of generally declining entrepreneurial activity in Germany. Our findings present a mixed but interesting empirical picture. We identify a positive effect of the policy mix on regional entrepreneurship, as dual-funded regions exhibit higher levels of new business registrations per capita than single-funded regions. We find support for the “added value” of the policy mix on new venture creation more generally.

Table 6 Difference-in-differences models estimating regional high-tech entrepreneurship

	Model V (<i>ExIn</i> vs. <i>None</i>)	Model VI (<i>LECC</i> vs. <i>None</i>)	Model VII (<i>Both</i> vs. <i>ExIn</i>)	Model VIII (<i>Both</i> vs. <i>LECC</i>)
Public policy				
Treatment group	0.00975 (0.0104)	-0.0158 (0.0103)	0.00546 (0.00976)	0.0260** (0.0109)
Treatment period	-0.0388*** (0.00255)	-0.0390*** (0.00259)	-0.0261*** (0.00521)	-0.0220*** (0.00694)
Treatment group x Treatment period	0.0137*** (0.00419)	0.0148*** (0.00509)	-0.0109* (0.00627)	-0.0161** (0.00792)
Region				
L.Density	0.000 (0.000)	0.000** (0.000)	0.000*** (0.000)	0.000*** (0.000)
L.Financial capacity	-0.416** (0.188)	-0.679*** (0.206)	0.207 (0.255)	-0.0462 (0.285)
L.East	0.00235 (0.0112)	-0.00112 (0.0111)	0.0451*** (0.0146)	0.0325** (0.0136)
University				
L.Students	-0.000*** (0.000)	-0.000*** (0.000)	-0.000 (0.000)	-0.000 (0.000)
L.Research focus	-0.00266** (0.00125)	-0.000659 (0.00144)	-0.00265 (0.00180)	-0.00147 (0.00196)
L.Industry focus	-0.000560 (0.00193)	-0.000840 (0.00198)	-0.00356 (0.00391)	-0.00610 (0.00436)
<i>N</i>	763	666	521	424
<i>n</i>	59	52	37	30
<i>R</i> ²	0.22	0.29	0.41	0.50

This table reports the results of our difference-in-differences estimation. We rely on a sample of data from 96 German planning regions (RORs) from 1998 to 2014. The dependent variable is regional high-tech entrepreneurship, measured as the logarithm of the number of high-tech start-ups in the private sector per 10,000 employees. Standard errors are reported in parentheses. Asterisks *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively. See Appendix 3 for the baseline model

ExIn Excellence Initiative, *LECC* Leading-Edge Cluster Competition

However, our results do not show consistently positive effects for the regional development of high-tech start-ups per capita or innovation activity, measured by patent applications per capita. Although the statistical coefficients do not show significant positive effects of the two policies—whether treated individually or as a policy mix—our results show that the adverse and declining trends in the desired variables were mitigated through policies fostering knowledge spillovers and new venture creation, at least in the treated regions. Taking the general trends of declining regional entrepreneurship and innovation as given, several potential explanations may account for the absence of the desired policy mix effect.

In addition to general limitations regarding study design and operationalization, it is possible that the two policy programs simply fail to provide the necessary conditions to establish a regional entrepreneurial ecosystem in which innovative entrepreneurship can flourish. Despite the overall significance of

the policy mix, our analyses did not reveal strong or consistent effects on the formation of high-tech start-ups and patent applications. The absence of consistent positive effects on high-tech start-ups, despite the knowledge-oriented objectives of the policy mix, may reflect a combination of structural and procedural limitations in the policy environment. From a theoretical perspective, these muted effects are consistent with prior work emphasizing misalignments between policy design, implementation, and entrepreneurial outcomes. While both policy programs explicitly target knowledge generation and diffusion, their core funding motivations remain strongly oriented toward research excellence, institutional collaboration, and incumbent-centered innovation structures (Colombelli et al., 2016; Dosi et al., 2006). As a result, policy-induced knowledge spillovers may disproportionately benefit actors that already possess strong organizational routines, complementary assets, and established commercialization capacities.

Table 7 Difference-in-differences models estimating regional innovation

	Model IX	Model X	Model XI	Model XII
	<i>(ExIn vs. None)</i>	<i>(LECC vs. None)</i>	<i>(Both vs. ExIn)</i>	<i>(Both vs. LECC)</i>
Public policy				
Treatment group	1.454*** (0.232)	0.831*** (0.266)	1.246*** (0.243)	1.582*** (0.265)
Treatment period	-0.00619 (0.0268)	-0.0152 (0.0277)	-0.0566 (0.0415)	-0.0210 (0.0518)
Treatment group x Treatment period	-0.0521 (0.0425)	-0.0333 (0.0510)	0.103** (0.0471)	0.0661 (0.0550)
Region				
L.Density	0.000 (0.000)	0.001 (0.001)	0.001*** (0.000)	0.001*** (0.000)
L.Financial capacity	-12.94*** (1.907)	-12.42*** (2.079)	-10.98*** (2.397)	-11.02*** (2.722)
L.East	-1.047*** (0.238)	-0.928*** (0.233)	-1.180*** (0.348)	-1.095*** (0.310)
University				
L.Students	-0.000*** (0.000)	-0.000*** (0.000)	-0.000*** (0.000)	-0.000*** (0.000)
L.Research focus	-0.000852 (0.0128)	0.00499 (0.0150)	-0.0548*** (0.0148)	-0.0754*** (0.0173)
L.Industry focus	-0.00877 (0.0197)	-0.00527 (0.0203)	0.00464 (0.0337)	0.0475 (0.0371)
<i>N</i>	880	769	595	484
<i>n</i>	60	53	37	30
<i>R</i> ²	0.11	0.12	0.12	0.35

