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Transformative Change in Higher Education: Entrepreneurial Universities and High-Technology Entrepreneurship

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Abstract

Whereas the positive externalities of entrepreneurial universities in the context of regional development in general and entrepreneurship in specific are undisputed, the effectiveness of policy measures trying to accelerate these beneficial effects is much less clear. Public policies focusing on the higher education landscape often pursue a paradigm shift among universities that may ultimately lead to the transformation towards entrepreneurial universities. Set in the German context, the purpose of this paper is to examine whether a higher education policy-induced transformation significantly influenced regional high-technology entrepreneurship. We thereby focus on the German Excellence Initiative, a higher education policy intervention designed to foster and support the transformative change of German universities towards an entrepreneurial paradigm. Our results reveal that the German Excellence Initiative had a positive and significant impact on regional high-technology entrepreneurship. Our results further show that the higher the interaction with industry, the more conducive universities become for regional high-technology entrepreneurship. In addition, universities' overarching scientific focus decisively affects regional high-technology entrepreneurship. Based on our results, we conclude our paper by outlining implications for policy makers, high-technology entrepreneurs and university managers as well as present future avenues for research.

Keywords: entrepreneurship; high-technology entrepreneurship;

entrepreneurial universities; Germany; Excellence Initiative; start-ups

1. Introduction

For regional economies, high-technology entrepreneurship provides considerable benefits and spillover effects that have economic and social impacts, such a bringing highly innovative ideas to the market (see Oakey, 2012; Van Praag and Versloot, 2007), thus contributes to faster economic growth (see Matejun, 2016). An important environmental factor to encourage and support high-technology entrepreneurship within a region are investments in research and development (Xue and Klein, 2010). Contemporary perspectives of universities view them as institutions that can support, pioneer and enhance entrepreneurship and innovation within and outside their institutional boundaries (Kirby et al., 2011). Within regions, universities have been accorded a central role in supporting innovation and entrepreneurship (Siegel and Wright, 2015). Collaborations with universities can confer benefits to industrial partners and simultaneously substantiate the new (entrepreneurial) role of the university within the society (see Audretsch, 2014; Cunningham and Link, 2015; Paleari et al., 2015). Universities are therefore mandated to integrate entrepreneurial

elements within their overall architecture to embrace third mission activities focused on commercialization and technology transfer (see Cunningham and Harney, 2006) that are supported or enabled through public sector entrepreneurship initiatives (see Leyden & Link, 2015). Other universities, so-called entrepreneurial universities, are going even further and fully embrace the entrepreneurial paradigm that shapes institutional and cultural aspects, processes and architecture that support the entire university community in pursuing third mission activities (Nelles and Vorley, 2011). Such transformative change can bring direct benefits to universities by increasing the levels of academic entrepreneurship within their institution and can also have regional spillover effects on the economic, technological and societal exploitation of knowledge (Urbano and Guerrero, 2013; Braunerhjelm, 2008).

Regions with high-technology entrepreneurship prosper, such as the Silicon Valley, and respective entrepreneurs focus on innovation through their entrepreneurial endeavors that are highly disruptive (Bahrami and Evans, 1995). The impact of high-technology entrepreneurship on Silicon Valley is described by Bahrami and Evans

(1995: 62) as follows: “The entrepreneurial spirit and commitment to innovation have so far proven effective in producing pioneering products and high value added jobs”. Access to knowledge, human capital and networks are thereby critical ingredients for regional development, competitiveness and prosperity. To support the development of such high-technology entrepreneurship regions, policy makers are constantly trying to develop and augment regional capabilities and competencies that support regional innovation and entrepreneurship (see Keeble and Wilkinson, 1999; Longhi, 1999). Within regions, universities are increasingly important supporting institutions for high-technology entrepreneurship through proprietary scientific research and development and human capital to support the exploitation of novel innovations and entrepreneurial opportunities. Studies have shown that there are local geographic spillovers between university research and high-technology entrepreneurship and innovation (see Anselin et al., 1997; Audretsch et al., 2016b; Brown, 2016;Cowan and Zinovyeva, 2013; Liu, 2015).

Within the growing literature on entrepreneurial universities, while there has been a focus on examining their economic impact on research, teaching and third mission activities (see Guerrero et al., 2015a; Urbano and Guerrero, 2013). There has been no empirical attention to date that examines whether higher education policy initiatives inducing transformative change among universities, i.e. creating entrepreneurial universities, are effective, hence influence regional high-technology entrepreneurship. Set in the German context, our study finds that the German Excellence Initiative – a higher education policy – had a positive and significant impact on regional high-technology entrepreneurship. We can further show that the higher the interaction with industry, i.e. the intensity of knowledge flowing and being transferred between the public and the private sector, the more conducive universities become for regional high-technology entrepreneurship. However, also universities' overarching scientific focus decisively affects regional high-technology entrepreneurship. Our findings emphasize that universities need guidance and support in their transformation towards an entrepreneurial paradigm to fully exploit and

leverage their potential for regional development. Not only well-established entrepreneurial universities but also universities undergoing transformative change bear potential to create positive impact within and beyond the academic spheres. Our study thus adds to the literature by highlighting that the concept of entrepreneurial universities should be much broader than just focusing on already transformed universities, embracing also universities that currently deal with transformative change towards an entrepreneurial paradigm.

The remainder of our paper is structured as follows. We begin with a review of high-technology entrepreneurship, entrepreneurial universities and their transformative change as well as higher education policy interventions. We then present our methodology and findings. We conclude the paper with a discussion of our findings and outline recommendations for policy makers, high-technology entrepreneurs and university managers as well as discuss some future avenues of research.

2. Literature Review

2.1 High-Technology Entrepreneurship

The rationale for supporting and encouraging high-technology entrepreneurship centers on economic growth, job creation, new innovations and growth in new venture creation (see Audretsch and Keilbach, 2004; Audretsch et al., 2005a; Mason and Brown, 2013; Van Stel et al., 2005). There are several factors that support the growth of high-technology regions such as research and educational infrastructure, government policies, location of major inventions, availability of (financial, human and social) capital, amenities, entrepreneurial spirit and technology-based spin-offs (see Audretsch et al., 2019a; Sternberg, 1996). To effectively support high-technology entrepreneurship in a region, Friar and Meyer (2003) argue that it requires both exogenous and endogenous approaches. In reflecting on a case study of the Aragon region in Spain, Sanchez and Perez (1998) argue that it is more challenging for peripheral regions to create high-technology entrepreneurship. Policy interventions to support high-technology firms in a European context should center on reducing the regulatory burden, marketing regions to attract capital – financial and human – and to

direct public supports through government agencies and bodies (see Cunningham et al., 2019; Grilli, 2014).