This table reports the results of our difference-in-differences estimation. We rely on a sample of data from 96 German planning regions (RORs) from 1998 to 2016. The dependent variable is regional innovation, measured as the logarithm of the number of filed patents per 10,000 employees. Standard errors are reported in parentheses. Asterisks *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively. See Appendix 4 for the baseline model
ExIn Excellence Initiative, *LECC* Leading-Edge Cluster Competition

Moreover, insights from the absorptive capacity and knowledge filter literature suggest that the translation of scientific knowledge into high-tech entrepreneurial activity is subject to substantial time lags and coordination frictions (Acs et al., 2003; Qian & Acs, 2013). High-tech venture creation typically requires not only access to knowledge but also risk capital, prior entrepreneurial experience, regulatory flexibility, and specialized intermediary support organizations. If these ecosystem elements are weakly developed at the regional level, increased knowledge production alone is unlikely to generate immediate surges of innovative start-ups, even in the presence of strong research activity and policy support (Cantner et al., 2021a, b). In this context, our findings align with prior evidence on delayed or muted policy effects in knowledge-intensive entrepreneurship (Braunerhjelm et al., 2018; Delmar et al., 2011). The absence of pronounced high-tech start-up and patent responses should therefore not be interpreted as a failure of knowledge generation per

se but as an indication that the mechanisms translating knowledge spillovers into entrepreneurial outcomes remain structurally constrained.

During the funding selection processes, political considerations and regional lobbying have at times been reported to override meritocratic evaluation principles. Anecdotal evidence from expert evaluations and public critiques during the funding periods indicated that, in several cases, funding was not necessarily awarded to the most innovative or entrepreneurial applications, but instead reflected regional policy interests or existing institutional influence (Mom & Besselaar, 2022). As a result, resources may have disproportionately accrued to incumbent actors or well-established institutions with higher absorptive capacity, thereby reinforcing existing structures rather than enabling transformative entrepreneurial dynamics (Heinze et al., 2025).

Finally, additional factors may operate that could induce the desired spillover effects yet produce different

outcomes (e.g., Braunerhjelm et al., 2018; Delmar et al., 2011). Further investigation is therefore required to clarify the underlying mechanisms of the policy mix and why consistent complementary effects on regional patenting and high-tech start-up activities are not observed. For this reason, we conduct additional post-hoc tests using the same regression approach with the same set of control variables to estimate the effects on dual-funded regions relative to single-funded regions.

6.1 Post-hoc tests and alternative spillover mechanisms

Based on our theoretical framework, we focus on three additional determinants that may affect knowledge spillover entrepreneurship⁵: (1) absorptive capacities, (2) workforce mobility, and (3) intrapreneurship. The results of these post-hoc tests are depicted in Table 8.

First, we examine the influence of regional absorptive capacities, measured by the number of regional R&D employees (see Lund Vinding, 2006; Qian et al., 2013). The literature on regional entrepreneurial ecosystems emphasizes that regionally bounded absorptive capacities are essential prerequisites for absorbing knowledge from R&D and translating it into entrepreneurial activity (e.g., Qian & Acs, 2013). Consequently, insufficient regional absorptive capacities could hinder the exploitation of knowledge spillovers, causing policy programs to fail in generating higher levels of innovative entrepreneurship.

The results of the regression analyses indicate that regions funded by both the Excellence Initiative and the Leading-Edge Cluster Competition exhibit higher levels of absorptive capacities than regions awarded funding by a single-policy initiative, namely either the Excellence Initiative (Post-Hoc I, $\beta=616.4$; $p<0.05$) or the Leading-Edge Cluster Competition (Post-Hoc II, $\beta=380.4$; $p>0.1$). Accordingly, in our empirical setting, a lack of absorptive capacity that “allows entrepreneurs to understand new knowledge, recognize its value, and commercialize it by creating a firm” (Qian & Acs, 2013: 185) does not adequately explain the lack of complementary effects of the policy mix on regional high-tech start-up activity.

Second, we test the role of workforce mobility, measured by the net migration outflow of employees (see

Maliranta et al., 2009; Simonen & McCann, 2008). A large strand in the innovation and entrepreneurship literature highlights the importance of knowledge workers leaving regions to work or start new companies elsewhere (e.g., Braunerhjelm et al., 2018; Campbell et al., 2012; Frederiksen et al., 2016). Our analyses show negative and statistically significant interaction terms—our treatment effect coefficients—for both model specifications (Post-Hoc III, $\beta=-5.113$; $p<0.01$; Post-Hoc IV, $\beta=-1.112$; $p<0.1$), indicating an inflow of employees. Hence, workforce mobility and the associated brain drain within regions do not explain the lack of complementary effects of the policy mix on regional high-tech start-up activity.

Third, we investigate whether internal expansion activities by incumbent firms—approximated by the number of newly established commercial units (e.g., dependent subsidiaries)—may explain our findings. While we acknowledge that this measure does not capture intrapreneurship in the narrow behavioral sense (i.e., entrepreneurial activities by employees within firms), it can be interpreted as a structural outcome indicative of internal innovation or diversification efforts. Such commercial unit growth may reflect firms’ attempts to exploit knowledge spillovers internally rather than through new venture creation. This interpretation aligns with prior research on corporate entrepreneurship and absorptive capacity in incumbent firms (e.g., Antoncic & Hisrich, 2001; Braunerhjelm et al., 2018). Our analyses reveal positive and statistically significant interaction terms—our treatment effect coefficients—for both model specifications (Post-Hoc V: $\beta=3034$; $p<0.01$ and Post-Hoc VI: $\beta=2911$; $p<0.01$).

While entrepreneurship decreased in dual-funded regions, intrapreneurship—entrepreneurial activity driven by large incumbent firms—increased. These findings are consistent with Cantner et al., (2021a, b), who investigated the dynamics of entrepreneurial ecosystems and found an oscillation among entrepreneurs and intrapreneurs. Buratti et al., (2023: 656) empirically confirmed this negative correlation, stating that “an increase in entrepreneurial activities leads to a decrease in intrapreneurial activities, and vice versa.” Incumbent firms, in particular, thus appear to have benefited from the policy mix, which may partly explain the positive and significant effect on patenting activity, primarily undertaken by incumbents.

In sum, both the Excellence Initiative and the Leading-Edge Cluster Competition positively impact regional start-up activity in isolation. However, when

⁵ See Appendix 5 for a detailed description of the variables and further descriptive statistics for the three variables.

Table 8 Post-hoc tests

	<i>Absorptive capacities</i>		<i>Workforce mobility</i>		<i>Intrapreneurship</i>	
	Post-Hoc I	Post-Hoc II	Post-Hoc III	Post-Hoc IV	Post-Hoc V	Post-Hoc VI
	<i>(Both vs. ExIn)</i>	<i>(Both vs. LECC)</i>	<i>(Both vs. ExIn)</i>	<i>(Both vs. LECC)</i>	<i>(Both vs. ExIn)</i>	<i>(Both vs. LECC)</i>
Public policy						
Treatment group	3718 (3108)	1791 (4008)	7.026** (3.487)	1.073 (1.022)	13,729** (6,356)	9316 (7981)
Treatment period	69.88 (223.4)	220.6 (309.2)	5.394*** (1.384)	0.291 (0.548)	2349*** (370.6)	2385*** (511.5)
Treatment group x Treatment period	616.4** (252.4)	380.4 (325.9)	-5.113*** (1.605)	-1.112* (0.608)	3034*** (418.7)	2911*** (539.2)
Region						
L.Density	12.74*** (1.904)	14.13*** (2.185)	-0.00136 (0.00264)	-0.000658 (0.000674)	30.01*** (3.586)	30.46*** (4.024)
L.Financial capacity	-22,378* (12,601)	-50,088*** (16,072)	88.15 (70.05)	110.3*** (23.94)	-33,891 (20,930)	-45,275* (26,596)
L.East	-9032** (4455)	-9195** (4660)	1.298 (5.098)	2.021 (1.258)	-14,257 (9131)	-13,848 (9293)
University						
L.Students	0.0923*** (0.00797)	0.0898*** (0.00932)	-0.000 (4.26e-05)	-0.000** (1.32e-05)	0.161*** (0.0133)	0.169*** (0.0155)
L.Research focus	139.0* (79.24)	205.3** (102.4)	-1.085** (0.465)	-0.0706 (0.156)	289.7** (131.5)	241.6 (169.6)
L.Industry focus	109.0 (176.0)	78.96 (221.2)	1.971* (1.033)	0.168 (0.360)	-222.6 (292.2)	39.09 (366.0)
<i>N</i>	632	514	632	514	632	514
<i>n</i>	37	30	37	30	37	30
<i>R</i> ²	0.29	0.25	0.03	0.17	0.48	0.49

This table reports the results of our post hoc difference-in-differences estimations. The prerequisites to run difference-in-differences regressions are satisfied. Standard errors are reported in parentheses. Asterisks *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively. See Appendix 6 for the baseline model

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jointly implemented within the same region, they help promote higher levels of regional entrepreneurship but not regional high-tech entrepreneurship. One possible explanation for this discrepancy is that promoting knowledge spillover entrepreneurship may require the following conditions: (1) investment in new knowledge facilitated by the Excellence Initiative and (2) spillover mechanisms promoted by the Leading-Edge Cluster Competition. Although each condition is necessary, together they may still be insufficient to enhance innovative entrepreneurship.

Our findings further demonstrate the importance of knowledge spillovers in promoting complementarity and how policy can thus stimulate regional innovation.