High-technology entrepreneurship is typically associated with geographical agglomerations such as the Silicon Valley in California and Route 128 in Boston in the US, Cambridge and Oxford in the UK, Tel Aviv in Israel, Bangalore in India, or Lund in Sweden (see Bieri, 2010; Cooper and Folta, 2017). Typically, policy interventions aimed at fostering the share of high-technology start-ups, so-called high-growth entrepreneurship policies, are thereby focused on the private sector (Autio and Rannikko, 2016; Audretsch et al., 2016a). Kuratko and Menter (2017: 31) argue that "despite the strong rationale of implementing comprehensive public policy approaches that create conducive conditions for the different types of ventures, policymakers tend to favor the high-technology sector, especially since knowledge and technology-based industries tend to exhibit high rates of growth". Dahlstrand (2007) shows that such technology-based firms are a highly regional phenomenon, constituting an effective means "when it comes to industrial invention and innovation" (see Oakey, 2012: 3).

For high-technology entrepreneurship firms to be successful, research and development, the management team and customer relationships are critical along with the capabilities of the founding team (Chorev and Anderson, 2006). Access to new knowledge to support high-technology entrepreneurship is essential (see Dai and Liu, 2009; Garnsey, 1998; Hart and Acs, 2011). Furthermore, access to venture capital can support the creation and expansion of high-technology entrepreneurship in a location (Lehmann et al., 2017). Where there is a high concentration of high-technology entrepreneurship and firms in a location, venture capital firms tend to fund locally, rather than these firms relying on venture capital funding from other locations (Florida and Kenny, 1988). According to Hayton (2005), studying high-technology new ventures in the US that issued an initial public offering, organizational reputation and human capital diversity of high-technology entrepreneurship firms are the most significant factors for their entrepreneurial performance. Gimmon and Levie (2010) in their study of Israeli technology incubation programs find that academic status was a factor in attracting capital investment but did not positively affect firm survival. High-

technology entrepreneurship firms require innovation and entrepreneurship efficiency based on a mix of strong and weak network ties (Elfring and Hulsink, 2003), whereby the creation of high-technology new ventures can suffer in situations where there are tight labor markets (Fairle and Chatterji, 2013).

Universities have a role to play in supporting high-technology entrepreneurship within regional entrepreneurship and innovation ecosystems (see Lehmann et al., 2020; Brown, 2016). Hülsbeck and Pickavé (2014: 121) highlight its context-dependency as they state that high-technology entrepreneurship "is highly dependent on regional knowledge production by industry *and* university, while technology entrepreneurship does largely not dependent on these factors". Thus, besides industry, universities as sources of new knowledge also play a crucial role in the process of high-technology firm birth. Founders of high-technology entrepreneurship firms are more likely to have a university background and the origins of these firms can be through spin-offs from universities or exiting firms (see Oakey, 2003). Based on their study of the Silicon Valley and the Berkeley Campus of the University of California,

Huffman and Quigley (2002: 403) conclude: “The results also reinforce the self-interested reasons for government investment in high-quality educational institutions, as measured by the return on the augmented human capital stock in the region”. Moreover, their study highlights how the state benefited from graduates staying in the locality through taxation and that the local economy benefited from graduates remaining on living in the region post university.

2.2 Entrepreneurial Universities and Transformative Change

Policy makers now view universities as actors, creating new knowledge to support innovation and entrepreneurship and exploiting this knowledge through technology and knowledge transfer (Cunningham and Link, 2015). There has been an increasing research focus on how universities become entrepreneurial universities, and especially how universities are adapting to an entrepreneurial paradigm (see Guerrero et al., 2016a; Ranga et al., 2003; Van Looy et al., 2011). Cunningham et al. (2017a) define the role of an entrepreneurial university as follows: “An entrepreneurial university simultaneously fulfils three different activities – teaching, research, and

entrepreneurship – while providing an adequate atmosphere in which the university community can explore and exploit ideas and contribute to the creation of a sustained competitive advantage that could be transformed into social and economic impacts". The changing nature of academic work (Cannizzo and Osbaldiston, 2016), entrepreneurship and innovation public policies (Siegfried et al., 2007), competition (Maringe, 2006) funding (Geuna, 2001), and managerialism (Lawrence and Sharma, 2002) are some of the factors that are driving universities to adapt an entrepreneurial paradigm. Moreover, universities are becoming even more influential by shaping actors within regions in supporting regional innovation and entrepreneurship (see Benneworth and Hospers, 2007) and bridging social and entrepreneurial capital (Nahapiet and Ghoshal, 1998). However, in some regions, as Brown (2016) notes, there is a lack of connectivity between local innovation and entrepreneurship ecosystems and universities. Nevertheless, studies to date have shown that universities and especially entrepreneurial universities do have an economic impact (Bramwell and Wolfe, 2008; Lehmann & Menter, 2016; Guerrero et al., 2016b).

Various interpretations and definitions of entrepreneurial universities have acknowledged that these institutions are a source of funding (Etzkowitz, 1983), new venture creation (Dill, 1995), foster networking (Formica, 2002) and are involved in commercialization and technology transfer activities (Jacob et al., 2003). Etzkowitz (2003: 112) argues that the entrepreneurial university functions as "a natural incubator, providing support structures for teachers and students to initiate new ventures: intellectual, commercial and conjoint". However, Röpke (1998: 2) goes further and suggests that "the university itself, as an organization, becomes entrepreneurial". Schulte (2004: 187) adds that respective universities "operate in an entrepreneurial manner". In essence, universities transforming to become an entrepreneurial university means, not alone structural and organizational changes, but also changes to organizational culture and decision-making that is entrepreneurial in nature.