We find that neither the Excellence Initiative nor the Leading-Edge Cluster Competition alone contributed to higher levels of regional patent activity. However, joint implementation increased the number of regional patent applications per capita. Furthermore, the findings of our post-hoc tests reveal that the policy mix stimulates intrapreneurship rather than high-tech entrepreneurship, suggesting that incumbent firms “absorb” knowledge spillovers to expand R & D and new business activities.

Such policy outcomes may suggest the presence of crowding-out effects: while the policy mix contributes to increased regional innovation and growth, these positive effects do not primarily materialize through new firm creation and innovative start-ups. Instead, both policies

may establish attractive regional labor markets for highly skilled researchers and engineers, which tend to channel entrepreneurial talent into well-paid corporate positions rather than high-risk new ventures (Colombelli et al., 2016; Stam, 2015). This crowding-out dynamic can be traced to several design and implementation features specific to both the Excellence Initiative and the Leading-Edge Cluster Competition. Both policy programs are primarily organized around large, research-intensive universities, established firms, and formalized collaborative networks. Incumbent organizations are thereby structurally better positioned than nascent entrepreneurial teams to access funding, strategic research infrastructures, and inter-organizational platforms (Audretsch et al., 2019; Cantner et al., 2021a, b).

Consequently, policy-induced knowledge spillovers are more likely to be internally absorbed by established firms, which can exploit these spillovers through corporate R&D, internal venture units, or existing business line expansion. In contrast, start-ups often face higher entry barriers to these networks due to limited absorptive capacity, weaker formal ties to universities, and limited reputational signaling (Acs et al., 2009; Colombelli et al., 2016; Qian & Acs, 2013). This mechanism is consistent with theoretical arguments on policy-induced crowding-out, according to which public support may disproportionately reinforce incumbent-centered innovation trajectories (Aghion et al., 2015; David et al., 2000).

Moreover, both policy instruments tend to strengthen regionally embedded high-skill labor markets, which can unintentionally redirect entrepreneurial talent away from high-risk start-up formation toward well-funded, lower-risk employment opportunities within incumbent firms and large research organizations (Colombelli et al., 2016; Stam, 2015). Accordingly, the policy mix may raise overall regional innovation capacity while simultaneously dampening the relative attractiveness of new venture creation. These mechanisms provide a policy-specific explanation for why dual-funded regions experience increased intrapreneurship and patenting activity, whereas high-tech start-up formation remains comparatively constrained (Audretsch & Belitski, 2021; Mennens et al., 2022).

Our results, though mixed, support the concept of complementarities in several ways, including its application in policy design, particularly in the context of a policy mix. Most crucially, the complementarity of instruments and variables may lead to multiple outcome patterns, but not as a “first best” or “one size fits all”

solution. Instead, non-concavity allows for multiple, distinct coherent points, or local maxima (peaks in the landscape), where each peak may represent a higher level of performance than another. The existence of multiple coherent patterns and local maxima thus leads to the problem of how to identify and reach them.

Decentralized search and experimentation offer one approach. For example, entrepreneurial firms can act as knowledge filters, absorbing the most promising ideas and commercializing them. Alternatively, as our results indicate, intrapreneurship and incumbent firms offer another avenue. In this case, decentralized search and experimentation by market participants—either incumbents, new ventures, or both—will reveal whether improvement is possible, indicating local maxima or the desired outcomes. Market participants will then make incremental changes in the desired direction to improve performance.

Complementarity, however, implies that minor changes do not alter outcomes. Leaving incumbent firms and new ventures to identify improvements on their own can fail to produce desired results. Firms, whether established or new, can be stuck at an inferior but coherent point. Numerous studies have documented poor performance in firms and clusters, even when supported by policies (see Duranton, 2011; Lehmann & Menter, 2018b; Martin et al., 2011; Uyerra & Ramlogan, 2016).⁶ If market participants find themselves at the wrong performance level and become trapped in a local but unsatisfying maximum—where search and experimentation do not enhance performance and leave the local maximum—then complementarity requires large, coordinated changes across all dimensions of choice. If decentralized search and experimentation are insufficient, coordination is needed not only *ex post* but

⁶ The so-called Swedish Paradox could serve as an example. The paradox has emerged in different versions, which share the common basics that Swedish R&D expenditures are high but do not produce sufficient economic results (see Ejerme et al., 2011). The Swedish case forms part of a broader debate on the relationship between R&D and growth at the European Union (EU) level. While the EU’s scientific performance is described as “excellent” compared with that of its principal competitors, Europe’s major weakness lies in its difficulties in transforming research results into innovation and competitive advantage (Dosi et al., 2006). An increase in a single choice variable, such as R&D expenditures, regardless of magnitude, cannot increase performance if other activities do not change as a consequence. Thus, the minimum level remains the same, and overall performance is unchanged.

also during the policy design stage. This requirement means that realizing the best design must be centrally coordinated, with a designated designer, while the new ventures and incumbents making the choices and decisions must communicate intensively. Well-defined and (self-)selected local and regionally bounded clusters could thus provide a perfect solution for search, experimentation, and intensive exchange of experience.