Entrepreneurial universities have responded and transformed in different ways to this entrepreneurial paradigm shift, such as through the creation of technology transfer offices (Siegel et al., 2003; Berbegal-Mirabent et al., 2012), supporting

graduate entrepreneurship (Guerrero et al., 2018; Hayter et al., 2017), student business plan competitions (Watson et al., 2018), or the creation of university based accelerators, incubators and science parks (Hobbs et al., 2017; McAdam et al., 2006; Phan et al., 2005). Such transformative change responses of universities to become entrepreneurial universities have seen some growth of academic entrepreneurship (Grimaldi et al., 2011; Miller et al., 2018; Shane, 2004) among faculty and a growth in scientists becoming publicly funded principal investigators to secure the necessary resources to purse knowledge creation and commercialization (see Cunningham et al., 2016; Menter, 2016).

Studies have highlighted that entrepreneurial universities adopt different approaches that reflect local, regional and national environmental factors. In a cross-country case study comparison between Irish and Spanish universities, Guerrero et al. (2014) find significant institutional differences in how they were making transformative changes in becoming an entrepreneurial university. There are differences concerning local, regional and environmental factors with respect to

attitudes towards entrepreneurship, reward systems, structures and incentives. Such differences in approaches are also reflected in the case studies undertaken by Clark (1998, 2004), as he suggests that what really matters is the manner in which universities have adopted to meeting external challenges and forces. In a study of Iranian entrepreneurial universities, Guerrero et al. (2015b) find that respective universities are highly dependent on state funding with the entrepreneurial transformation process being directly influenced by the internal entrepreneurial architecture of these institutions. According to Cunningham et al. (2017a), institutional context, resources and the characteristics of university communities are critical determinant factors for entrepreneurial universities. The institutional context influences the transformation of universities to become an entrepreneurial university – both through formal (economic, political, regulatory) and informal factors (culture, values, attitudes) (see North, 1990).

The resources and capabilities that are available within the university will determine the scope and scale of their transformation to becoming an entrepreneurial

university (O'Reilly et al., 2019). Governance, finances, people, physical assets, engagement in networks are just some of the factors that influence the extent of such a transformative change. In particular, financial resources will determine the pace of the transformative change and potential spillover benefits within and beyond the university, highlighting the important role of the government to direct and guide universities in their transformative processes particularly within regions (Budyldina, 2018). In summary, entrepreneurial universities have become an important actor within regional entrepreneurial and innovation ecosystems by creating and building local knowledge and intellectual capital that is necessary to ultimately support regional high-technology entrepreneurship.

2.3 Higher Education Policy Interventions

The rationale of higher education policy interventions is to increase the overall quality of funded institutions, mainly with regard to teaching and research but increasingly also to transferring knowledge. Hence, building close relationships with industry seems to be a crucial element of such programs. According to Kitagawa (2004: 846),

“those relationships growing between universities and their regions are an important strategic and policy issue for universities, industry, communities and for governments alike in order to construct 'advantage' within the multi-level governance structure of knowledge economies”. Studies have found that universities’ activities do have an impact on regions (see Batterbury and Hill, 2005; Drucker and Goldstein, 2007; Huggins et al., 2008). Based on public sector entrepreneurship initiatives, policy makers try to drive and shape transformative processes through the provision of financial resources. Studies of higher education policy interventions at a national and regional level have focused mainly on different aspects such as entrepreneurial education and training (see Galvão et al., 2018), entrepreneurial intention (Passaro et al., 2018), business formation (Fotopoulos and Storey, 2019), or technology business incubators (Lamine et al., 2018). Specifically, there has been a concentration of studies examining higher education policy interventions from an entrepreneurial education perspective across different countries (see Ahmad, 2013; İlhan Ertuna and Gurel, 2011; Solomon and Matlay, 2008). However, especially the impact of higher

education policies on entrepreneurial activities beyond academic boundaries has not received much scholarly attention.

The most recent higher education policy intervention in Germany, the Excellence Initiative, was meant to foster the transformation of German universities towards an entrepreneurial paradigm and create outstanding conditions for cutting-edge research across all disciplines. Not by chance, the slogan of the Technical University of Munich (TUM) in their first funding application was “TUM: The Entrepreneurial University”. Based on overall three different funding lines that supported the creation of *Graduate Schools*, *Clusters of Excellence*, and *Institutional Strategies*, with a total funding exceeding € 4.6 billion, the Excellence Initiative was implemented in order to increase the competitiveness of the higher education sector and augment positive externalities of universities through the promotion of top-level research and the improvement of the quality of universities and research institutions in general (DFG, 2013). The initiative itself took place in two phases (first phase from 2005-2012 and second phase from 2012-2017) and funded the creation of in total 51

Graduate Schools, 49 Clusters of Excellence and 14 Institutional Strategies. Whereas Graduate Schools aimed at improving the promotion of young scientists and researchers, Clusters of Excellence were meant to bundle universities' research potential and expand universities' networks beyond academic spheres, thus encouraged collaborations with non-university research institutions and industrial partners. Institutional strategies promoted universities as a whole and aimed at enabling funded universities to compete globally by enhancing top-level research and promoting young scientists and researchers. Thus, only those universities were eligible for the nomination as an elite university, i.e. receiving financial support through the third funding line, which had been awarded at least one Graduate School and one Cluster of Excellence. It is important to note that the focus of the German Excellence Initiative was not directly related to high-technology entrepreneurship, but rather aimed at creating conducive environments within and beyond academic spheres that facilitate knowledge spillovers, which might ultimately serve as the breeding ground for regional entrepreneurial activities.

Studies examining the effects of the Excellence Initiative are limited and have found rather mixed results with regard to its effectiveness. Whereas the report of the International Expert Commission on the Excellence Initiative (IEKE), evaluating the first phase of the Excellence Initiative, indicates that this policy initiative was a great success, making the entire German university system more competitive and dynamic (IEKE, 2016), Gawellek and Sunder (2016) find a drop in efficiency among applying universities, whereby positive effects did not extend beyond the actual funding. Lehmann and Stockinger (2018: 70) focus on the impact the Excellence Initiative had on university outcomes (e.g. patents or industry engagement) and conclude that this policy intervention "created an advantage for the whole of Germany while being an Excellence University does not have an impact on academic entrepreneurship with regards to patenting activity". Menter et al. (2018) find that the Excellence Initiative positively contributed to augmented research performance among promoted universities, yet argue that not the political initiative itself but rather the announcement of funding fostered the performance of the German higher education system.

3. Dataset and Methodology

This paper studies the policy-induced impact of universities' transition towards an entrepreneurial paradigm on regional high-technology entrepreneurship. As high-technology start-ups push technological boundaries and as universities are perceived as engines of innovation (Thorp & Goldstein, 2013), the transition towards an entrepreneurial university might stimulate and encourage entrepreneurial activities within a region.

We consider regions in terms of spatial planning regions (*Raumordnungsregionen, RORs*) as utilized by the German Statistics Office[2]. Taking a view on Germany reveals large differences across both regions and universities (see Table 1). Whereas some regions are highly innovative (see *regional innovativeness*),

[2] Germany consists of in total 96 RORs. However, for our empirical analysis, we only consider RORs that also inhere at least one university (in sum 63 RORs). Hence, we compare university regions that have received funding from the Excellence Initiative (in sum 32 RORs) with university regions that have not received any funding from the Excellence Initiative (in sum 31 RORs).

others lack sufficient resources as indicated by a rather low GDP per capita ratio (see *regional prosperity*). Likewise, some universities in those regions have strong linkages with industry whereas other higher education institutions are rather stuck in their traditional (ivory tower) paradigm as reflected by the low share of industry funds compared to all third-party funds (see *industry focus*). Overall, our dataset captures 102 German universities nested within 63 RORs within a timeframe from 2001 to 2014.

- Insert table 1 about here -

Analyzing the bivariate correlations of our utilized variables reveals further insights into the context dependency of high-technology entrepreneurship (see Table 2). As confirmed by previous studies (Adler et al., 2019; Carlino et al., 2007; Acs & Varga, 2005), regional density is rather highly correlated with high-technology entrepreneurship ($r = 0.598$). Further, university size, as reflected by the number of

graduates, is rather highly correlated with entrepreneurial activities (*r = 0.491*) as well as with innovative activities (*r = 0.640*). Despite the partially high correlations (all correlation coefficients are yet below 0.70), the calculation of the variance inflation factors reveals the non-presence of multicollinearity (see Hair et al., 2013). The mean variance inflation factors for all model specifications is around 2.

- Insert table 2 about here -

In order to analyze our dataset, we rely on difference-in-differences estimations, enabling the differentiation between funded regions (*treatment group*) and non-funded regions (*control group*). Out of the investigated 63 RORs, 32 RORs received at least funding from one funding line of the Excellence Initiative. An adoption of a difference-in-differences approach requires testing a similar development of the treatment and control group prior to the actual treatment, i.e. getting funded through the German Excellence Initiative, the so-called common trends

assumption. Appendix 1 to 4 confirm this common trends assumption graphically. We control for both regional specifics (regional density, regional prosperity and regional innovativeness) and university specifics (industry focus, graduates, research output and scientific orientation) as suggested by multiple studies.

Due to our dataset time structure (2001 to 2014), we specifically focus on the first phase of the Excellence Initiative, as it allows us to consider sufficient time periods before and after the treatment (in 2007), i.e. the implementation of the first phase of the Excellence Initiative. We utilize four model specifications in order to investigate the overall impact of the Excellence Initiative (Model I/V) as well as the isolated effects of each funding line (Model II-IV(VI-VIII) on regional high-technology entrepreneurship. We operationalize high-technology entrepreneurship by the logarithmized number of regional high-technology start-ups as classified by the Institute for Employment Research (see Schmucker et al., 2018). In order to test the robustness of our results, we employ the same estimation approach, yet exchange our dependent variable by taking the share of regional high-technology start-ups in

relation to the workforce (in 10,000). As effects on regional high-technology entrepreneurship may be not immediate, we include time lags in our empirical approach to take account of this fact.

4. Findings and Discussion

The findings of our empirical analysis are shown in Table 3. A higher education policy-induced transformative change of universities towards an entrepreneurial paradigm significantly affects regional high-technology entrepreneurship – across all three funding lines of the Excellence Initiative (as indicated by the positive and significant variable *treatment effect*). Our results thus illustrate that irrespective of the type of funding (Graduate Schools, Clusters of Excellence, or Institutional Strategies) supporting universities to become entrepreneurial universities, higher education policy interventions seem to have a wider impact beyond the university sphere. These results extend existing studies by highlighting the importance of universities within a regional context with respect to high-technology entrepreneurship (Calcagnini et al., 2016; Lehmann & Menter, 2016; Shane, 2004). Our study further affirms the important

function that entrepreneurial universities play in a regional context particularly in enhancing and fostering high-technology entrepreneurship. One explanation for these beneficial effects may be the fact that additional funding may overcome the disconnection between universities and local innovation and entrepreneurship ecosystems (see Brown, 2016).

- Insert table 3 about here -

Our control variables show the expected results and thereby confirm previous studies. Collaborations with industry and the associated orientation towards applied research (as represented by the variable *industry focus*) have a positive and significant effect on high-technology business creation. The overarching scientific focus of a university further positively affects the creation of highly innovative start-ups, indicating the existence of positive spillover effects of universities (Anselin et al, 1997; Audretsch et al., 2005b). The variable graduates, our control for size effects of

universities, shows a negative and significant effect on high-technology entrepreneurship (see Guerrero et al., 2018). From a regional perspective, especially the density of regions might positively affect high-technology entrepreneurship (Glaeser et al., 2010), whereas regional prosperity seems to negatively influence innovative new business formation. Finally, regional innovativeness shows a positive and significant impact on regional high-technology entrepreneurship.

These results indicate that a higher education policy-induced institutional re-orientation of universities may not only impact the scientific, but also the regional spheres with regard to high-technology entrepreneurship (see Eesley et al., 2016). Changing the entrepreneurial paradigm of a university along with the provision of additional financial resources to enhance the research infrastructure and entrepreneurial architecture has thus stimulated an entrepreneurial spark within and beyond an academic setting. Hence, the German Excellence Initiative has succeeded in creating stimuli for the institutional change towards entrepreneurial universities. Our results thereby suggest that all different higher education policy instruments, either

focusing on fostering human capital (via Graduate Schools), promoting advanced research (via Clusters of Excellence) or the combination thereof (via Institutional Strategies) seem to be effective policy instruments in the context of stimulating regional high-technology entrepreneurship. These results are rather robust as confirmed by our alternative regression approach (see table 4): funding through the Excellence Initiative results in augmented levels of regional high-technology entrepreneurship.