6.2 Limitations

As with all empirical research, our study is subject to limitations. We investigate the impact of two policy instruments on regional (high-tech) entrepreneurship and innovation. Therefore, our measures do not capture all possible dimensions of innovative entrepreneurship affected by policy-induced knowledge spillovers between different regions and clusters. Furthermore, our empirical approach does not control for firm–firm and firm–university networks, nor does it capture the effects of potentially concurrent policy interventions within each region—either at the local or supranational level—that might complement and significantly affect regional (high-tech) entrepreneurship and innovation outcomes. Additional determinants of entrepreneurship, such as labor market dynamics, digital infrastructure, and industry structure, are also not included in our study. In particular, while we interpret the number of new commercial units by incumbent firms as a structural indicator of intrapreneurial activity, we acknowledge that this proxy does not capture the behavioral or processual dimensions typically associated with intrapreneurship. Due to data limitations, we are also unable to capture how much of the awarded funding was invested in the projects and how funds were ultimately spent within universities and clusters. Such information would also allow for the calculation of dosage effects (“bang-for-the-buck”) and the assessment of the “within-program” policy mix, that is, potential interactions between subcomponents of each policy initiative.

Moreover, the staggered implementation of both policy programs presents an additional challenge: while both programs were introduced in 2007, they were rolled out in multiple waves and funding rounds. For instance, the Leading-Edge Cluster Competition distributed funding across three waves, with the second and third rounds starting in 2010 and 2012, respectively. Similarly, the Excellence Initiative followed a multi-phase approach, with different funding lines (e.g.,

graduate schools and excellence clusters) awarded at different points in time. Due to data constraints, we lack detailed information on the precise timing and allocation of funds at the regional level, making it difficult to fully control for dynamic treatment effects. While staggered difference-in-differences models could, in principle, account for policy start date variation, we opted for a pooled difference-in-differences specification. This choice was driven by our central research aim to examine the joint and potentially complementary effects of both policies, rather than marginal treatment effects based on staggered entry. Additionally, the overlapping and partially endogenous rollout of both programs complicates causal identification under staggered difference-in-differences, as treatment timing is not random but likely correlated with unobserved regional characteristics. Our pooled approach thus offers a more robust estimation strategy for understanding policy interaction effects within regional innovation systems.

Finally, the observed time period may be too short to capture long-term effects. For these reasons, it is possible that we underestimated the complementary effects of both the Excellence Initiative and the Leading-Edge Cluster Competition. Gaps in our data could be particularly critical for interpreting the effects of policy on regional innovation. Previous research has shown that (1) patent activity is reasonably constant over time and (2) patenting is a tedious and lengthy process, requiring at least two to three years from initial application to successful grant. Given our model specifications, incorporating a one-year time-lag effect, combined with the relatively short time period of 18 years (including a 10-year treatment period) of our data, the validity of our findings may be limited.⁷ Future research could extend the time horizon to capture longer-term effects and potential structural shifts.

7 Conclusion

In conclusion, inducing higher levels of knowledge spillovers through public policies to foster innovative entrepreneurship and innovation may be necessary but not sufficient. Interpreting our findings through the lens of complementarity theory, they suggest that two

⁷ However, when estimating our models using a 3-year lag structure, we do not observe any significant changes. Time lags thus appear to be substantial in the context of patenting.

distinct types of policy may have substantially different impacts on the development of innovative entrepreneurship. Although both the Excellence Initiative and the Leading-Edge Cluster Competition in isolation promote regional entrepreneurship and regional high-tech entrepreneurship, the combination of both policy instruments produces complementary effects for regional entrepreneurship but not for regional high-tech entrepreneurship. In addition, regional innovation is positively affected only when regions are funded by both initiatives. Furthermore, intrapreneurship is promoted through the policy mix. Accordingly, while both initiatives are vital policies supporting the creation and commercialization of knowledge, they exhibit clear differences in how they affect innovative entrepreneurship.

Our findings suggest that policies intended to ultimately enhance the level of innovation and innovative entrepreneurship should not only focus on knowledge generation but also on the entrepreneurial absorptive capacity of regions. One way to achieve this is by initiating policy programs that consider the prerequisites for innovative entrepreneurship (see Tödting & Trippel, 2005). Our insights resonate with Leyden (2016: 563), who argues that “not all entrepreneurs are the same, and therefore, policy changes in general are likely to have differential effects.” Thus, policy effectiveness requires not only generating knowledge but also ensuring its diffusion, considering the specific context and mechanisms through which knowledge is transferred and absorbed. All these insights should be reflected in institutional policy design and underlying policy elements to effectively shape intended policy outcomes. Our findings thus have important implications for future policymaking; both new start-ups and incumbent firms should be addressed in policies targeting entrepreneurial ecosystems.