- Insert table 4 about here -

5. Conclusions and Future Research Avenues

In conclusion, our study demonstrates that a policy-induced transformative change of universities towards an entrepreneurial paradigm significantly affects regional high-technology entrepreneurship: the more universities transform towards an entrepreneurial university, the more high-technology start-ups arise within the respective region. Hence, universities that have adopted an entrepreneurial paradigm

serve as a positive and significant element impacting regional high-technology entrepreneurship. Our results also suggest that the overarching scientific focus of a university has a significant impact on regional high-technology entrepreneurship. Further, collaborations with industry and the associated orientation towards applied research seem to stimulate entrepreneurial endeavors and enhance regional high-technology entrepreneurship.

Our paper is not without limitations. Due to the design of our study, we have a single-country focus limiting the generalizability of our results. Cross-country comparisons might be one way to tackle this issue, yet provoke potential conflicts with regard to the comparability, e.g. of university focused policy initiatives. In addition, our empirical setting does not capture non-university research institutes (e.g. Fraunhofer institutes or the institutes comprising the Max Planck Society and the Leibnitz Society) that also constitute important institutions with regard to knowledge dissemination and diffusion. We also do not test for the potential cross-fertilization of basic and applied research (see Leyden & Menter, 2018). Moreover, we do not

consider the simultaneous impact of further policy instruments that try to stimulate regional high-technology entrepreneurship, i.e. the policy mix. Finally, the observed time period might be too short to capture long-term effects of the Excellence Initiative.

Our paper reveals several implications for policy makers. Higher education policy instruments aimed at building capacity to support the transformation of universities to adopt an entrepreneurial university paradigm have a positive impact on the institution and the region that they inhabit. Therefore, policy makers need to give careful consideration to the design of the policy tools as well as the intended and unintended consequences. Policy makers need to ensure that such policy instruments provide sufficient institutional autonomy to enable universities to adapt to regional contextual dynamics, while simultaneously moving in a sustainable manner to realize an entrepreneurial university paradigm. This allows universities to experiment and to take risks irrespective of the current performance and standing. However, a university targeting innovation and technology transfer is not a means in itself as universities should be designed to contribute to what Kitagawa (2004: 847) describes as economic

and social cohesion.

Consideration also needs to be given in relation to how higher education policies such as the German Excellence Initiative complement other innovation and entrepreneurship policy interventions. Hence, the policy mix needs to be taken into account in order not to displace resources and actor efforts in achieving desired policy outcomes (see Munari et al., 2016). What is worth reflecting on the German Excellence Initiative is that it was broad enough in scope, in terms of specific program initiatives and funding lines, but also flexible enough to ensure that universities where able to make further institutional progress to adopt the entrepreneurial university paradigm, based on individual strengths and resources. The elements of the higher education policy allowed for institutional autonomy that is necessary to create positive externalities through knowledge spillovers alongside the necessary institutional building activities. Nevertheless, policy makers need to be more aware of the circular effect such public investments may have in supporting regions in a more sustainable manner in terms of issues such as increased taxation revenue, retention of high skilled

labor that Huffman and Quigley (2002) outline with respect to Silicon Valley. Moreover, our study again illustrates that public investments in entrepreneurial universities do pay off and further enhance the university at the center of the 'local entrepreneurial fulcrum' as Budyldina (2018) posits.

For high-technology entrepreneurship and entrepreneurs, our study again reaffirms the importance of location in order to set up a new venture. High-technology entrepreneurs need to locate in a region and an environment where there is a concentration of such firms, so-called entrepreneurial ecosystems (see Audretsch et al., 2019b; Cantner et al., 2020;). Therefore, the determinant factors of the local environment that Sternberg (1996) outlines should factor into the decision-making of high-technology entrepreneurs in terms of where they are going to locate their venture. Moreover, our study highlights that high-technology entrepreneurs should develop close collaborative relationships with universities and academic entrepreneurs that can contribute to the development of novelty and originality with regard to product and/or service design. Such collaborations can also contribute to enhancing the invention,

innovation and entrepreneurship efficiency that are necessary to purse high-technology entrepreneurship.

For university managers, our study highlights the positive effects of adopting the entrepreneurial university paradigm through proactively responding to a higher education policy initiative. Our study highlights that all dimensions of the university – teaching, research and technology transfer – have an impact on regional high-technology entrepreneurship. We suggest that universities experiment with different interventions and approaches that are aligned with local needs of high-technology entrepreneurs while also furthering the entrepreneurial university transformation agenda. Not all activities will work and some will fail or not achieve the desired impacts and outcomes, yet potential benefits might be ultimately overcompensated. This should be factored in and recognized as part of the transformational agenda.

University managers also need to consider which practical supports they can provide at an institutional level to support high-technology entrepreneurship for the members of the university community. For faculty, it is important to consider how

universities' institutional architecture actually supports the enhancing of individual career status irrespective of gender, diversity and stage of career considerations to purse high-technology entrepreneurial opportunities. In addition, the overarching scientific focus of a university might have decisive impacts on regional high-technology entrepreneurship.

Our study finally provides the basis to build some fruitful research avenues that further our understanding of the relationship between entrepreneurial universities' transformation and high-technology entrepreneurship. There is a need to extend and initiate cross-country studies and comparisons to better understand if similar results, as presented in our study, are prevalent. At a more micro level, using mixed methodological approaches (see Cunningham et al., 2017b), more research should be devoted to the classification, measurement and evaluation concerning the different approaches and strategies used by entrepreneurial universities to pursue the entrepreneurial paradigm. A final avenue of research should focus on graduate education and how it should support high-technology entrepreneurship (Guerrero et al,

2018). What are the optimal pedagogical approaches, curricula and extra-curricular support programs that are required to truly support high-technology entrepreneurship and nascent high-technology entrepreneurs? In this context, the role of supporting institutions like technology transfer offices but also specific centers (see Dolan et al., 2019), e.g. entrepreneurship centers or cooperative research centers, needs to be better understood to enhance the efficiency and effectiveness of prevalent mechanisms.

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Table 1 – Descriptive Statistics

Variable	Obs	Mean	SD	Min	Max	Description/Source
High-tech. entrepreneurship (abs.)	896	3.123	4.732	0	57	Number of high-technology start-ups; Source: German Institute for Employment Research
High-tech. entrepreneurship ratio	895	0.056	0.046	0	0.420	Number of high-technology start-ups in relation to the regional workforce (in 10,000); Source: German Institute for Employment Research, German Statistics Office
Scientific orientation	896	0.250	0.433	0	1	Indication of technical university (dummy variable); Source: German Statistics Office
Industry focus	880	0.215	0.141	0	1	Ratio of university third-party funding by industry in relation to total university third-party funding; Source: German Statistics Office
Research output	896	0.319	0.157	0	0.976	Publications per research fellow; Source: Scopus, German Statistics Office
Graduates	896	3,045	2,665	0	20,242	Number of university graduates: Source: German Statistics Office
Regional density	896	405.92	563.33	58.71	3,867	Citizens per square kilometer; Source: German Statistics Office
Regional prosperity	896	29,531	8,160	14,459	59,787	Gross domestic product per capita; Source: German Statistics Office
Regional innovativeness	896	38.81	50.95	0.868	291.67	Patents per workforce (in 10,000); Source: OECD REGPAT Database, German Statistics Office

Note: This table shows descriptive data on 63 German planning regions (RORs) observed from 2001 to 2014.

Table 2 – Correlation matrix

		1	2	3	4	5	6	7	8	9
1	High-tech. entrepreneurship (log.)	1								
2	High-tech. entrepreneurship ratio	0.677	1							
3	Scientific orientation	0.378	0.163	1						
4	Industry focus	0.178	0.067	0.136	1					
5	Research output	0.118	-0.038	0.175	-0.012	1				
6	Graduates	0.491	0.063	0.274	-0.027	0.439	1			
7	Regional density	0.598	0.292	0.293	-0.027	0.164	0.579	1		
8	Regional prosperity	0.184	-0.288	0.129	0.088	0.158	0.514	0.392	1	
9	Regional innovativeness	0.630	0.193	0.343	0.104	0.158	0.640	0.563	0.541	1

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

Table 3 – Estimation results

	Model I (Excellence Initiative)	***Model II (Graduate Schools)***	***Model III (Clusters of Excellence)***	***Model IV (Institutional Strategies)***
PUBLIC POLICY				
Treatment group	**0.339*** **	0.117	**0.397*** **	0.196
	(0.098)	(0.094)	**(0.103)**	(0.143)
Treatment period	**-0.204*** **	**-0.205*** **	**-0.195*** **	**-0.196*** **
	(0.029)	**(0.028)**	**(0.027)**	**(0.025)**
Treatment effect	**0.074** **	**0.057***	**0.079** **	**0.108** **
	(0.032)	**(0.032)**	**(0.033)**	**(0.048)**
UNIVERSITY				
L.Scientific orientation	**0.299*** **	**0.265** **	**0.228** **	**0.244** **
	(0.104)	**(0.105)**	**(0.104)**	**(0.105)**
L.Industry focus	**0.249*** **	**0.251*** **	**0.248*** **	**0.252*** **
	(0.079)	**(0.080)**	**(0.079)**	**(0.080)**
L.Research output	-0.084	-0.032	-0.054	-0.013
	(0.129)	(0.131)	(0.127)	(0.128)
L.Graduates	**-0.000*** **	**-0.000*** **	**-0.000*** **	**-0.000*** **
	(0.000)	**(0.000)**	**(0.000)**	**(0.000)**
REGION				
L.Reg. density	**0.001*** **	**0.001*** **	**0.001*** **	**0.001*** **
	(0.000)	**(0.000)**	**(0.000)**	**(0.000)**
L.Reg. prosperity	**-0.000*** **	**-0.000*** **	**-0.000*** **	**-0.000*** **
	(0.000)	**(0.000)**	**(0.000)**	**(0.000)**
L.Reg. innovativeness	**0.003*** **	**0.004*** **	**0.003*** **	**0.004*** **
	(0.001)	**(0.001)**	**(0.001)**	**(0.001)**
R^2	0.48	0.45	0.49	0.45
N	878	878	878	878
n	63	63	63	63

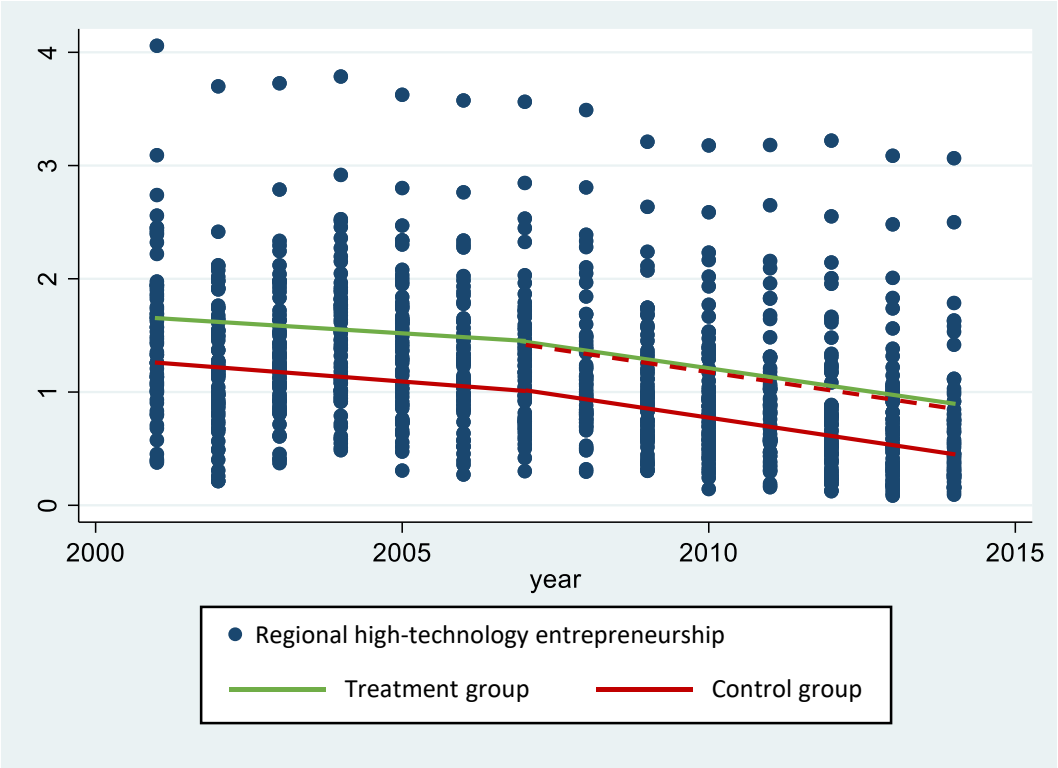
Note: This table reports the results of our difference-in-differences estimation approach. We rely on a sample of 63 German planning regions (RORs) ranging from 2001 to 2014. The dependent variable is regional high-technology entrepreneurship measured by the logarithmized number of high-technology start-ups. Standard errors are reported in parentheses.
*p < .10; ** p <.05; ***p < .01.