A new wave of studies emphasizes that innovative entrepreneurship manifests in ways that are not homogenous across different contexts but are context-specific (see Acs et al., 2018; Autio et al., 2014; Stam, 2015). The results of our study reveal that the same applies to the policy mix for innovative entrepreneurship. The real mechanisms through which a specific policy affects innovative entrepreneurship vary across the different instruments and the context of each policy. Rather than being frustrated by the search for a universal determination on whether public policies work in general, future research may be better served by recognizing and incorporating the plethora of policy instruments that

influence the effectiveness of any specific policy instrument within its particular context. Thus, the relevant question is not whether public policy works. Instead, researchers must ask the following three questions: (1) Which specific type of policy instrument stimulates innovation and innovative entrepreneurship in which context? (2) How do different policy instruments work together? and (3) What is the return on investment? We thus call for further studies investigating the impact of policy mixes tailored to specific types of policies and policy contexts, as proposed by Rocha and Sternberg (2005: 289) more than two decades ago: “Clusters and entrepreneurship policies should be designed together, rather than in an isolated fashion.”⁸ The interplay between national and supranational policy programs might offer a promising starting point, as only well-coordinated initiatives are likely to generate synergistic outcomes. Investigating the announcement effects of policy measures further constitutes a promising future avenue of research. Finally, our results strongly call for considering intrapreneurship and associated intrapreneurial activities when analyzing the effectiveness and efficiency of entrepreneurship policies. Future research should thus include intrapreneurship to capture the holistic effect of innovative entrepreneurship policy.

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Data availability The data used in this study is available upon request from the corresponding author.

Declarations

Ethical approval This research does not involve human participants, animals, or sensitive personal data and therefore does not require ethical approval.

Conflict of interest The authors declare no competing interests.

⁸ We would also like to add that this applies not only to clusters but to all types of regional agglomeration policies, such as ecosystems in a more recent contexts (see Audretsch et al., 2019; Rocha & Audretsch, 2022; Wang et al., 2023).

Appendix

Figure 2 and Tables 9, 10, 11, 12, 13.

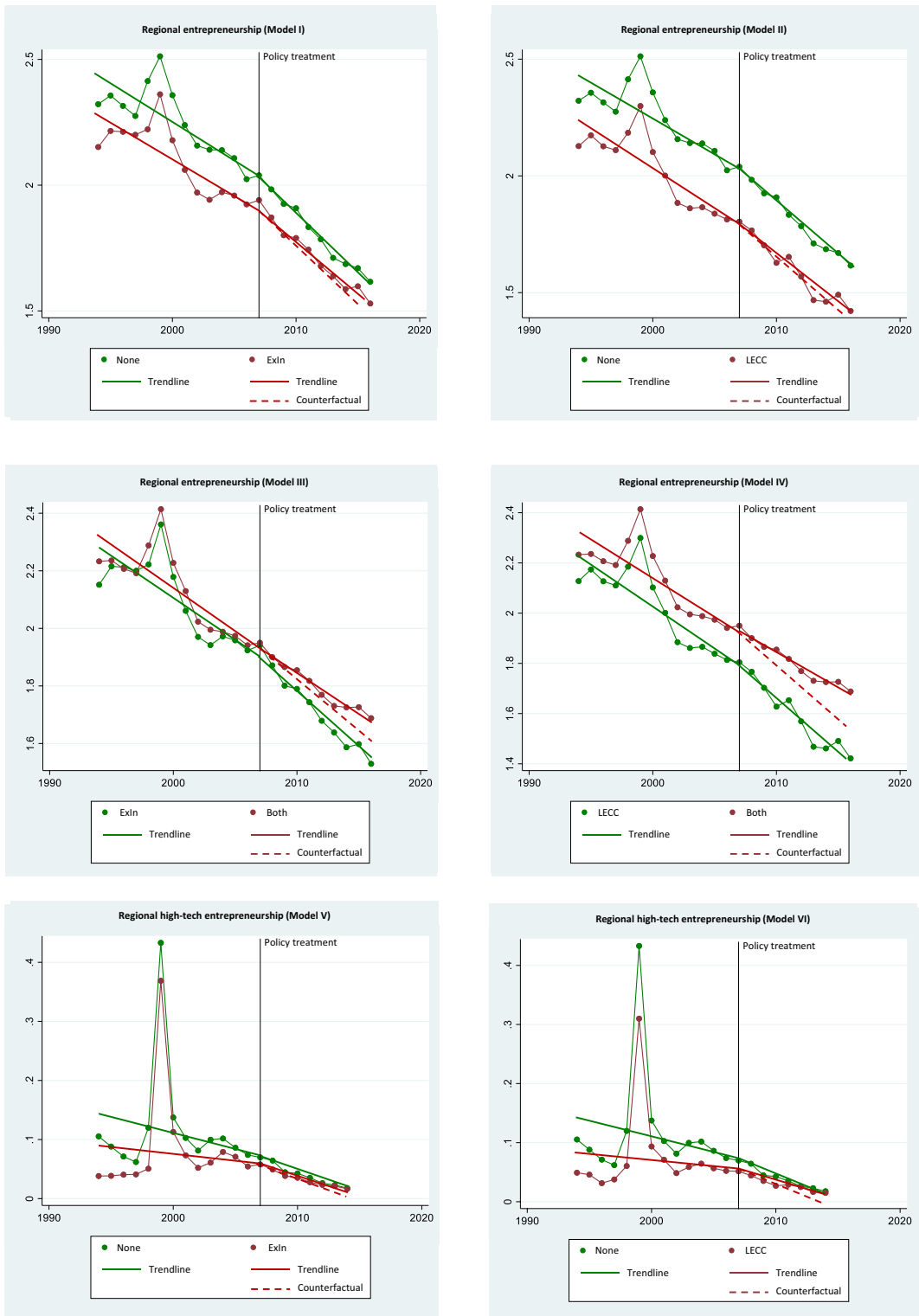


Fig. 2 Parallel trends assumptions

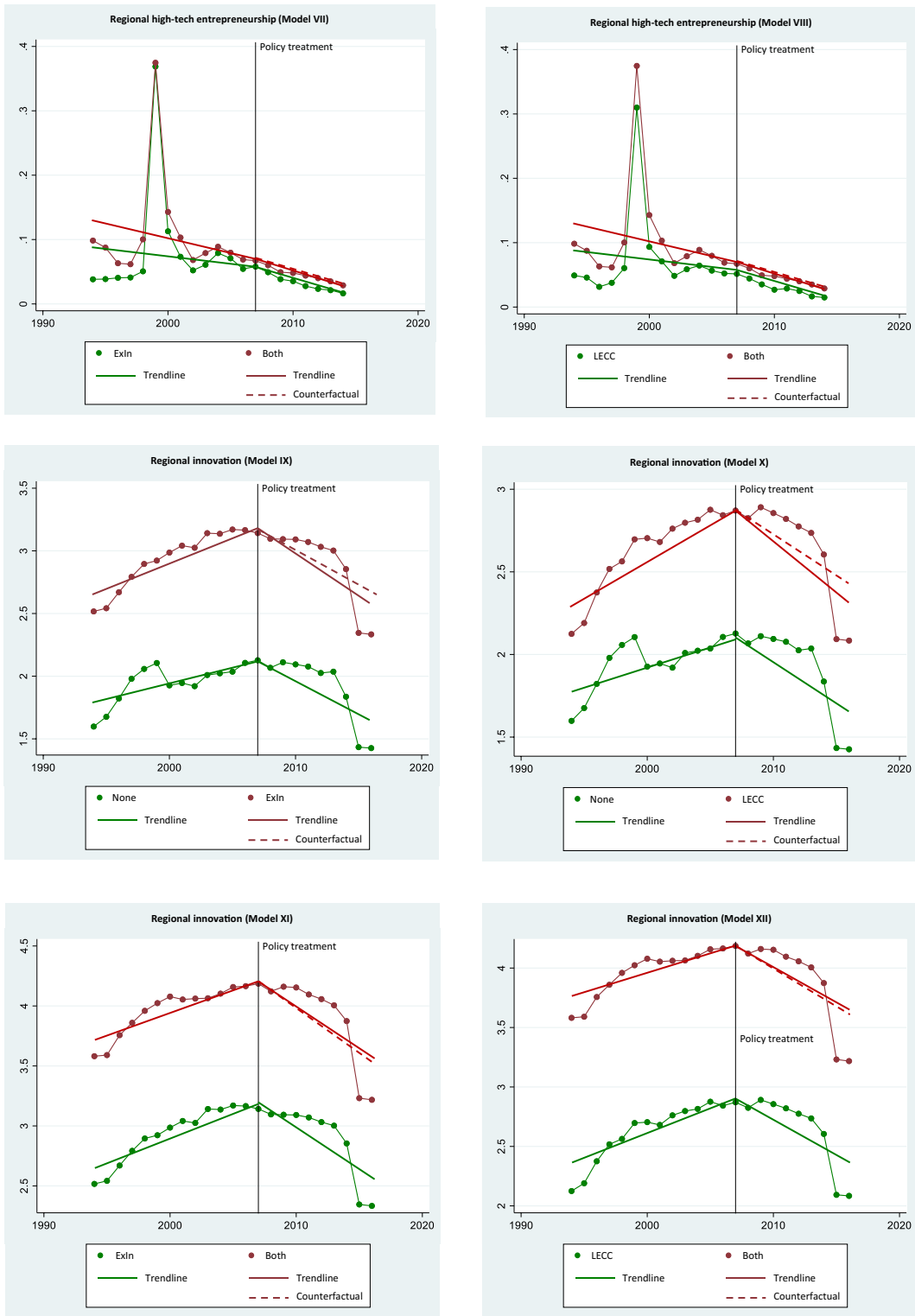


Fig. 2 (continued)

Table 9 Difference-in-differences models estimating regional entrepreneurship (baseline)

	Model I' (<i>ExIn</i> vs. <i>None</i>)	Model II' (<i>LECC</i> vs. <i>None</i>)	Model III' (<i>Both</i> vs. <i>ExIn</i>)	Model IV' (<i>Both</i> vs. <i>LECC</i>)
Public policy				
Treatment group	-0.186 (0.130)	-0.262* (0.154)	0.0530 (0.186)	0.129 (0.217)
Treatment period	-0.459*** (0.0122)	-0.459*** (0.0128)	-0.371*** (0.0163)	-0.416*** (0.0229)
Treatment group x Treatment period	0.0880*** (0.0229)	0.0430 (0.0295)	0.0319 (0.0224)	0.0769*** (0.0281)
N	1361	1200	822	661
n	61	54	36	29
R²	0.16	0.19	0.10	0.11