Table 4 – Robustness tests

	Model V (Excellence Initiative)	*Model VI (Graduate Schools)*	*Model VII (Clusters of Excellence)*	*Model VIII (Institutional Strategies)*
PUBLIC POLICY				
Treatment group	**0.015****	**0.011***	**0.011***	**0.027*****
	(0.006)	**(0.006)**	**(0.007)**	**(0.009)**
Treatment period	**-0.021*****	**-0.020*****	**-0.021*****	**-0.019*****
	(0.003)	**(0.003)**	**(0.003)**	**(0.002)**
Treatment effect	**0.006***	0.002	**0.008****	-0.004
	(0.003)	(0.003)	**(0.003)**	(0.005)
UNIVERSITY				
L.Scientific orientation	**0.012***	0.010	0.008	0.008
	(0.006)	(0.006)	(0.006)	(0.006)
L.Industry focus	**0.014***	**0.014***	**0.014***	**0.015***
	(0.008)	**(0.008)**	**(0.008)**	**(0.008)**
L.Research output	-0.019	-0.016	-0.014	-0.010
	(0.012)	(0.012)	(0.012)	(0.011)
L.Graduates	**-0.000*****	**-0.000*****	**-0.000*****	**-0.000*****
	(0.000)	**(0.000)**	**(0.000)**	**(0.000)**
REGION				
L.Reg. density	**0.000*****	**0.000*****	**0.000*****	**0.000*****
	(0.000)	**(0.000)**	**(0.000)**	**(0.000)**
L.Reg. prosperity	**-0.000*****	**-0.000*****	**-0.000*****	**-0.000*****
	(0.000)	**(0.000)**	**(0.000)**	**(0.000)**
L.Reg. innovativeness	**0.000****	**0.000*****	**0.000****	**0.000****
	(0.000)	**(0.000)**	**(0.000)**	**(0.000)**
R^2	0.42	0.42	0.42	0.44
N	878	878	878	878
n	63	63	63	63

Note: This table reports the results of our difference-in-differences estimation approach. We rely on a sample of 63 German planning regions (RORs) ranging from 2001 to 2014. The dependent variable is the regional high-technology entrepreneurship ratio measured by the amount of high-technology start-ups in relation to the regional workforce (in 10,000). Standard errors are reported in parentheses.
*p < .10; ** p <.05; ***p < .01.

Appendix 1 – Common Trends Assumption | Excellence Initiative



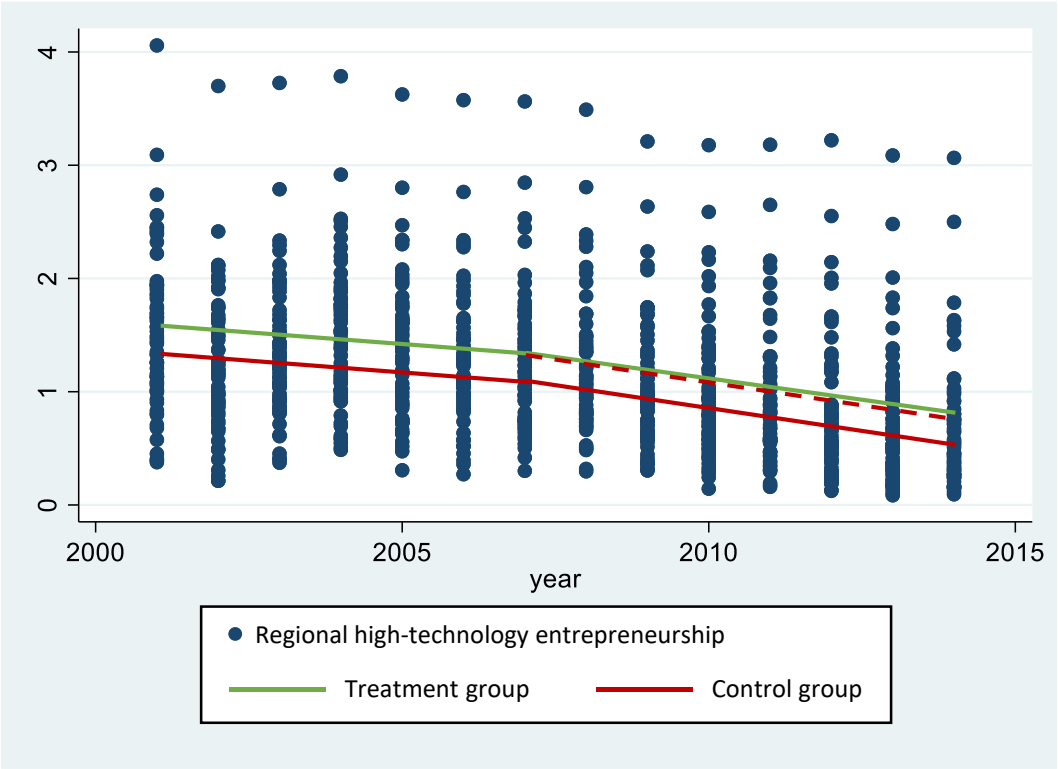
Note: This figure visualizes the development of our dependent variable regional high-technology entrepreneurship measured by the logarithmized number of high-technology start-ups over time. The treatment group classifies all regions that have been funded by the Excellence Initiative (either in the first funding line (Graduate Schools), and/or the second funding line (Clusters of Excellence), and/or the third funding line (Institutional Strategies)).

High-technology entrep.

Treatment group

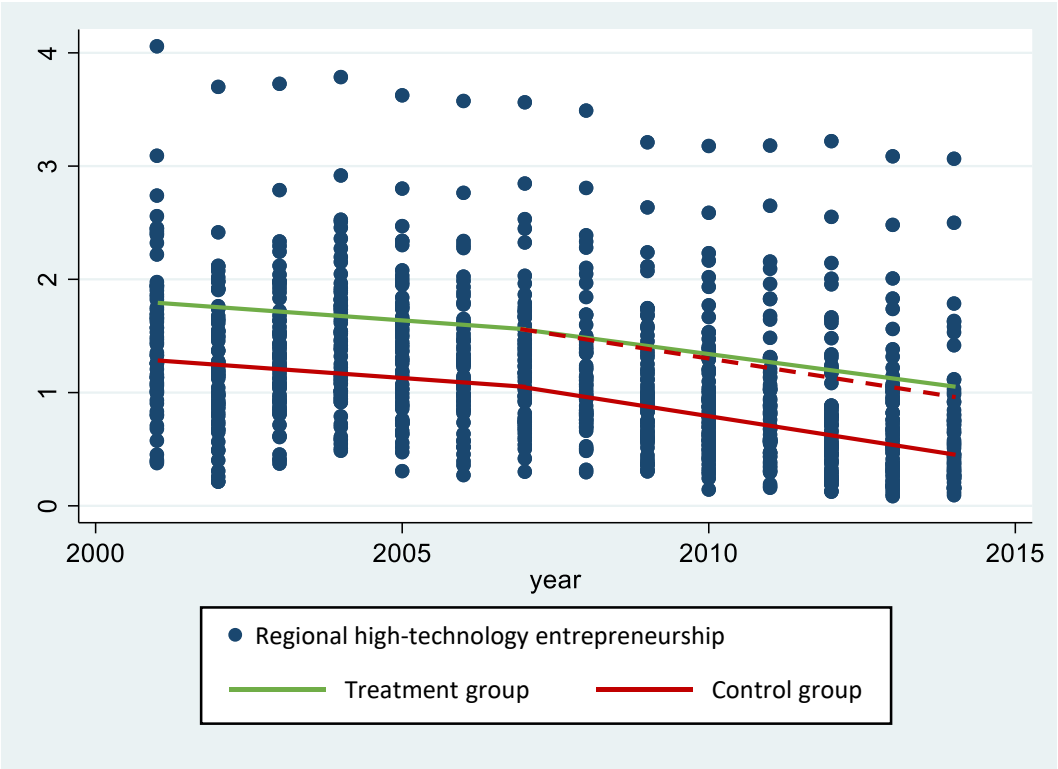
Control group

Appendix 2 – Common Trends Assumption | Graduate Schools



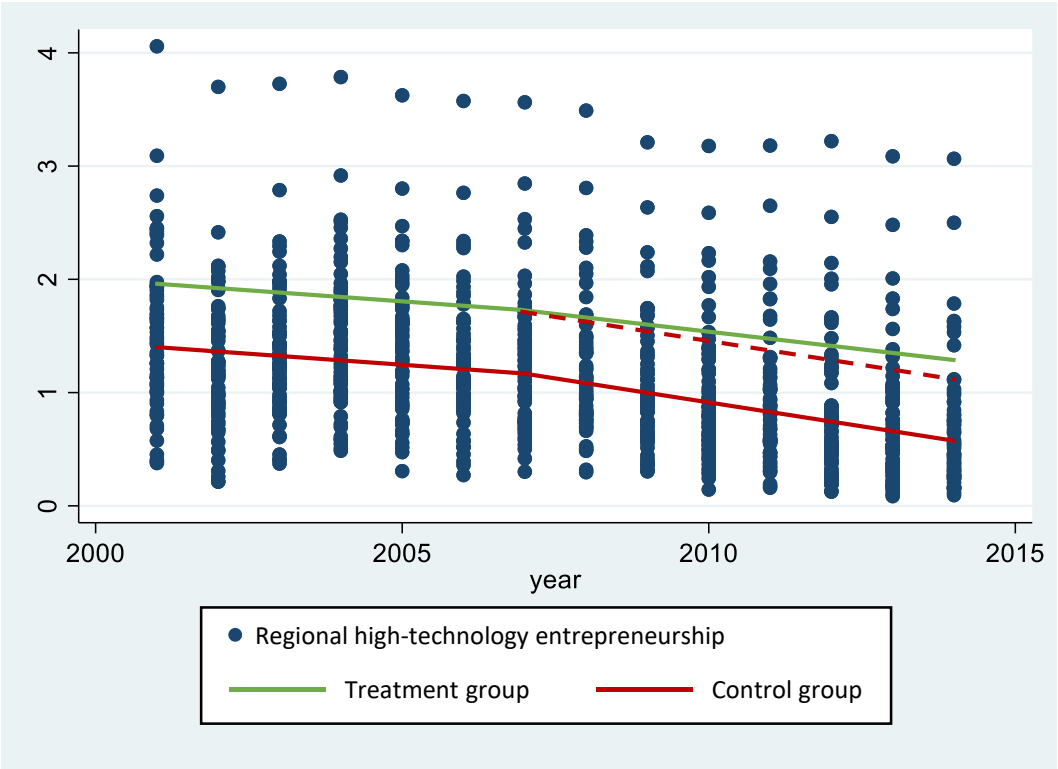
Note: This figure visualizes the development of our dependent variable regional high-technology entrepreneurship measured by the logarithmized number of high-technology start-ups over time. The treatment group classifies all regions that have been funded in the first funding line (Graduate Schools).

Appendix 3 – Common Trends Assumption | Clusters of Excellence



Note: This figure visualizes the development of our dependent variable regional high-technology entrepreneurship measured by the logarithmized number of high-technology start-ups over time. The treatment group classifies all regions that have been funded in the second funding line (Clusters of Excellence).

Appendix 4 – Common Trends Assumption | Institutional Strategies



Note: This figure visualizes the development of our dependent variable regional high-technology entrepreneurship measured by the logarithmized number of high-technology start-ups over time. The treatment group classifies all regions that have been funded in the third funding line (Institutional Strategies).