This table reports the results of our difference-in-differences estimation. We rely on a sample of data from 96 German planning regions (RORs) from 1998 to 2016. The dependent variable is regional entrepreneurship, measured by the logarithm of the number of start-ups in the private sector (manufacturing, services, construction) per 10,000 employees. Standard errors are reported in parentheses. Asterisks *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively

ExIn Excellence Initiative, *LECC* Leading-Edge Cluster Competition

Table 10 Difference-in-differences models estimating regional high-tech entrepreneurship (baseline)

	Model V' (<i>ExIn</i> vs. <i>None</i>)	Model VI' (<i>LECC</i> vs. <i>None</i>)	Model VII' (<i>Both</i> vs. <i>ExIn</i>)	Model VIII' (<i>Both</i> vs. <i>LECC</i>)
Public policy				
Treatment group	-0.0353** (0.0176)	-0.0434* (0.0224)	0.0259* (0.0157)	0.0340* (0.0188)
Treatment period	-0.0778*** (0.00622)	-0.0778*** (0.00624)	-0.0493*** (0.00892)	-0.0445*** (0.0112)
Treatment group x Treatment period	0.0284** (0.0122)	0.0333** (0.0151)	-0.0130 (0.0121)	-0.0179 (0.0137)
N	1341	1194	771	624
n	66	59	37	30
R²	0.10	0.10	0.10	0.11

This table reports the results of our difference-in-differences estimation. We rely on a sample of data from 96 German planning regions (RORs) from 1998 to 2014. The dependent variable is regional high-tech entrepreneurship, measured by the logarithm of the number of high-tech start-ups in the private sector per 10,000 employees. Standard errors are reported in parentheses. Asterisks *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively

ExIn Excellence Initiative, *LECC* Leading-Edge Cluster Competition

Table 11 Difference-in-differences models estimating regional innovation (baseline)

	Model IX' (<i>ExIn</i> vs. <i>None</i>)	Model X' (<i>LECC</i> vs. <i>None</i>)	Model XI' (<i>Both</i> vs. <i>ExIn</i>)	Model XII' (<i>Both</i> vs. <i>LECC</i>)
Public policy				
Treatment group	1.034*** (0.225)	0.744*** (0.268)	1.029*** (0.281)	1.319*** (0.321)
Treatment period	0.0286 (0.0199)	0.0286 (0.0196)	-0.0231 (0.0332)	0.0168 (0.0428)
Treatment group x Treatment period	-0.0517 (0.0375)	-0.0117 (0.0454)	-0.0246 (0.0449)	-0.0646 (0.0521)
<i>N</i>	1361	1200	845	684
<i>n</i>	61	54	37	30
<i>R</i> ²	0.21	0.10	0.25	0.34

This table reports the results of our difference-in-differences estimation. We rely on a sample of data from 96 German planning regions (RORs) from 1998 to 2016. The dependent variable is regional innovation, measured by the logarithm of the number of filed patents per 10,000 employees. Standard errors are reported in parentheses. Asterisks *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively

ExIn Excellence Initiative, *LECC* Leading-Edge Cluster Competition

Table 12 Additional descriptive statistics

Variable	Obs.	Mean	Std. Dev.	Min.	Max.	Description/Source
Absorptive capacities	1824	6402	8278	448	63,474	Number of R&D employees. Source: Institute for Employment Research
Workforce mobility	1824	0.18	9.55	-173	25	Net migration outflow of employees (outflows minus inflows) per 1000 citizens. Source: Federal Office for Building and Regional Planning
Intrapreneurship	1824	28,470	21,639	6574	125,280	Number of commercial units of incumbent firms. Source: Institute for Employment Research

Table 13 Difference-in-differences models post-hoc tests (baseline)

	<i>Absorptive capacities</i>		<i>Workforce mobility</i>		<i>Intrapreneurship</i>	
	Post-Hoc I' (<i>Both</i> vs. <i>ExIn</i>)	Post-Hoc II' (<i>Both</i> vs. <i>LECC</i>)	Post-Hoc III' (<i>Both</i> vs. <i>ExIn</i>)	Post-Hoc IV' (<i>Both</i> vs. <i>LECC</i>)	Post-Hoc V' (<i>Both</i> vs. <i>ExIn</i>)	Post-Hoc VI' (<i>Both</i> vs. <i>LECC</i>)
Public policy						
Treatment group	10,534*** (3178)	10,723** (4186)	5.198* (3.118)	-0.220 (1.244)	26,441*** (7140)	25,216*** (9,486)
Treatment period	1030*** (187.5)	892.7*** (269.1)	3,454*** (0.885)	-0.0915 (0.443)	6403*** (561.1)	6167*** (801.2)
Treatment group x Treatment period	1,420*** (255.2)	1,558*** (329.6)	-4,418*** (1.204)	-0.872 (0.543)	7,370*** (763.8)	7,606*** (981.2)
<i>N</i>	957	774	851	690	957	774
<i>n</i>	37	30	37	30	37	30
<i>R</i> ²	0.27	0.22	0.02	0.01	0.35	0.28

This table reports the results of our post-hoc difference-in-differences estimations. The prerequisites for applying difference-in-differences regressions are satisfied. Standard errors are reported in parentheses. Asterisks *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively

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